MAR 19820001: POINTE BASE

Received date: Dec 31, 1982

Public release date: Jan 01, 1984

19820001

HUDSON'S BAY OIL AND GAS COMPANY LIMITED
REPORT ON
GEM-8 MULTI-FREQUENCY ELECTROMAGNETIC SURVEY

QUARTZ MINERAL EXPLORATION PERMIT NO. 6879030003
IN TOWNSHIP 113, RANGE 6, W4M
POINTE BASSE, N.E. ALBERTA

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APRIL 1982

TABLE OF CONTENTS

	Page
SUMMARY	1
CONCLUSIONS & RECOMMENDATIONS	2
INTRODUCTION	3
LOCATION AND ACCESS	3
PHYSIOGRAPHY	5
MINERALS EXPLORATION HISTORY	5
GEM-8 MULTI-FREQUENCY ELECTROMAGNETIC SURVEY (1982)	6
DISCUSSION OF RESULTS	7
REFERENCES	9

APPENDICES

APPENDIX I	STATEMENT OF EXPENDITURES
APPENDIX II	LIST OF PERSONNEL
APPENDIX III	GEM-8 TECHNICAL INFORMATION
APPENDIX IV	FIGURES 2 - 12 INCLUSIVE

Seporte

LIST OF FIGURES

FIGURE 1	POINTE BASSE PERMIT NO. 6879030003 PERMIT AND GRID LOCATION	Page 4
FIGURE 2	POINTE BASSE GEM-8 EM TURAM SURVEY PERMIT NO. 6879030003 TWP 113, RGE 6, W4M 41Hz, F0	Appendix IV
FIGURE 3	POINTE BASSE GEM-8 EM TURAM SURVEY PERMIT NO. 6879030003 TWP 113, RGE 6, W4M 82 Hz, F1	Appendix IV
FIGURE 4	POINTE BASSE GEM-8 EM TURAM SURVEY PERMIT NO. 6879030003 TWP 113, RGE 6, W4M 164 Hz, F2	Appendix IV
FIGURE 5	POINTE BASSE GEM-8 EM TURAM SURVEY PERMIT NO. 6879030003 TWP 113, RGE 6, W4M 328 Hz, F3	Appendix IV
FIGURE 6	POINTE BASSE GEM-8 EM TURAM SURVEY PERMIT NO. 6879030003 TWP 113, RGE 6, W4M 656 Hz, F4	Appendix IV
FIGURE 7	POINTE BASSE GEM-8 EM TURAM SURVEY PERMIT NO. 6879030003 TWP 113, RGE 6, W4M 1 312 Hz, F5	Appendix IV
FIGURE 8	POINTE BASSE GEM-8 EM TURAM SURVEY PERMIT NO. 6879030003 TWP 113, RGE 6, W4M 2 624 Hz, F6	Appendix IV

FIGURE 9	POINTE BASSE GEM-8 EM TURAM SURVEY PERMIT NO. 6879030003 TWP 113, RGE 6, W4M 5 248 Hz, F7	Appendix IV
FIGURE 10	POINTE BASSE GEM-8 EM TURAM SURVEY PERMIT NO. 6879030003 TWP 113, RGE 6, W4M ELLIPTICITY	Appendix IV
FIGURE 11	POINTE BASSE GEM-8 EM TURAM SURVEY PERMIT NO. 6879030003 TWP 113, RGE 6, W4M TILT ANGLE	Appendix IV
FIGURE 12	POINTE BASSE GEM-8 EM TURAM SURVEY PERMIT NO. 6879030003 TWP 113, RGE 6, W4M FREQUENCY VS AMPLITUDE LINE 13E	Appendix IV

SUMMARY

A GEM-8 multi-frequency electromagnetic survey was conducted on Quartz Mineral Exploration Permit 6879030003 during February 1982. The survey was undertaken to determine sub-surface conductivity in an area where previous work had encountered gravity, resistivity and airborne electromagnetic anomalies.

Interpretation of the GEM-8 survey suggests the presence of three different conductive features. The first of these is believed to be conductive lake bottom sediments and is spacially associated with airborne electromagnetic and weak gravity anomalies. The second, apparently more conductive anomaly, is associated with a stronger gravity anomaly and pronounced structural lineament. The third feature is thought to be a moderately conductive fault zone which is associated with a structural lineament.

CONCLUSIONS AND RECOMMENDATIONS

The cause or causes of the related geophysical anomalies of the Pointe Basse property and their prospectiveness for vein-type uranium mineralization are not fully determined by the surveys performed to date. Further work including ground surveys and interpretive modelling of gravity, electromagnetic and other geophysical methods is required to determine the nature of these anomalies in a more definitive manner.

INTRODUCTION

Quartz Mineral Exploration Permit 6879030003 consisting of the NW¼ of Section 3, the N½ of SW¼ of Section 4, Section 5, the W½ of Section 8, the S½ and NE¼ of Section 10, the NW¼ of Section 11 and Section 14 of Township 113, Range 6, west of the 4th Meridian, covers approximately 1 165 ha (2 880 acres) on the north shore of Lake Athabasca, NE Alberta (Figure 1).

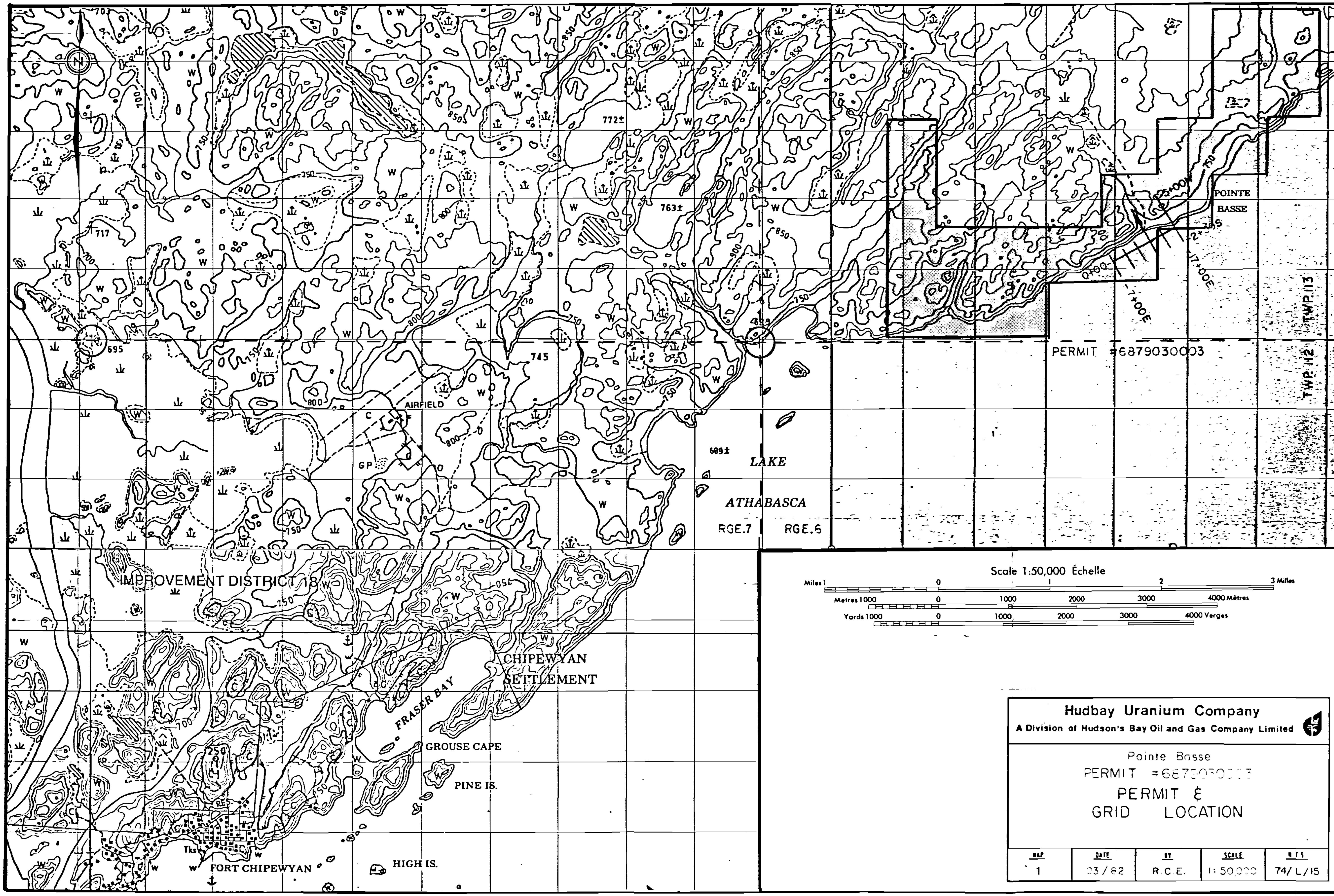
Hudson's Bay Oil and Gas Company Limited (HBOG), of 700 Second Street S.W., Calgary, Alberta, was granted the Permit by Alberta Energy and Natural Resources under the Quartz Mining Regulations on March 15, 1979.

Exploration work in February, 1982 consisted of a multi-frequency ground electromagnetic survey employing a GEM-8 instrument package.

LOCATION AND ACCESS

Permit 6879030003 is located about 12 km (7.5 miles) north and east of Fort Chipewyan on the north shore of Lake Athabasca in northeast Alberta (latitude 58°47'30"N, longitude 110°55'30"W) (Figure 1).

The 1982 programme was mobilized on February 16, 1982 via commercial air transport from Calgary to Fort Chipewyan, Alberta and demobilized February 26, 1982 by the same means. The survey crew stayed in the town of Fort Chipewyan and commuted by truck over the Dorey Lake Road and an ice road along the north shore of Lake Athabasca to the Permit area.



IMPROVEMENT DISTRICT 18
AIRFIELD
GP
717
695
745
772±
763±
689±
LAKE
ATHABASCA
RGE.7
RGE.6
TWP.112
TWP.113
PERMIT #6879030003
POINTE
BASSE
CHIPEWYAN
SETTLEMENT
FRASER BAY
GROUSE CAPE
PINE IS.
HIGH IS.
FORT CHIPEWYAN
RES
Tks
Scale 1:50,000 Échelle
Miles 1
3 Miles
Metres 1000
4000 Mètres
Yards 1000
4000 Verges
Hudbay Uranium Company
A Division of Hudson's Bay Oil and Gas Company Limited
Pointe Basse
PERMIT &
GRID LOCATION
MAP
1
DATE
BY
R.C.E.
SCALE
1:50,000
NTS
74/L/15

PHYSIOGRAPHY

The western half of the Permit area consists of a rocky upland with sparse overburden cover, rising 15 - 25 metres above lake level. The eastern half consists of much flatter outwash sands and gravels with numerous remnant beaches and only scattered outcrops of granitic gneiss (Brown, 1980).

MINERAL EXPLORATION HISTORY

There is no record of exploration having been undertaken on the property prior to the acquisition of the Permit area by HBOG. Government geological mapping of the area, indicates that the erosional margin of the Helikian Athabasca Formation may lie in overburden covered areas, in the eastern area of the property (Godfrey, 1978). This, coupled with the presence of uranium showings in basement lithologies west of the Permit area, led to the acquisition of Quartz Mineral Exploration Permit 6879030003.

1st

Between March and June 1979, HBOG carried out intermittent field work on the permit. Airborne electromagnetic (EM) and gamma spectrometer surveys and ground electromagnetic and induced polarization surveys along with geologic mapping and prospecting were completed (Brown, 1980). The airborne EM located conductors in gneissic basement units in the western portion of the Permit area and in the east on the shore of Lake Athabasca under what may be the Helikian Athabasca Formation.

2nd

In February to April 1980, induced polarization-resistivity, magnetic (King, 1980) and gravity surveys (Olson, 1980) were undertaken to determine the nature of a strong airborne electromagnetic anomaly located in 1979 on the shoreline. The induced polarization-resistivity survey indicated a thin, low resistivity horizon at an estimated depth near 250 metres and a low resistivity surface layer. The magnetic survey results showed little deviation from the generally low magnetic relief of the area. Gravity results indicated geologic and/or fault related features in the vicinity of the airborne electromagnetic anomaly.

GEM-8 MULTI-FREQUENCY ELECTROMAGNETIC SURVEY (1982)

In February 1982, a deep penetrating EM survey was undertaken on the eastern portion of the Permit. The survey was conducted on a chained and compassed grid which was reconstructed on the ice from pre-existing hand-cutlines established during the 1980 season. The grid of 200 metre spaced lines was marked at 50 metre intervals with pin flags which were retrieved at the end of the survey. The survey was targeted over the 1979 airborne electromagnetic and 1980 gravity anomalies betwen lines 7+00E and 17+00E of the reconstructed grid (Figure 1).

The instrument used in this survey is a GEM-8 multi-frequency electromagnetic prospecting tool manufactured by McPhar Geophysics. The GEM-8 measures the phase difference and the amplitude ratio of a combined electromagnetic field composed of transmitted primary and induced secondary fields. These values are recorded at any of eight frequencies (41, 82, 164, 328, 656, 1 312, 2 624 and 5 248 Hertz), from two orthogonal receiver coils. The phase and ratio values are used to calculate the tilt angle (in degrees) and the ellipticity (in percent), of the ellipse of polarization of the combined primary and secondary electromagnetic field. Technical information for the GEM-8 is contained in Appendix III.

The Gem-8 can be used in a variety of receiver-transmitter configurations. The "Turam point mode" was employed for this survey (Eby, 1981). In this configuration, a stationary transmitter antenna of single strand 18 gauge magnet wire was deployed in a rectangle 500 x 800 metres. The long (northern) edge of the loop was 400 metres south of and parallel to grid baseline. The receiver was traversed over the target on 200 metre spaced lines perpendicular to the northern edge of the loop recording data on all eight frequencies at 50 metre intervals. The time required to collect a set of readings for all eight frequencies at a given location varied from one-half to three-quarters of an hour.

The calculated tilt angle and ellipticity were plotted in profile at a plan scale of 1:5 000, first by individual frequency (Figures 2 to 9 inclusive) and then by combining all the frequencies (Figures 10 and 11). The tilt angle data is plotted with a base value of ninety degrees which is the orientation of the primary field in the absence of a conductor.

DISCUSSION OF RESULTS

The results of the GEM-8 "Turam" electromagnetic survey were examined for divergent responses of the tilt angle and ellipticity values with respect to frequency and station. The data was reviewed with tilt angle and ellipticity amplitude plotted against station location for each frequency. Two anomalous zones were noted and plotted on Figures 2 to 9 inclusive. The range of these zones is also plotted on Figures 10 and 11 with the multi-frequency ellipticity and tilt angle profiles.

Zone 1 is the prominent anomaly. It exhibits a greater conductivity thickness than Zone 2 by virtue of its response to a wide range of frequencies (Keller). Zone 2, however, is considerably shallower than Zone 1 as noted from its much shorter anomaly wave length. This interpretation is supported by an interpretation of the airborne electromagnetic data (after Palacky, 1973) that produces a greater than three fold difference in relative conductivity thickness with the stronger response of Zone 1 at greater than twice the depth of the shallow, weaker conductor.

Both zones also exhibit a dramatic shift to grid north with increase in frequency. This is attributed to the shift of the induced current axis to the edge of the conductive formation with increase in frequency. Such a large shift to the north indicates the edge of a very shallow dipping body which extends to grid south.

The data was reviewed again with the tilt angle and ellipticity amplitudes plotted against frequency for 100 m stations on line 13+00E (Figure 12). This data presentation displays response features particular to specific frequencies or range of frequencies. Starting with station 2+50S, L13E, two distinct ellipticity features are noted. Feature A exhibits a response to low frequencies while Feature B responds well to high frequencies. The relationship persists northward on line 13E until Features A and B subside at 1+50N and 2+50N respectively. The fading of A and B coincides roughly with the limits of Zones 1 and 2 respectively. This observation corroborates the interpretation of horizontal conductors as causes for the anomalous Zones 1 and 2.

A third response, Feature C persists from 2+50N to the end of the line. This feature exhibits a relative conductivity thickness less than Feature A but substantially greater than Feature B. Feature C is presumed to be a conductive fault zone which sub-parallels line 13E, evident from a prominent structural lineament.

Zones 1 (Feature A) and 2 (Feature B) are interpreted as overlapping very shallow dipping horizons. Zone 2 is weakly conductive and shallow and extends lakeward from approximately 100 m offshore. It is roughly coincident with a weak gravity step and airborne electromagnetic anomaly. It is most likely conductive lake bottom sediments. Zone 1 is more highly conductive and deeply seated. It coincides with a strong gravity step and prominent structural lineament which sub-parallels the lakeshore. It is also interpreted as a deep moderately conductive anomaly from airborne electromagnetic data. This feature may represent a fault bounded conductive regolith or saline aquifer within the Athabasca Formation.

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Respectfully submitted

A. A. Brown, P. Geol.
Manager, Uranium Exploration

[redacted]

R. C. Everett
Staff Technologist

APPENDIX I

STATEMENT OF EXPENDITURES

HUDSON'S BAY OIL AND GAS COMPANY LIMITED
QUARTZ MINERAL EXPLORATION PERMIT 6879030003

HUDSON'S BAY OIL AND GAS COMPANY LIMITED has incurred costs for mineral exploration work relating to the above Quartz Mineral Exploration Permit pursuant to the Quartz Mining Regulations, during the period March 15, 1981 to April 15, 1982, as follows:

Salaries	$ 6 636.00
Materials & Supplies	681.55
Truck Rental	489.00
Ice Road Ploughing	720.00
Airfares	1 308.60
Geophysical Equipment	3 136.00
Accommodation	1 270.60
Trucking & Freight	1 034.59
Miscellaneous Expenses	104.80
TOTAL	$15 381.14

APPENDIX II

LIST OF PERSONNEL

QUARTZ MINERAL EXPLORATION PERMIT 6879030003

LIST OF PERSONNEL

Name & Address	Position	Days
A. A. Brown, P. Geol. [redacted] CALGARY, Alberta T2K 2C3	Manager, Uranium Exploration	3
A. R. Bays [redacted] COCHRANE, Alberta T0L 0W0	Geophysicist	4
R. C. Everett [redacted] CALGARY, Alberta T3B 1W8	Staff Technologist	20
R. H. Dearden [redacted] CALGARY, Alberta T2B 2C9	Minerals Technician I	14
R. J. O'Shea [redacted] CALGARY, Alberta T2E 3E4	Minerals Technician III	14

APPENDIX III

GEM-8

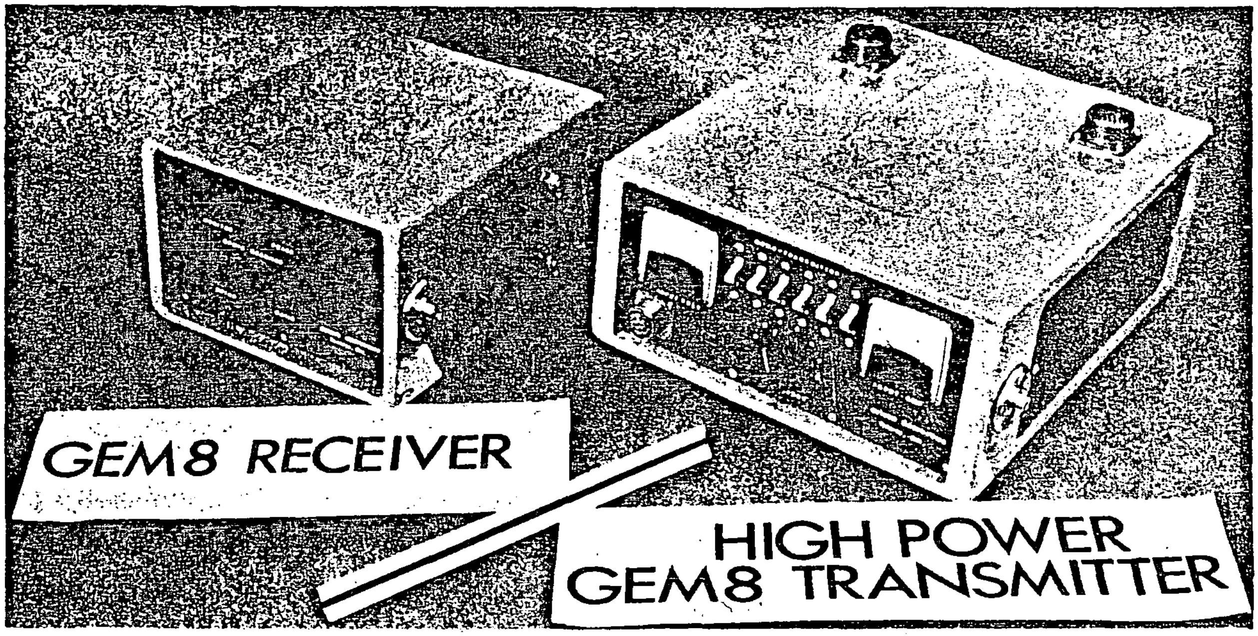
GROUND ELECTROMAGNETIC SYSTEM

TECHNICAL INFORMATION

May, 1981

GEM® 8

8 Frequency Ground Electro Magnetic System



. Frequencies from 41 Hz to 5248 Hz.
. 50 m to 2000 m coil separations, depending on system configuration.
. Measures Ratio and Phase difference deriving Ellipse parameters.
. No physical or radio link between transmitter and receiver.
. Simple operation means accuracy is independent of operator experience.
. Depth penetration in excess of 1000 meters.

. Wide range of system configurations means flexible applications.
- Horizontal or Vertical Loop Tx.
- Fixed Tx, Inline or Broadside Surveying,
- Parametric, Geometric or combined depth Sounding,
- V/H terrain compensation similar result to SHOOTBACK without Tx-Rx exchange,
- Multi-receiver operation,
- Point and Gradiant mode TURAM surveying.

GEM8 is a flexible ground EM system with a range of capabilities normally requiring many individual instruments.

The Ellipse parameters are inherently normallized and do not require precise station setting. This means easy operation and inexpensive survey cost.

The receiver (Rx) console and coil is common to all configurations. The 5Kg console and air-core coil avoid field distortion problems associated with iron and ferrite cores and can be operated by inexperienced personnel.

GEM8 can help solve most EM exploration problems by appropriate selection of transmitter console, coil and power source, and the survey configuration.

One of our experts can help you configure the ideal <u>system or survey</u> for your needs.

GEM8 RECEIVER

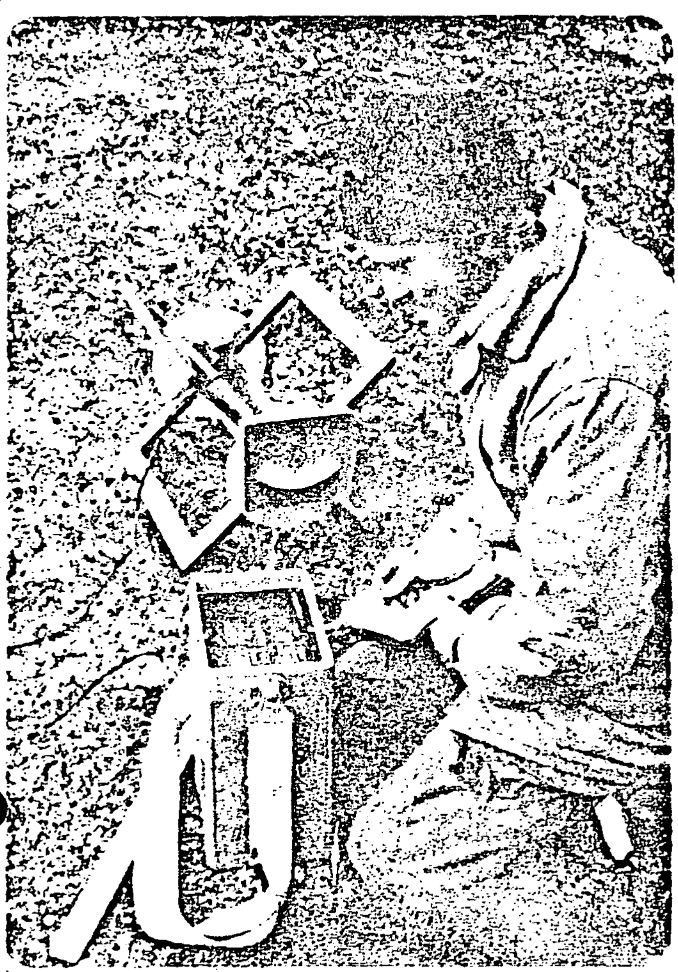
The receiving system, consisting of console, crossed-coils and power supply, is common to all configurations.

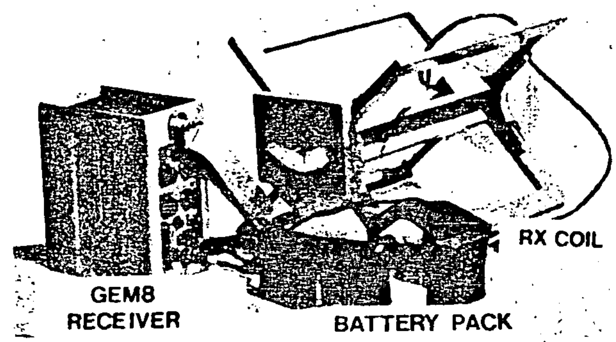
CONSOLE: The compact fibre-glass case with side mounted controls is easy to carry and convenient to use. Four windows in the front panel digitally display field measurements and instrument monitoring parameters.

CROSSED COIL: The coils are air-core to avoid field distortion, characteristic change by temperature, and electrostatic problems associated with iron and ferrite cores.

POWER SUPPLY: A leather waist belt containing the rechargeable battery pack can be worn comfortably for hours.

FIELD OPERATION: To avoid extraneous conductor effects, arbitrarily orient the coil on the ground, remote (2 m) from both operator and console. After noting the coil inclinometer reading, simply select the desired frequency and read the amplitude ratio and phase.





RESULTS: A simple calculation, using a pocket calculator, converts the ratio and phase to Tilt Angle and Ellipticity. These parameters are virtually independent of Rx-coil orientation and fluctuation of Tx-field and insensitive to inaccuracy in the Tx-Rx coil separation.

GEM8 TRANSMITTER

The transmitting system consists of a console, transmitter loop and power supply. Due to inverse cubic power law in distance, the primary field strength decreases from 64000 to 1 as Tx-Rx distance increases from 50m to 2000m. Therefore it is necessary to configure your Tx system with the proper choice of console, loop and power supply according to the survey scale.

CONSOLE: Compact fibre glass cases are easy to carry and operate. Power and voltage control permits choice of optimum signal strength and power consumption.

LOOP: Depending on the application, one or more 30m cables in series, portable framed coil on a tripod, or a large single conductor loop for TURAM operation is available.

POWER SUPPLY: Based on the power required, a JLO back-packed generator or rechargeable battery pack belt is available.

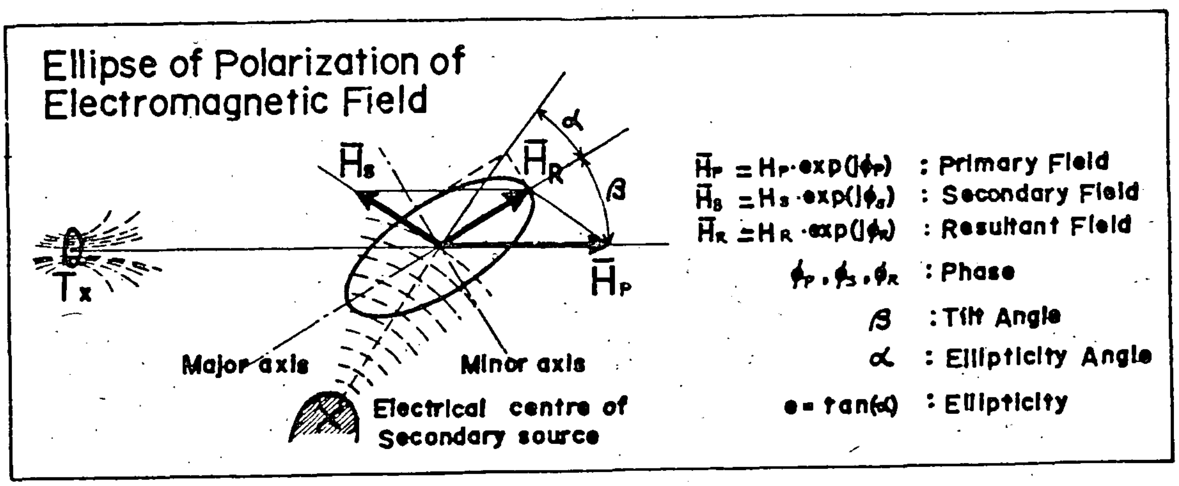
FIELD OPERATION: The Tx coil is quickly erected in position. Rotate the frequency selector to the desired position and the survey has begun. Depending on the power-console-coil configuration best suited to your needs and the local geological conditions, the response from the eight accessible frequencies permits depth sounding for strata definitions to better than half the Tx-Rx Separation. In addition the range of conductivities covered includes virtually all ore body types.

An electromagnetic field may be completely described by two parameters of the ellipse of polarization, the ellipticity and tilt angle. Work by N.R. Paterson and S.H. Ward have indicated the usefullness of these parameters as a means of obtaining geophysical information without resorting to a connecting reference cable between the transmitter and receiver. In 1970, S.H. Ward suggested that two orthogonal receiver coils could be used to determine the ellipse parameters without resorting to the "NULL" method.

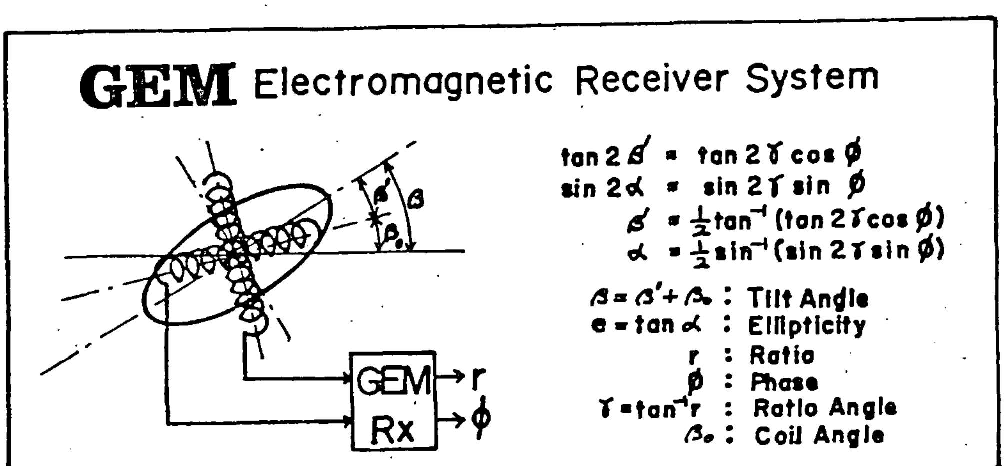
The ellipse parameters are insensitive to transmitter moment fluctuations and less sensitive to distance variations between transmitter and receiver than inphase and quadrature quantities as measured by loop-loop EM. Knowledge of the transmitter moment magnitude is unnecessary for interpretation since the ellipse parameters, inherently are normalized quantities.

Because the importance of EM measuring at multi-frequenceies and at lower frequency has been emphasized by S.H. Ward, N.R. Paterson and many other geophysicists, GEM8 measurements are made at eight frequencies as a standard provision; the lowest frequency is as low as 41 Hz.

Because the secondary electromagnetic field induced by a conductor in transmitting the primary electromagnetic field may be out of phase with the primary field, the resulting field at the receiving position is elliptically polarized. The parameters, ELLIPTICITY and TILT ANGLE, define the ellipse of polarization of an electro magnetic field, thus indicating the nature of the source of the secondary field.

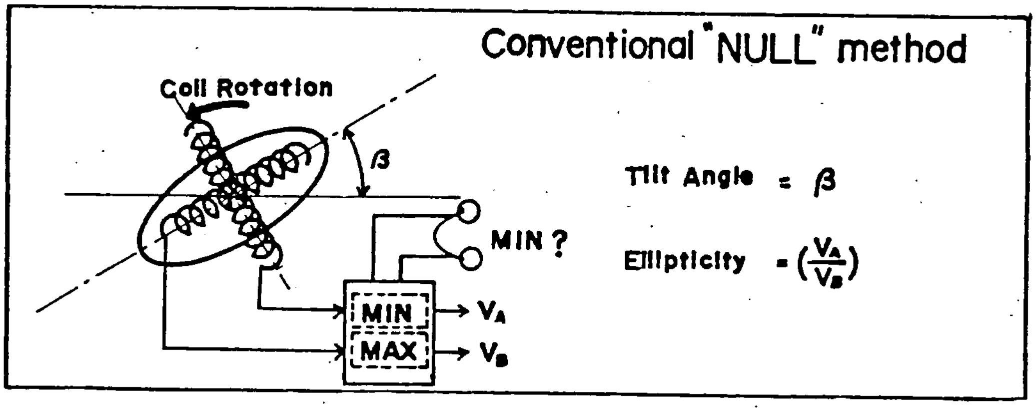


In the **GEM** system, the transmitter (Tx) generates an alternating electromagnetic field at the specified frequency. The receiver orthogonal coils (Rx-coils), placed on the ground at some distance from Tx, receive the electromagnetic field. The signal is digitally processed to give the amplitude ratio (r) and the phase difference (ø) between the two signals.

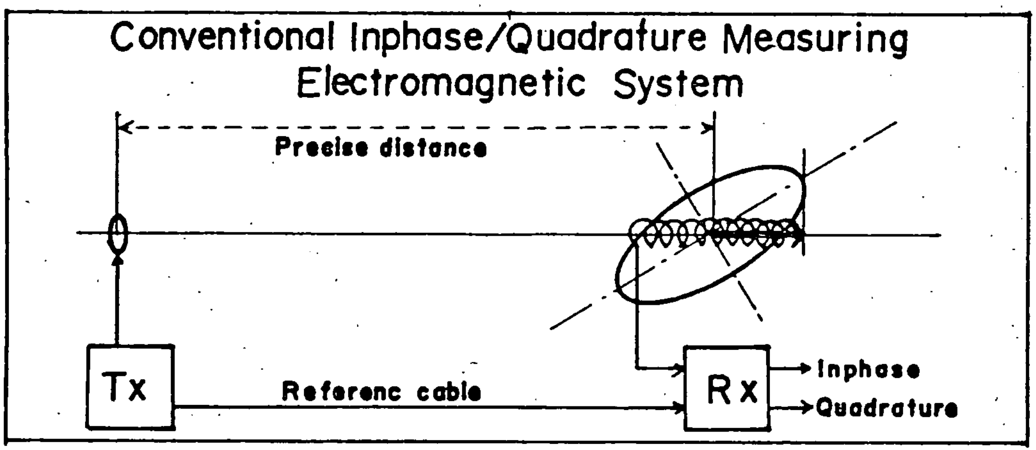


As indicated in the figure, two ellipse parameters are derived from the amplitude ratio and the phase difference between the Rx-coils. The Ellipticity is independent of the inclination of the Rx-coils. The Tilt Angle referred to the primary field direction can be obtained by subtracting or adding the inclinometer reading to the measured Tilt Angle. Therefore, leveling of the Rx-coil is not required.

Geophysical prospecting methods which measure ellipse parameters are not new. In conventional "NULL" methods, orthogonal coils are rotated until the output of the reference coil is minimized. As shown in the figure, the ratio of the signal amplitudes from the two coils and the angle between the horizontal and one coil axis at the "NULL" position are measured to determine ellipticity and tilt angle.



Other conventional EM systems (eg: the slingram method) measure a projection of the total field along the Tx-Rx axis. This projection is frequently defined in terms of inphase and quadrature components. These methods require a reference cable and precise Tx-Rx distance measurements as well as accurate leveling of the Tx and Rx coils.

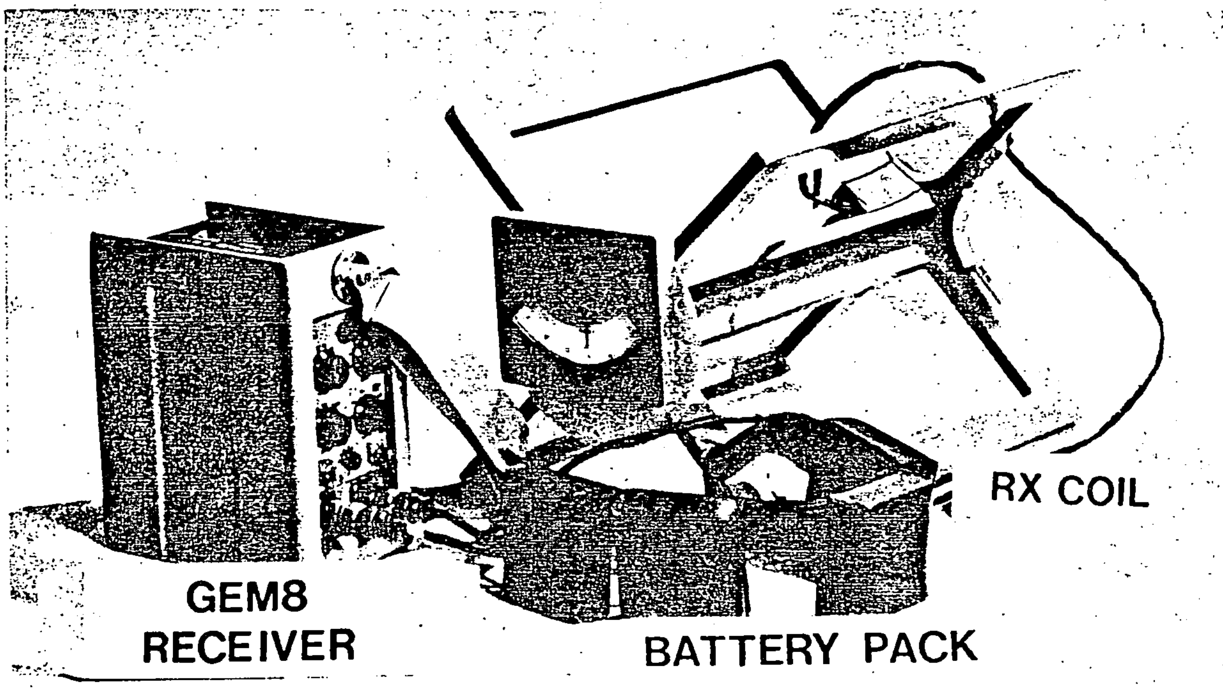


The **GEM** system has the following advantages:

1. No "Nulling", no "Leveling", no "Tuning", no "Tx-Rx link", (neither cable nor radio), no "Rx-coils leveling".
2. Inherently normalized parameters at Rx results in negligible effects from magnitude fluctuations of Tx field and variation of Tx-Rx distance.
3. Signal enhancement and phase/frequency filtering are achieved by sampling the signal at 16 points/cycle and stacking the samples.
4. Complete definition of the electromagnetic polarization ellipse compared to the measurement of a projection of one dimensional component of the field.
5. The ellipticity is derived with a sign (positive or negative) depending upon which way the ellipse rotates while conventional "NULL" methods give only absolute value (always positive).
6. Simple and effective terrain correction for tilt angle. The ellipticity parameter is independent of coil misorientation due to elevation difference between Tx and Rx.

GEM®

GROUND ELECTRO-MAGNETIC SYSTEM



GEM8 RECEIVER SPECIFICATIONS

CONSOLE: Rugged, splash-proof fibre glass case 5 Kg, 16 cm X 25 cm X 30 cm

POWER SUPPLY: Rechargeable leather battery pack belt weighs only 4 Kg. Fully charged pack lasts 15 hours at 20°C.

RECEIVER COIL: Rugged, self-standing air-core crossed-coils with inclinometer. 5 Kg, 50 cm X 50 cm X 50 cm

DISPLAYS: Four 4-digit all-weather LCD (LED option) digital display windows on the front panel.

PARAMETERS MEASURES:
- RATIO - 4 digits, 3 decimal places, 0.1% accuracy
- PHASE - 360 degrees, 4 digits, 1 decimal place, 0.1 degree accuracy

FREQUENCIES: 41 Hz, 82 Hz, 164 Hz, 328 Hz, 656 Hz, 1312 Hz, 2624 Hz, and 5248 Hz.

SENSITIVITY: 1 nano A/m (1×10^{-9} A/m)

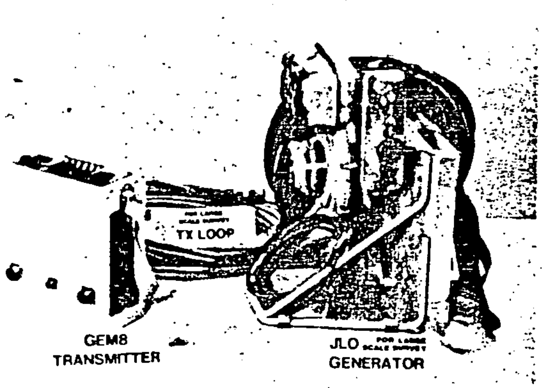
GAIN: 8 positions in factors of 2

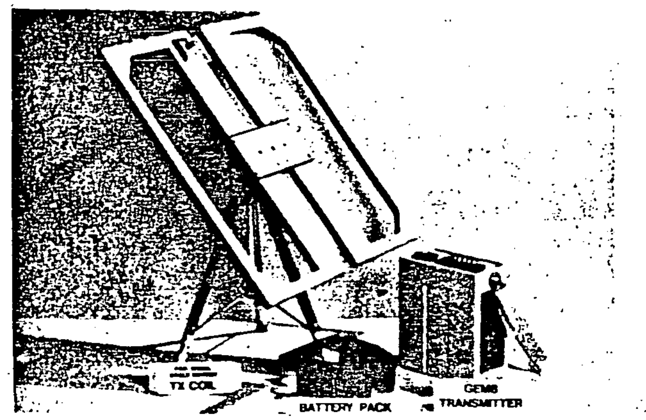
MONITORS: Battery level, Noise strength, Signal strength, Frequency and Gain indicater, and optional inclinometer reading.

REPEATABILITY: Tilt Angle .1 degree, Ellipticity .1%, under ideal conditions in the mid-frequency range. Field repeatability depends on coil separation, frequencies and field conditions.

SIGNAL ENHANCEMENT: The input signal is filtered by stacking 16 equi-spaced samples per cycle thus insuring complete signal definition.

Figure 1 shows a block diagram of the GEM-8 receiver. After the signal from each coil is preamplified, two stages of sophisticated filtering reduces random noise to a negligible level. Exchange of the coils and processing channels permits elimination of all instrument bias and a virtually noise free read-out.





GEM8 TRANSMITTER SPECIFICATIONS

<u>CONSOLE:</u> Rugged, splash-proof fibre glass case, 11 kg, 17 cm X 33 cm X 38 cm for High Power System and kg, 16 cm X 24 cm X 30 cm for Portable System.

<u>POWER SUPPLY:</u> Depends on the survey scale and Tx loop.

<u>JLO back-packed generator</u> - 1.5kw maximum output, 34kg weight with gasoline, for large loop Tx.

<u>Rechargeable leather batter pack belt</u> - 17 ampere-hour, 6 kg for portable coil.

Other types of power source are available.

<u>TRANSMITTER LOOP:</u> Depends on the survey scale and method.

<u>30 m cable</u> - one or more in series. 19 conductors, neoprene, horizontal on the ground or vertical with a mast. Maximum moment at 41 Hz, with four 30 m cables is approximately 7.2 X 10^4 Am^2 and maximum Tx-Rx is 2000 m for good ground and noise conditions.

<u>Portable framed coil</u> - 1m X 1m mounted on a tripod for horizontal, vertical or V/H topo-cancel operation. Maximum moment at 41 Hz is approximately 500 Am^2 and maximum Tx-Rx distance is 300m for good noise condition.

<u>TURAM loop</u> - Single conductor loop of normal TURAM size (several km long). Survey distance from loop is several km depending on the loop size.

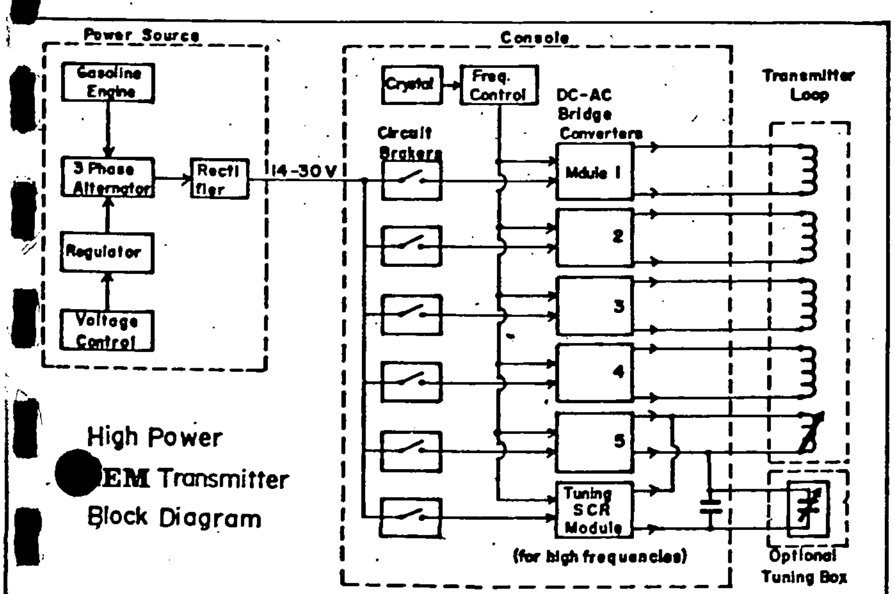
Other types of Tx loop are optional.

<u>FREQUENCIES:</u> 41 Hz, 82 Hz, 164 Hz, 328 Hz 656 Hz, 1312 Hz, 2624 Hz, and 5248 Hz.

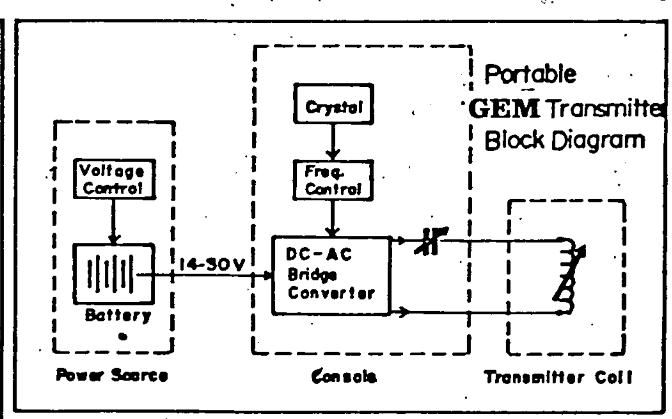
<u>OUTPUT MOMENT:</u> Variable depending on loop size, frequency, applied voltage and type of console.

<u>OUTPUT CONTROL:</u> Input voltage control and number control circuit breakers applied for high power transmitter console.

<u>DIAGNOSTICS:</u> Input voltage, output ampere and frequency indicator.



High Power GEM Transmitter Block Diagram



Portable GEM Transmitter Block Diagram

(Note: E_A and E_B are possible amplifier error sources)

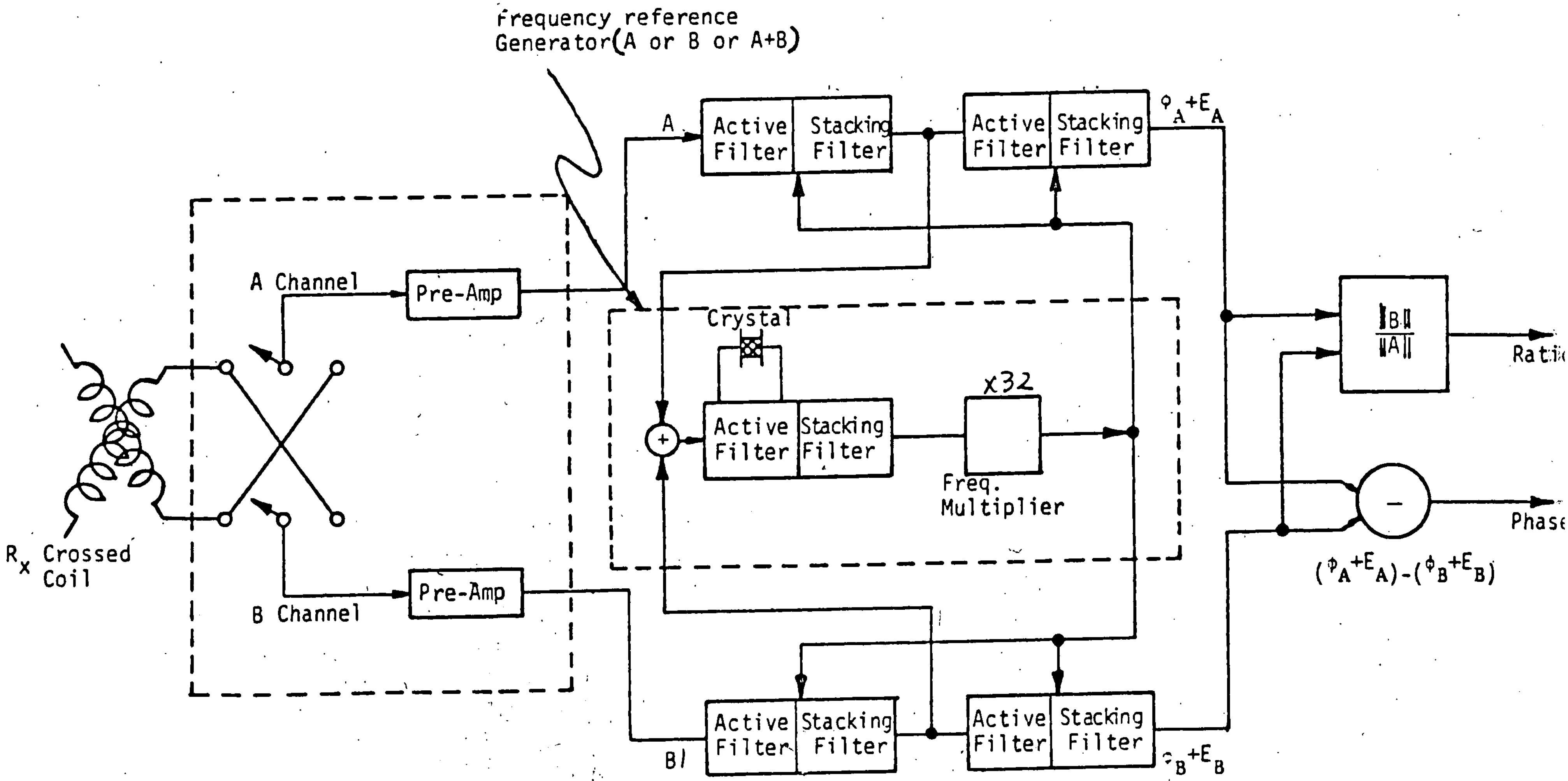


FIGURE 1: GEM-8 Receiver Block Diagram

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H.L-Tx MULTI-Rx/DEPTH SURVEY: Results give pseudo-section resistivity information like dipole-dipole IP or resistivity surveys. The multi-frequency measurements give more detailed information than resistivity survey.

POINT/GRADIANT MODE TURAM: Deep penetration surveys for large area coverage. Point mode survey can be performed by one-man Rx operator and with random station distribution. The point mode operation measures total field in terms of the ellipse of polarization parameters. There is no weak-field problem due to a large field tilt. A conventional TURAM method measures vertical component only and has a measurement problem when the field is tilted away from vertical.

FIXED V.L-Tx SURVEY: Locating deep conductors accurately.

ELECTROMAGNETIC DEPTH SOUNDING

Ward et al (1974) evaluated a multi-spectral electromagnetic system that has some of the characteristics of **GEM** This work was oriented towards the examination of the known massive sulphide deposits of the Cavendish Test Site in Ontario. While satisfied with the potential of the system, these investigators state:

"Existing interpretation techniques are limited both in scope and in application. The scope can be extended by expanding the range of simple single unit models upon which interpretation is based."

In their extensive discussion of electromagnetic induction methods, Grant and West (1965) point out that: "Depth sounding can be performed by the electromagnetic induction method in a manner analogous to the way it is done by D-C conduction." Further, it is also theoretically possible to achieve virtually similar results by varying the current frequency and keeping transmitting and receiving coils a fixed distance apart. Indeed, Slichter (1933) demonstrated that if an alternating magnetic dipole lies at the surface of a medium whose electrical conductivity is a function of depth only, the conductivity of the medium everywhere at depth may be completely determined by measurements of the field intensity at the surface. While this theorem has not, as yet, led to a practical method for direct interpretation, it is valuable in establishing the uniqueness of solutions to depth-sounding problems.

In spite of the firm theoretical foundation for electromagnetic depth sounding, it has not been popular. The D-C conduction method has tended to be used in place of electromagnetic method. Grant and West suggest that one of the reasons for the disuse of electromagnetic sounding is that theoretical curves for more than one surface layer overlaying a half space are not generally available.

Dey and Ward(1970) outline a complete solution of the boundary value problem of a horizontal magnetic dipole over a homogeneous and n-layered half-space. These authors suggest that the ellipticity, (a parameter derived from **GEM** measurements), is the best field parameter for use both with parametric and geometric sounding.

Other studies of multi-spectral depth sounding using tilt angle and ellipticity have been carried out by Ryu, Morrison, and Ward (1972); by Glenn and Ward (1976); and by Pridomore, Ward, and Motter (1979).

A number of studies suggest that practical automatic techniques for the direct interpretation of multi-frequency electromagnetic data can be developed. Daniels, Keller, and Jacobson (1976) outline a computer assisted method of depth sounding. They make use of an algorithm presented by Ghosh (1971) to evaluate and Hankel transform integral. Recently, Anderson (1979) has developed an algorithm that is more accurate than that suggested by Ghosh, without loss of efficiency.

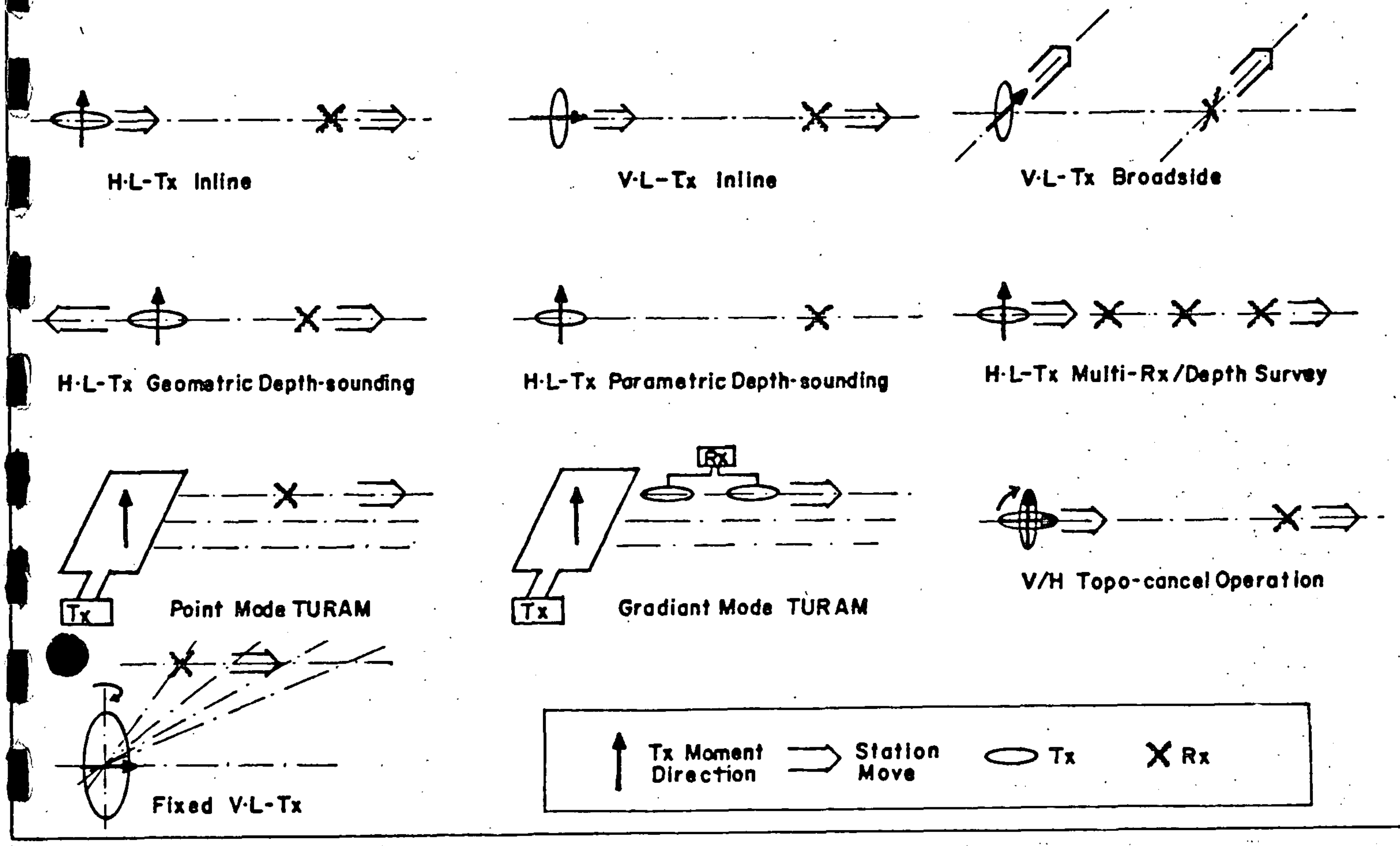
Further, Lajoie, Alfonso-Roche, and West (1975) have suggested expressing the electromagnetic response of a layered earth in rectangular co-ordinates. A solution may then be obtained as a double inverse Fourier transform. The fast Fourier transform algorithm may be used to evaluate the fields.

With the assistance of the National Research Council of Canada, McPHAR is developing an automated computer interpretation method for the GEM8.

GEM®

GROUND ELECTRO-MAGNETIC SYSTEM

GEM Survey Confguration



The **GEM** system fully defines the field and requires no Tx-Rx reference link. These characteristics permit maximum flexability in survey design.

McPHAR can help you configure the ideal system and survey for your application.

H.L-Tx INLINE: Applied for horizontal profiling for conductor location. Suitable for massive sulfides and flat lying conductors. When all eight frequencies are applied at each station, the depth sounding capability gives continuous stratagraphic information.

V.L-Tx INLINE: Horizontal profiling for conductor search. When combined with measurements by H.L-Tx Inline, the results clearly indicated whether the conductor is vertical dyke type or flat lying.

V.L-Tx BROADSIDE: For accurate locating of conductors, due to the cross-over type response.

H.L-Tx GEOMETRIC DEPTH SOUNDING: For stratigraphic surveying, depth to basement or defining geothermal reservoirs.

H.L-Tx PARAMETRIC DEPTH SOUNDING: An alternative to GEOMETRIC DEPTH SOUNDING for use in rough terrain area. Suitable to quickly map stratigraphy because of innecessity of changing Tx-Rx separation.

McPHAR

Sold By: McPHAR GEOPHYSICS
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ONTARIO, CANADA M2H 2R9
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CALCULATION OF ELLIPSE PARAMETERS

GEM System Parameters

RATIO (r))
between the two coils of Rx crossed-coil
PHASE (ϕ) in degree)

Coil Angle (β_0) in degree

EQUATIONS TO DERIVE TILT ANGLE (β) AND ELLIPTICITY (e)

$$\gamma = \tan^{-1} r \quad \text{(RATIO ANGLE)}$$

$$\beta' = \tfrac{1}{2} \tan^{-1} (\tan 2\gamma \cos \phi)$$

$$\alpha = \tfrac{1}{2} \sin^{-1} (\sin 2\gamma \sin \phi) \quad = \text{(Ellipticity Angle)}$$

$$\beta = \beta' + \beta_0 \quad \text{in degree}$$

$$e = \tan \alpha$$

This calculation can be performed by a simple hand held calculator. The chart figure overleaf is used to obtain, graphically, the tilt angle and ellipticity from the ratio and the phase.

REFERENCES

Dey, A. and Ward, S.H.;
Inductive Sounding of a layered earth with a horizontal magnetic dipole: Geophysics, Vol. 35, No. 4, August 1970.

Ryu, J., Morrison, H.F. and Ward, S.H.;
Electromagnetic fields about a loop source current: Geophysics, Vol. 35, No 5, October 1970.

Ryu, J., Morrison, H.F. and Ward, S.H.;
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A portible multi-frequency EM system for elipse of polarization measurements: Presented at the 43rd Annual Meeting the SEG, October 1973 in Mexico City.

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Broadband electromagnetic measurements over a massive sulfide prospect: Geophysics, Vol. 4, No. 10, 1979.

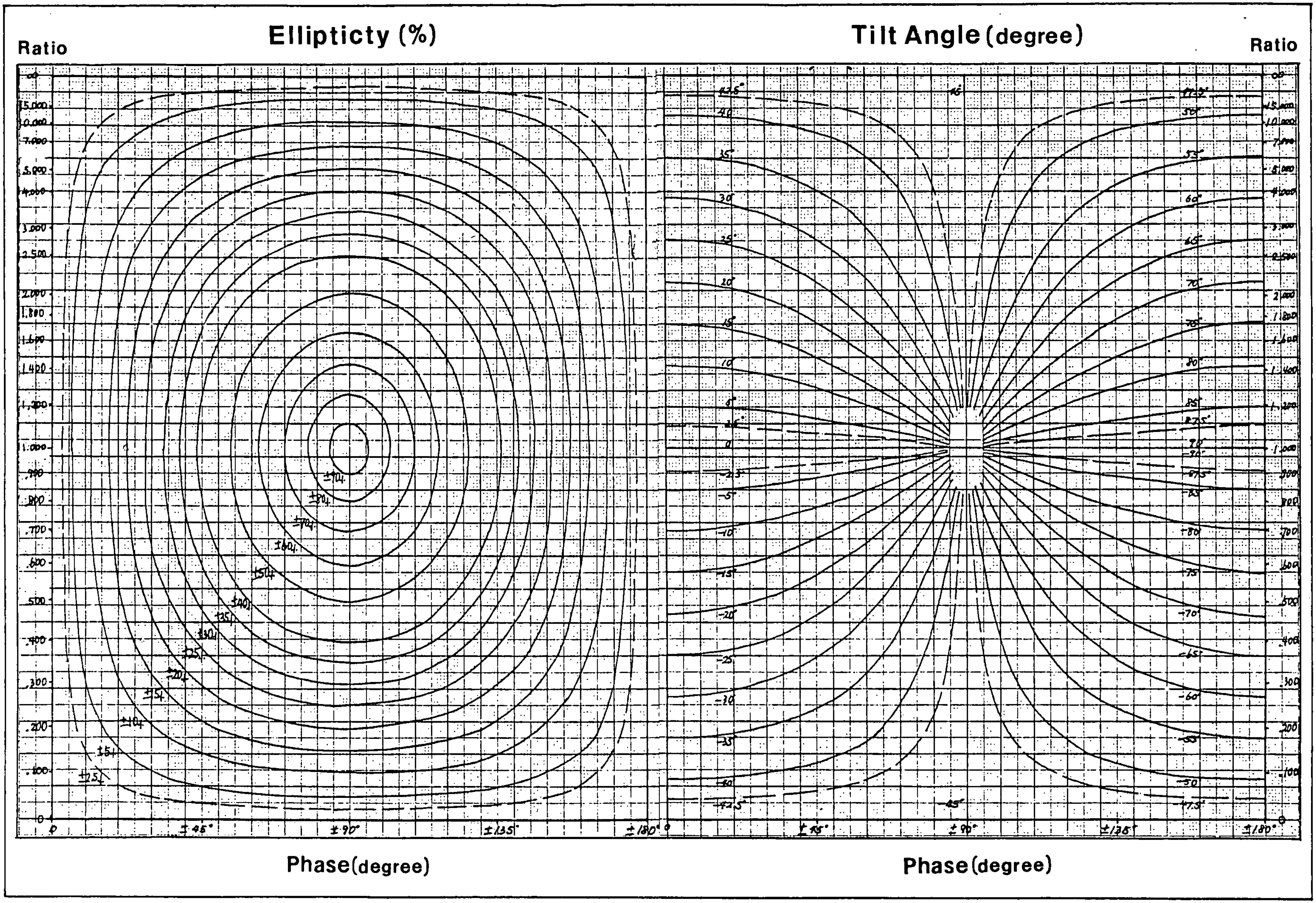

Fig. A

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GROUND ELECTRO-MAGNETIC SYSTEM

VERTICAL CONDUCTOR RESPONSE

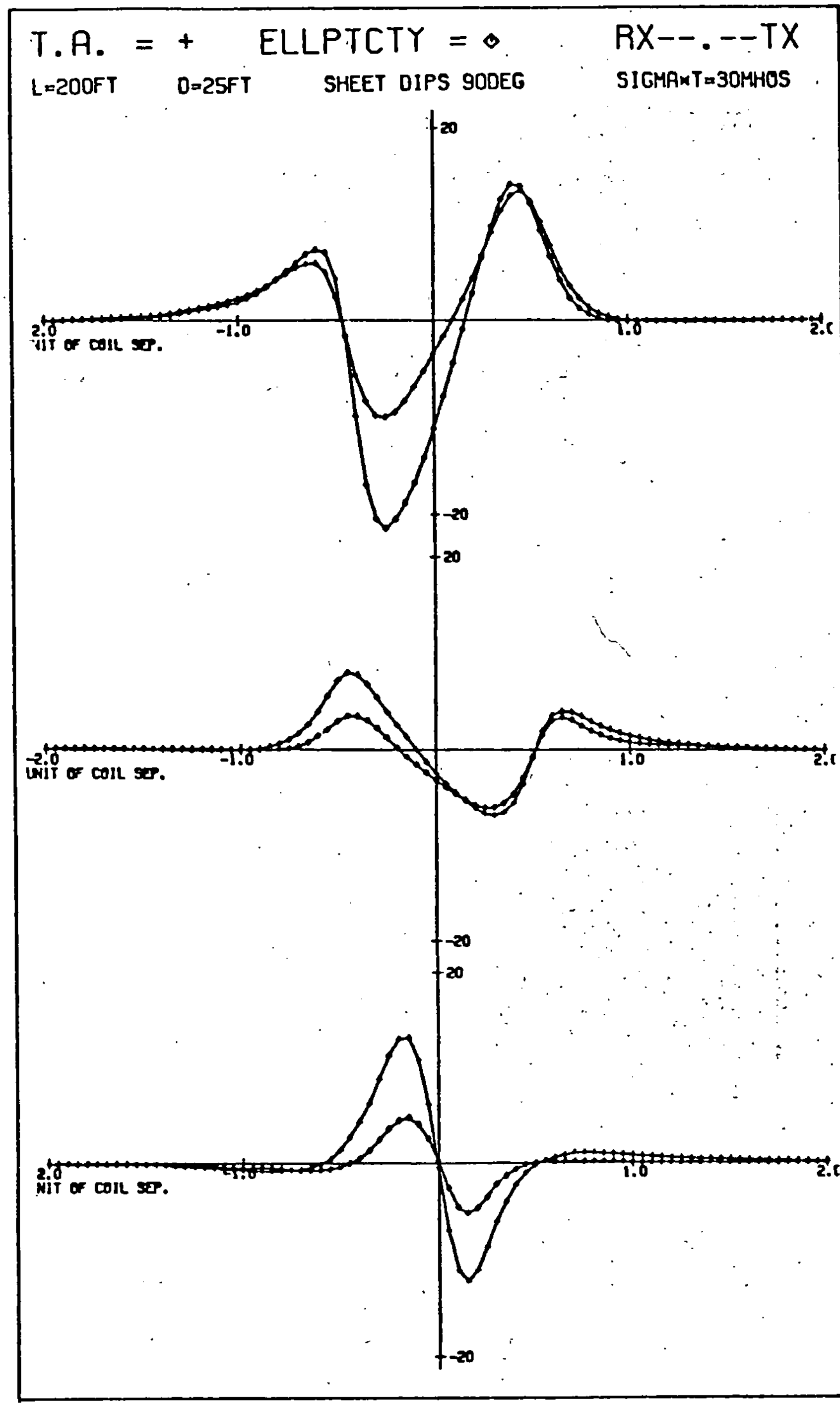
The right figure shows typical responses of tilt angle and ellipticity over vertical conductors. These are Horizontal Loop Tx Inline, Vertical Loop Tx Inline and Vertical Loop Tx Broadside from the top to the bottom in the figure:

The data was obtained using a scale model experiment of a thin conductor sheet in free space. The experiment was carried out for various σt (conductivity - thickness), depth and dip of the conductor.

The figures on the back of this page are summarized from responses for various dips and depths of conductors.

Although work by Ward and others has indicated the limitations of free-space modelling, these data indicate the response characteristics of the system and can simulate the response over conductors in high resistive host rock, such as Canadian shield, environments.

McPHAR is presently conducting studies using the tank model facility of the University of Toronto. These studies will give additional information on the effect of conductive terrains and conductive over-burdens.



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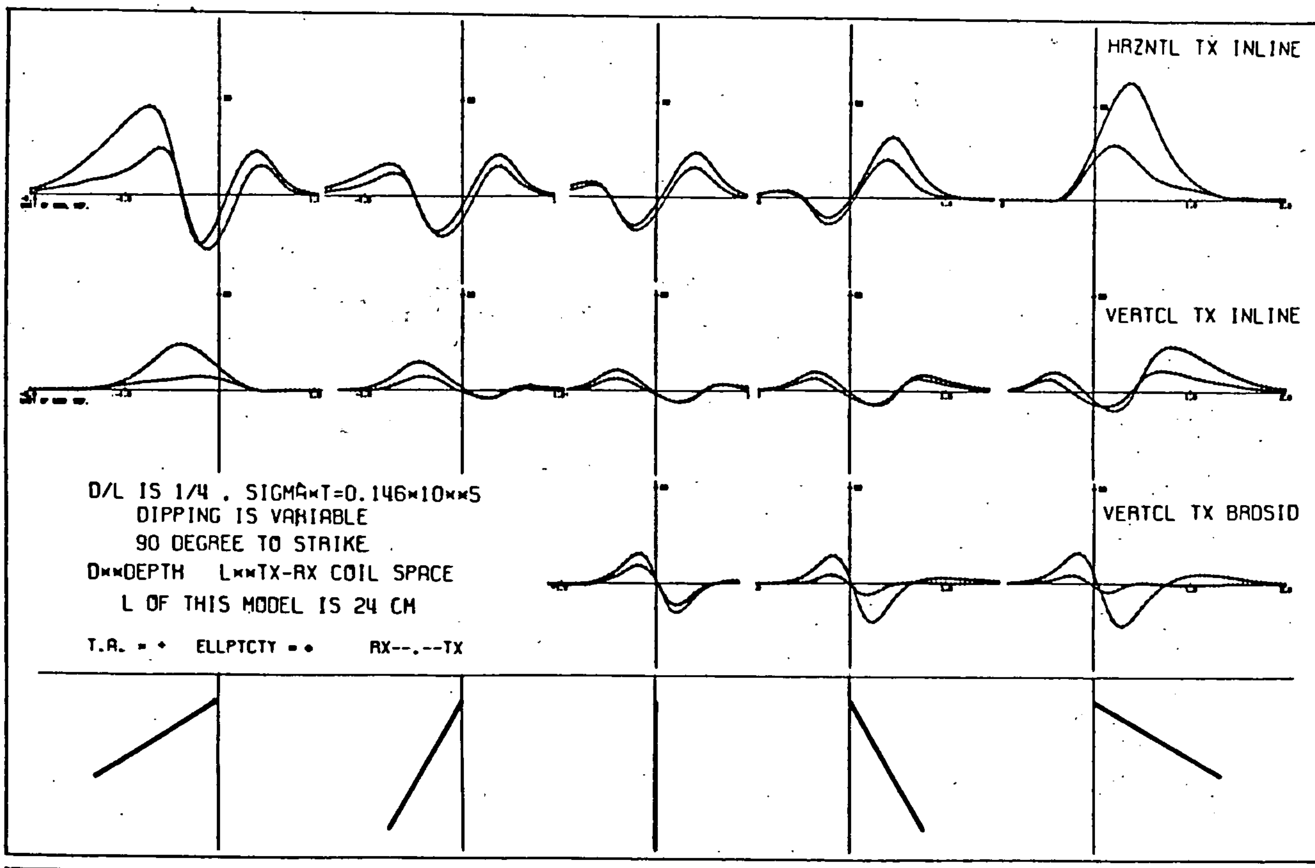
TELEPHONE: (416) 497-1700 TELEX 065-25305



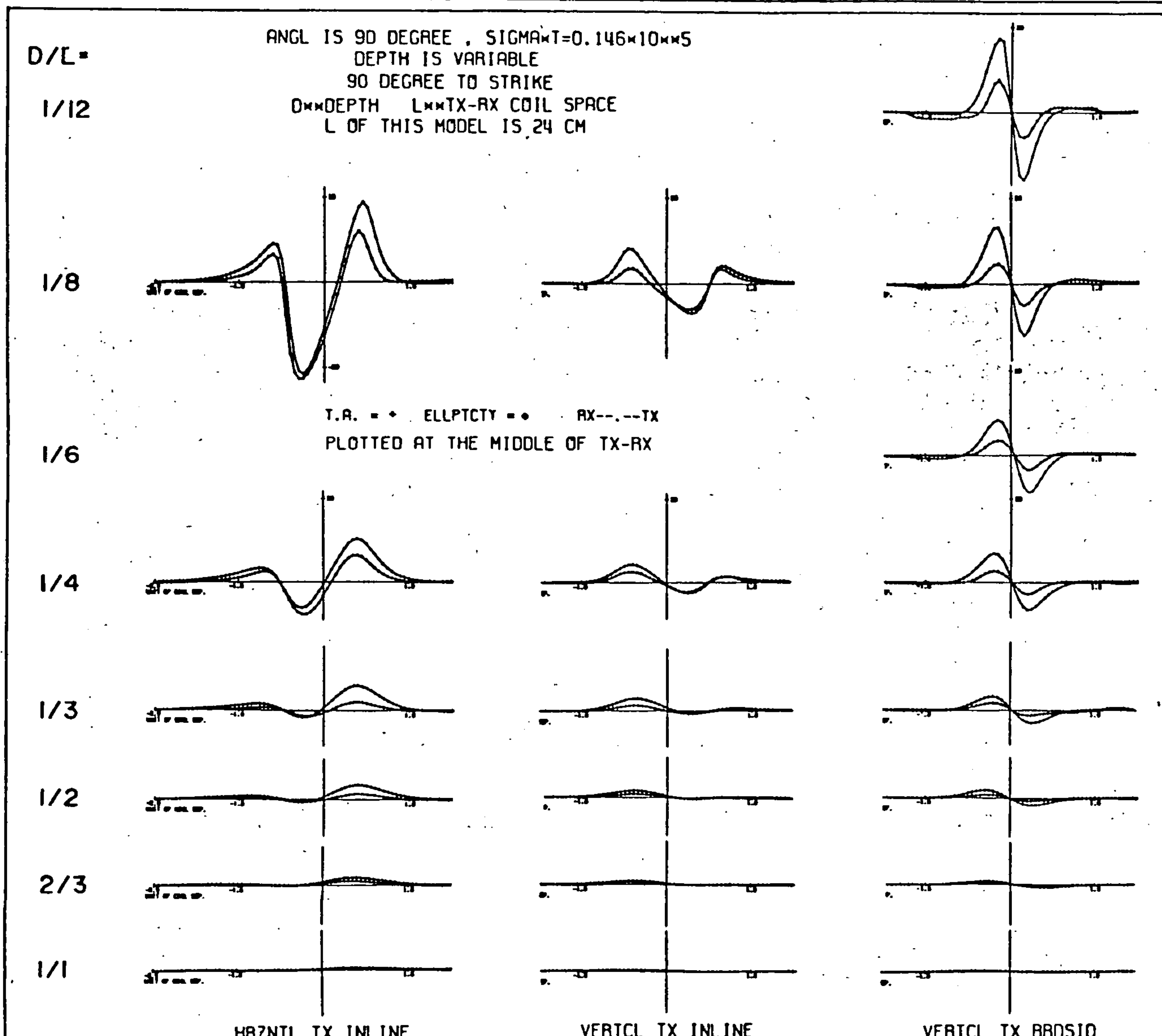


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Fig B

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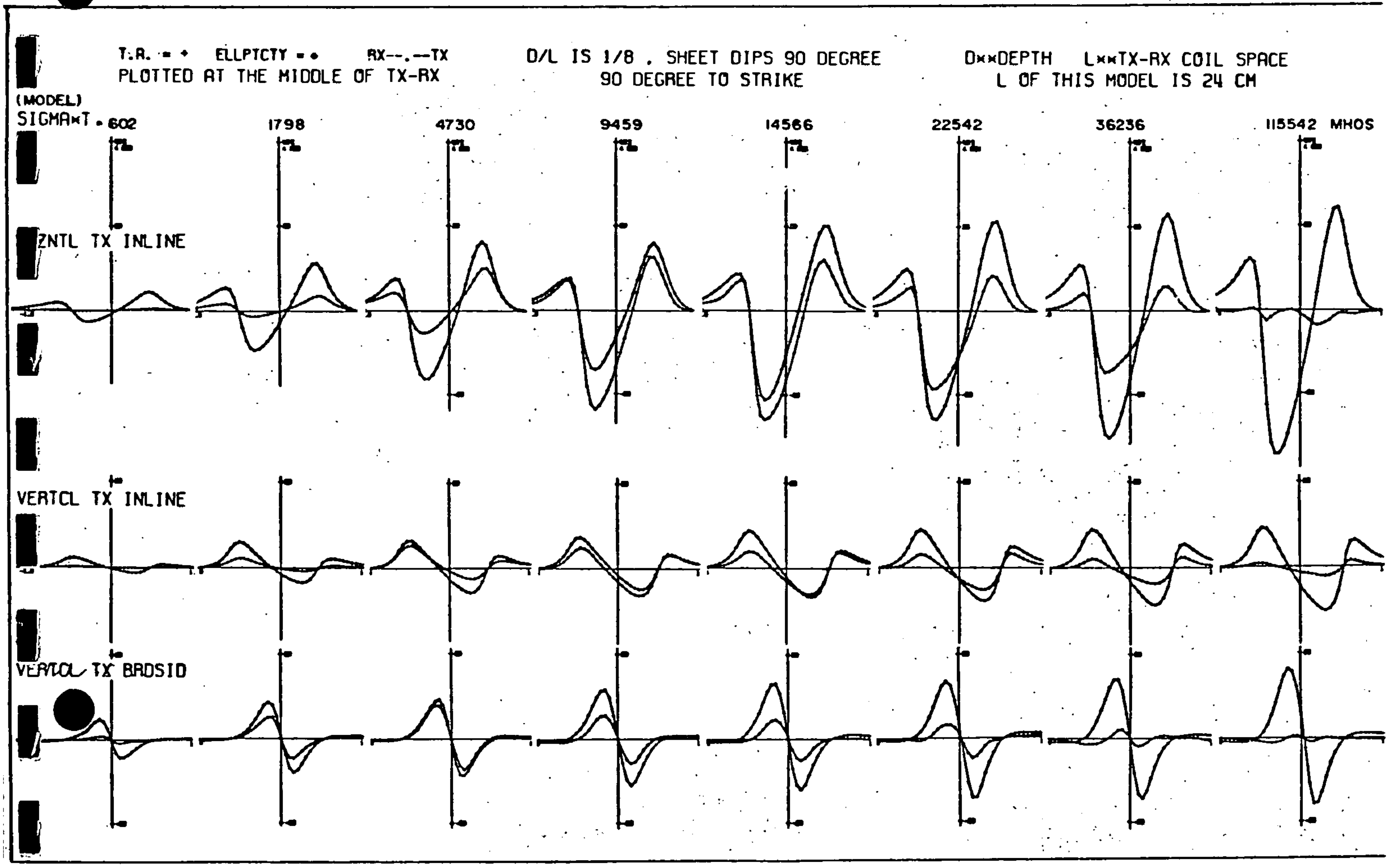
GROUND ELECTRO-MAGNETIC SYSTEM



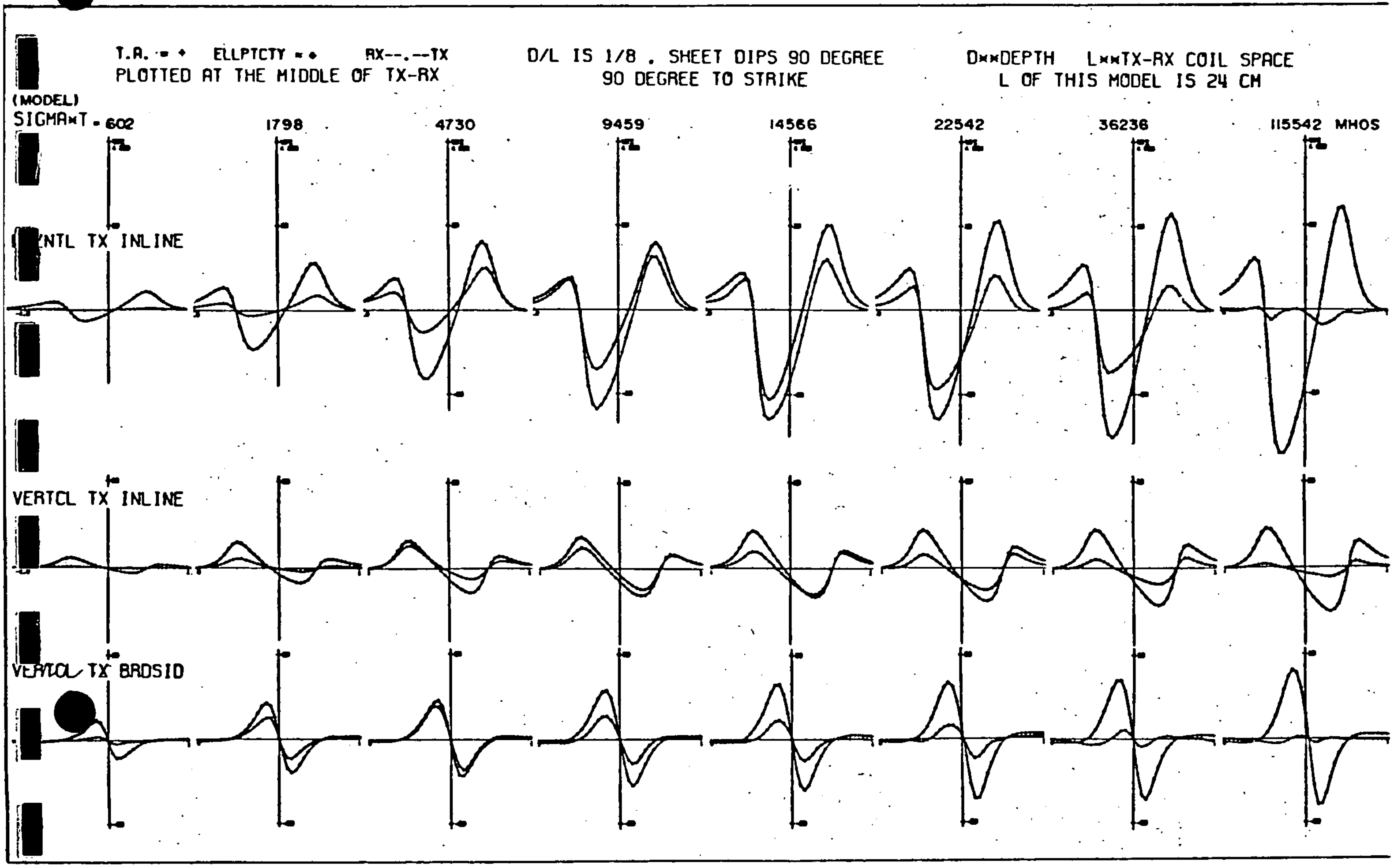
GEM responses of vertical sheet conductors of various σt (conductivity-thickness) are summarized in the figure above. We note a very small ellipticity response at low values of σt. As σt increases, the amplitude of the ellipticity increases to a maximum value near a σt of 14000 $\mho$/m. Beyond this value of σt, the ellipticity decreases with increasing σt. The tilt angle response, however, increases with increasing σt over the entire range shown toward saturation. This behavior is similar to the Quadrature and Inphase response of conventional EM System, and is diagnostic of anomaly sources.

All three of the above Tx-Rx configurations show similar anomaly behaviour.

The **GEM8** CONDUCTIVITY SPECTRUM (overleaf) shows the peak-to-peak response over steeply dipping dykes. This spectrum was constructed from experimental profiles. The lower portion of the figure indicates a variety of ore-body conductivity thicknesses. The range illustrated spans all economical mineral occurances. Although this spectrum is based on free space models it remains valid for the determination of apparent σt for real anomalies.

GEM®

GROUND ELECTRO-MAGNETIC SYSTEM



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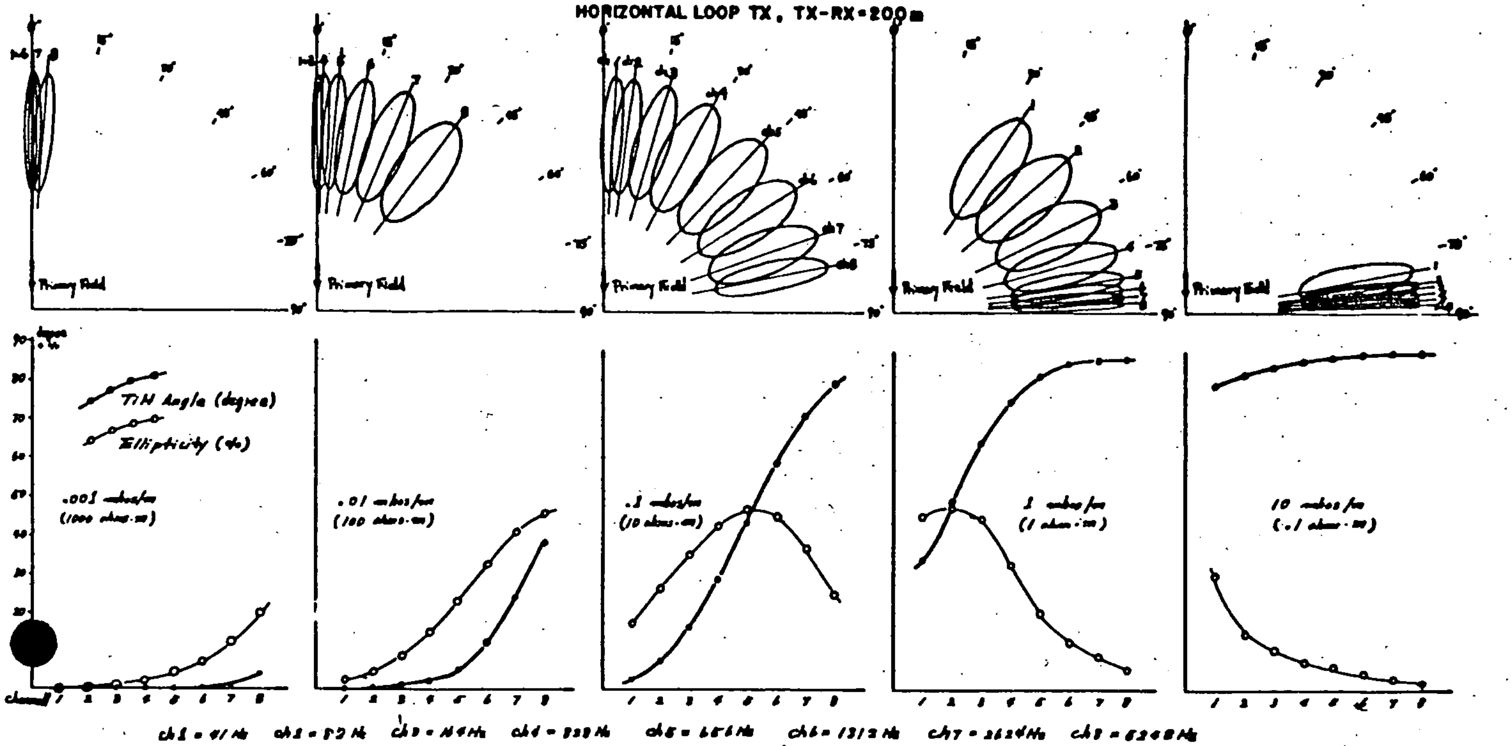
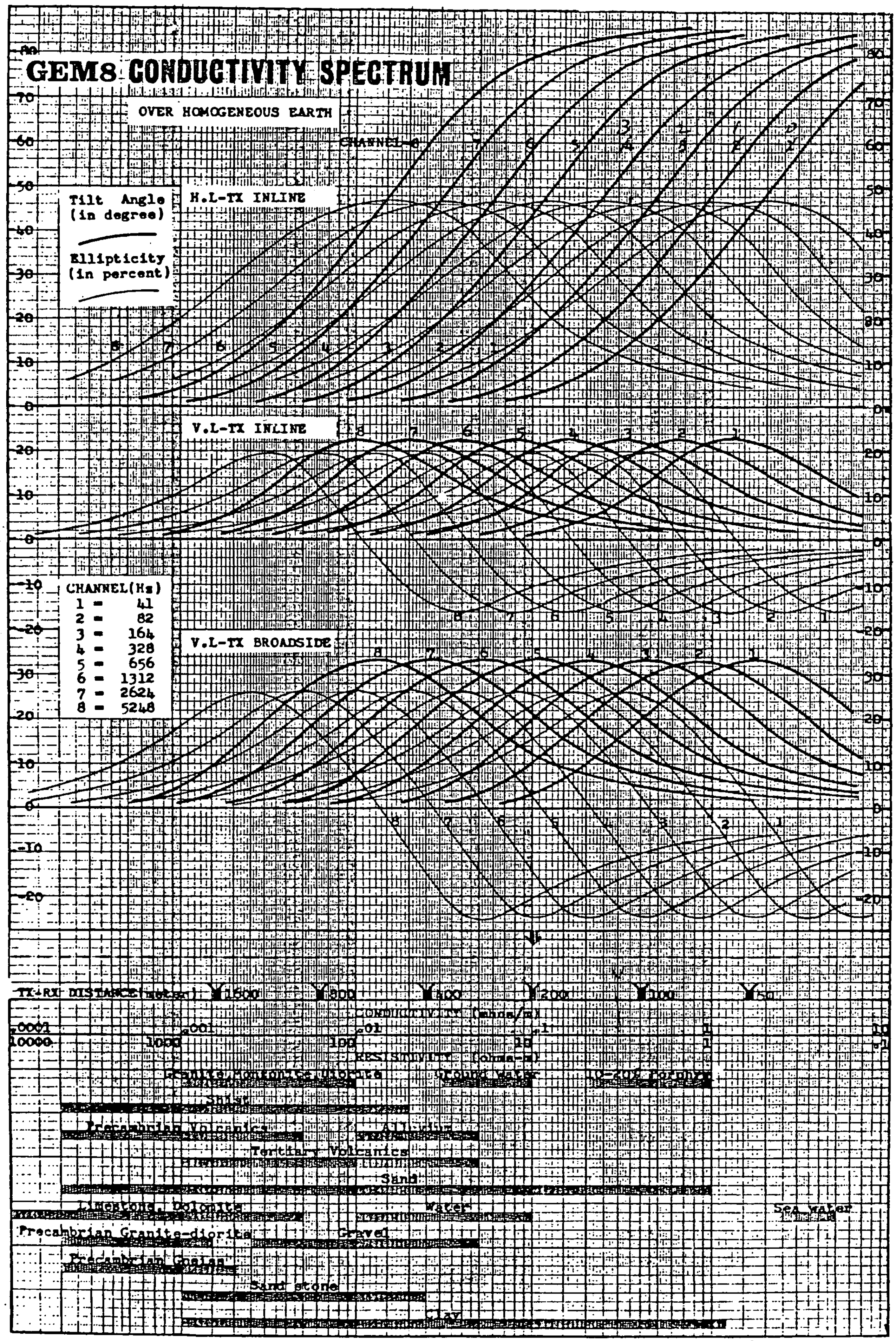
ELLIPSE OF POLARIZATION OF ELECTROMAGNETIC FIELD
OVER HOMOGENEOUS EARTH
HORIZONTAL LOOP TX, TX-RX=200m



The figure above illustrates the ellipse of polarization response over homogeneous earth of various conductivities (σ). The case shown is for a horizontal loop Tx and vertical primary field at Rx. Similar to the thin sheet conductor case, the tilt angle increases as σ increases toward saturation. Ellipticity increases as σ increases to a maximum value, then decreases with further increases of σ. Similar characteristics are indicated for increasing frequency because the induction parameter of the earth is related to the product of σt and f (frequency).

GEM8 CONDUCTIVITY SPECTRUM is shown in the figure overleaf. The conductivity of various geology is indicated. Generally, the response from the host rock has a negative influence on conductor location surveys. Knowledge of the response from the geology of a survey area is important in survey planning and interpretation.



1982001

Fig C

REMOVAL OF TERRAIN EFFECTS

GEM parameters (tilt angle and ellipticity)are virtually independent of small fluctuations in Tx-Rx distance. In addition the ellipticity is not significantly dependant on coil mis-orientation due to Tx-Rx elevation differences. However, elevation differences do affect the tilt-angle. The tilt angle error is dependant on the angle formed between the horizontal and a line joining the Tx and Rx as shown in the figure overleaf. This error may be corrected using anyone of the following three methods.

METHOD 1: If the angle (θ) between a proper direction and actual Tx-Rx line is known, the actual direction of primary field at Rx can be derived from the simple formulas or graph shown. This method is suitable when the relative elevation of each station is known and the angle of the Tx plane is known. However it is difficult to measure an accurate plane angle; particulary for a large horizontal cable loop lying on the ground.

METHOD 2: If we assume that the tilt-angle response at a sufficiently low frequency is small, the measured tilt-angle represents the primary field direction. Thus this value may be used to correct measurements at other frequencies. GEM's tilt-angle response at 41 hz may be used in this way except in the presence of a very strong conductor. Thus this correction is suitable for most multi-frequency survey measurements.

METHOD 3: The third method, simpler and more reliable than the first two, is similar to the well known SHOOTBACK technique. However, no Tx-Rx exchange is required. Simply level the Tx coil for a reading, then rotate at 90 and repeat the reading. The two readings are added (see overleaf formulas) to eliminate tilt angle problems. The remaining tilt angle error is less than $\pm$ 0.1 degree when the elevation angle (θ) is within $\pm$ 7 degrees; less than $\pm$ 0.5 degrees when θ is within $\pm$ 18 degrees; and less than $\pm$1 degree when θ is within $\pm$ 21 degrees. For extremely rough terrain, the first coil allignment may have to be within about $\pm$ 15 degrees for $\pm$ 0.5 degree accuracy. This method is suitable for horizontal profilling for conductor detection surveys using a framed Tx coil. It is especially suitable for a survey using a small portable Tx in rough terrain.

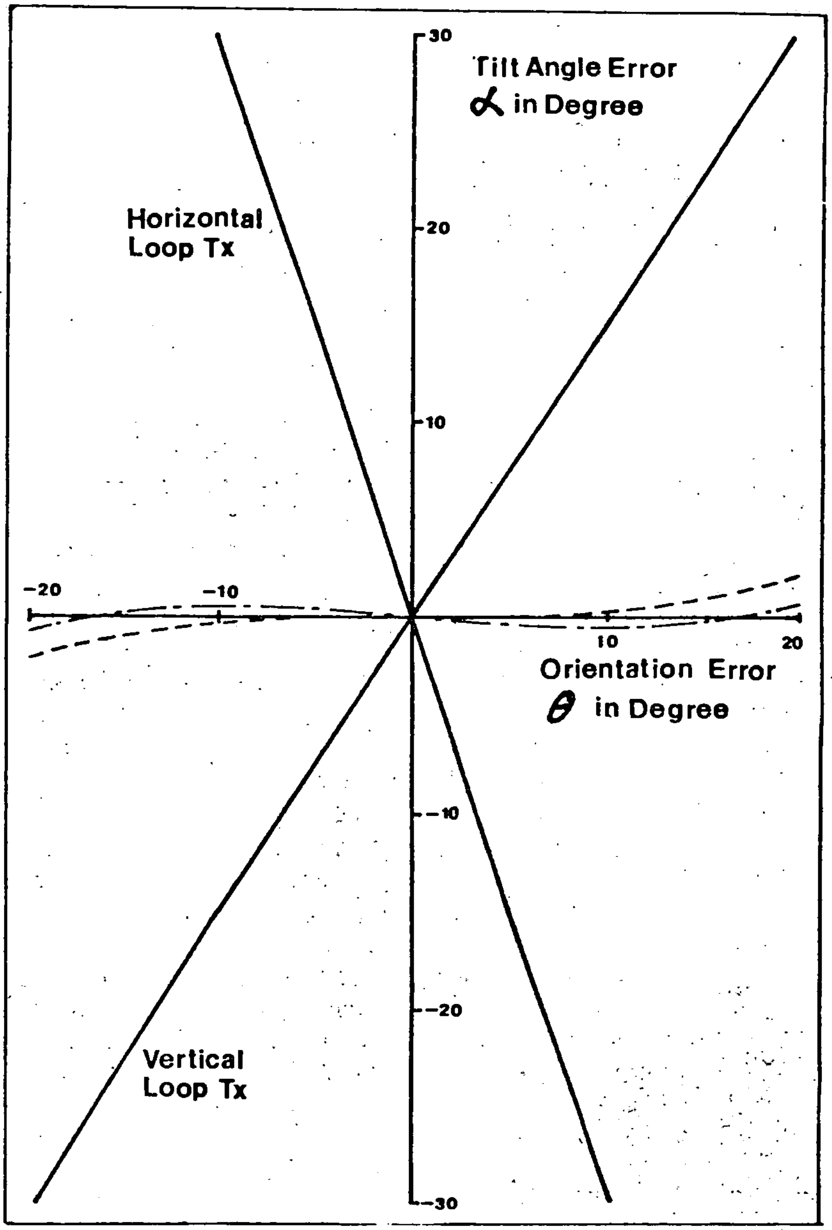
Tilt Angle Response at 41Hz
(Horizontal Loop Tx, Tx-Rx Separation = 200 m)

Over Homogeneous Earth

Resistivity (ohms/m)	Tilt Angle (degrees)
1000	nil
300	nil
100	nil
30	.5
10	3.5

Over Steeply Dipping Conductor
(Depth = Tx-Rx Separation/8)

Conductivity-thickness (mhos)	Tilt Angle (degrees)
1	nil
3	nil
10	nil
20	.7
30	2.



Horizontal Loop Tx:

$$\mathrm{Tan}\,\alpha = \frac{3\,\mathrm{Sin}\,\theta\,\mathrm{Cos}\,\theta}{3\,\mathrm{Sin}^2\theta - 1}$$

Vertical Loop Tx:

$$\mathrm{Tan}\,\alpha = \frac{3\,\mathrm{Sin}\,\theta\,\mathrm{Cos}\,\theta}{3\,\mathrm{Cos}^2\theta - 1}$$

After V/H Conpensation:

(dashed line) $\alpha = (\beta_H + 2\beta_V)/2$

(dash-dot line) $\alpha = (\beta_H + 1.9\beta_V)/2$

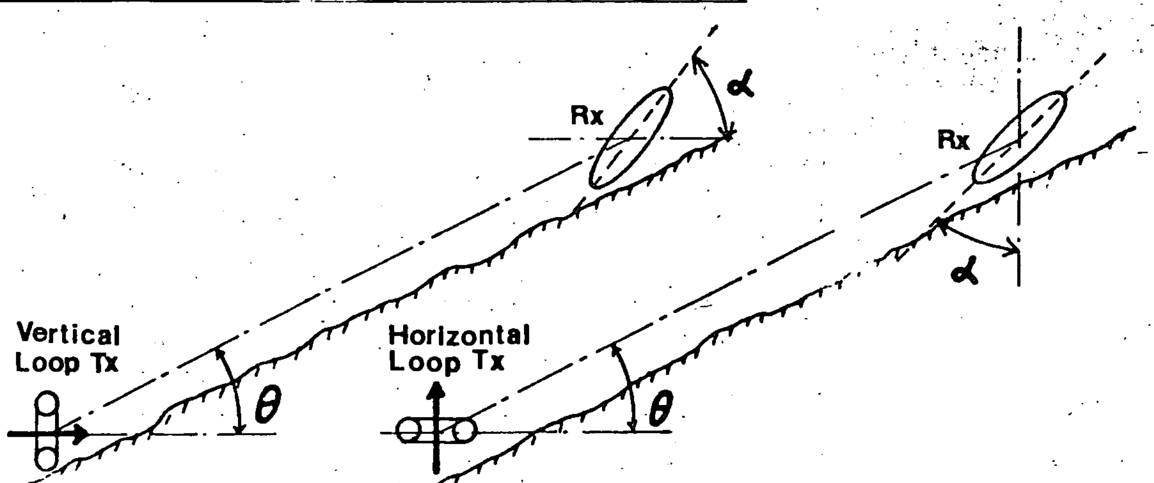


Fig. D

19820001

Fig. E. 19820001

Cavendish Township
Geophysical Test Range
ONTARIO, CANADA

GEM8 SURVEY

Horizontal-Loop-Tx In-line
R–T separation = 100 m

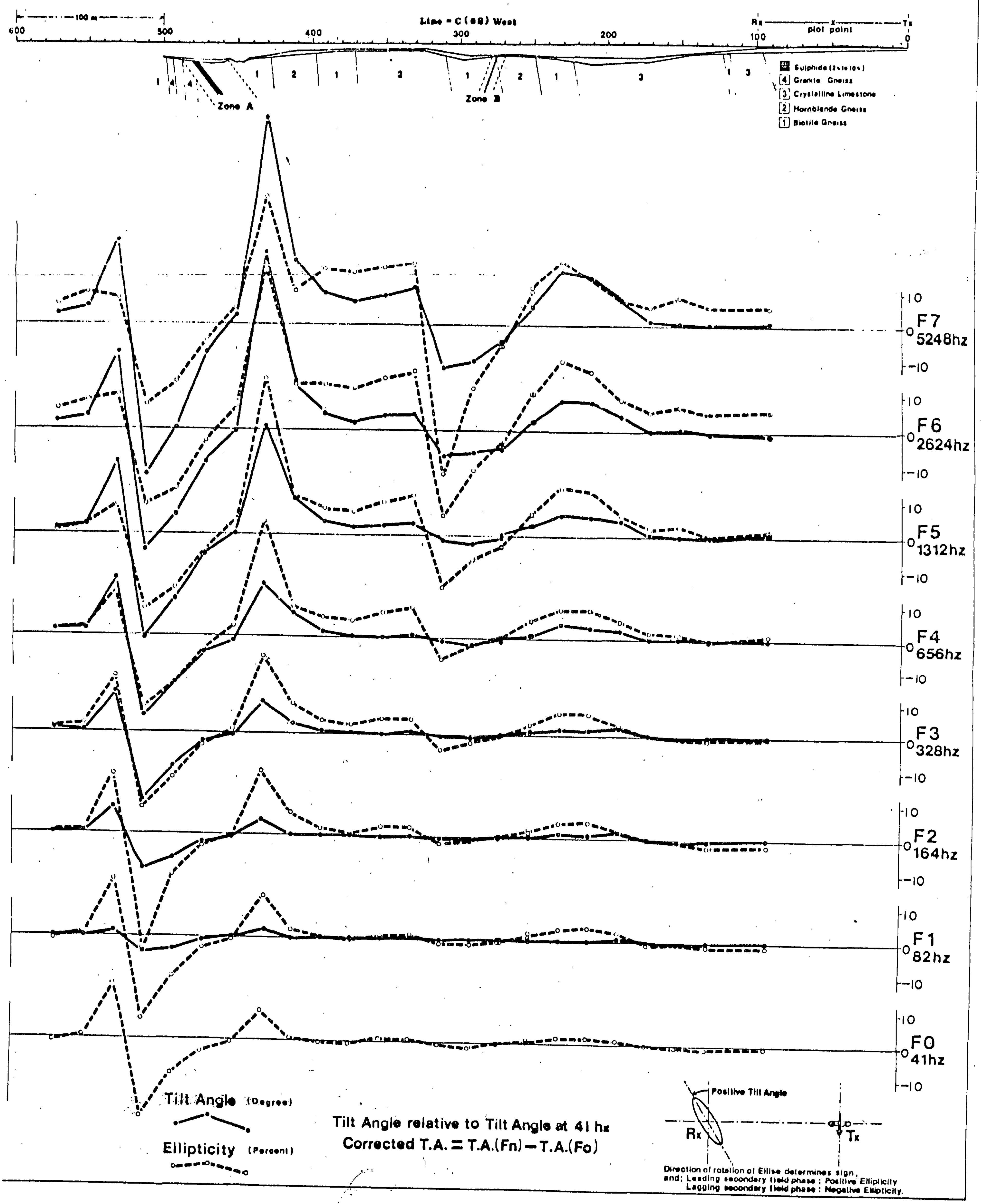


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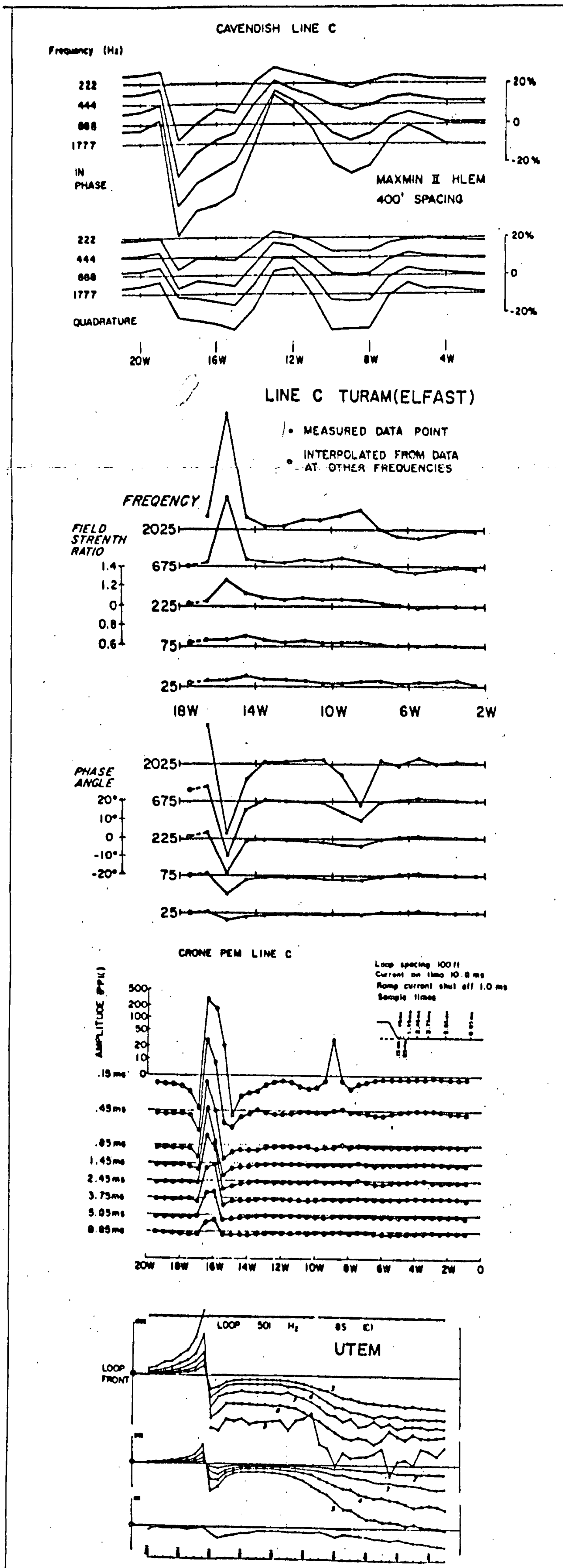
Fig F



COMPARISON PROFILES FROM "THE CAVENDISH TEST SITE: A UTEM SURVEY PLUS A COMPILATION OF OTHER GROUND GEOPHYSICAL DATA" BY JAMES C. MACNAE, DEPARTMENT OF PHYSICS, UNIVERSITY OF TORONTO.

NOTE: GENERALLY POOR RESOLUTION OF ZONE B.

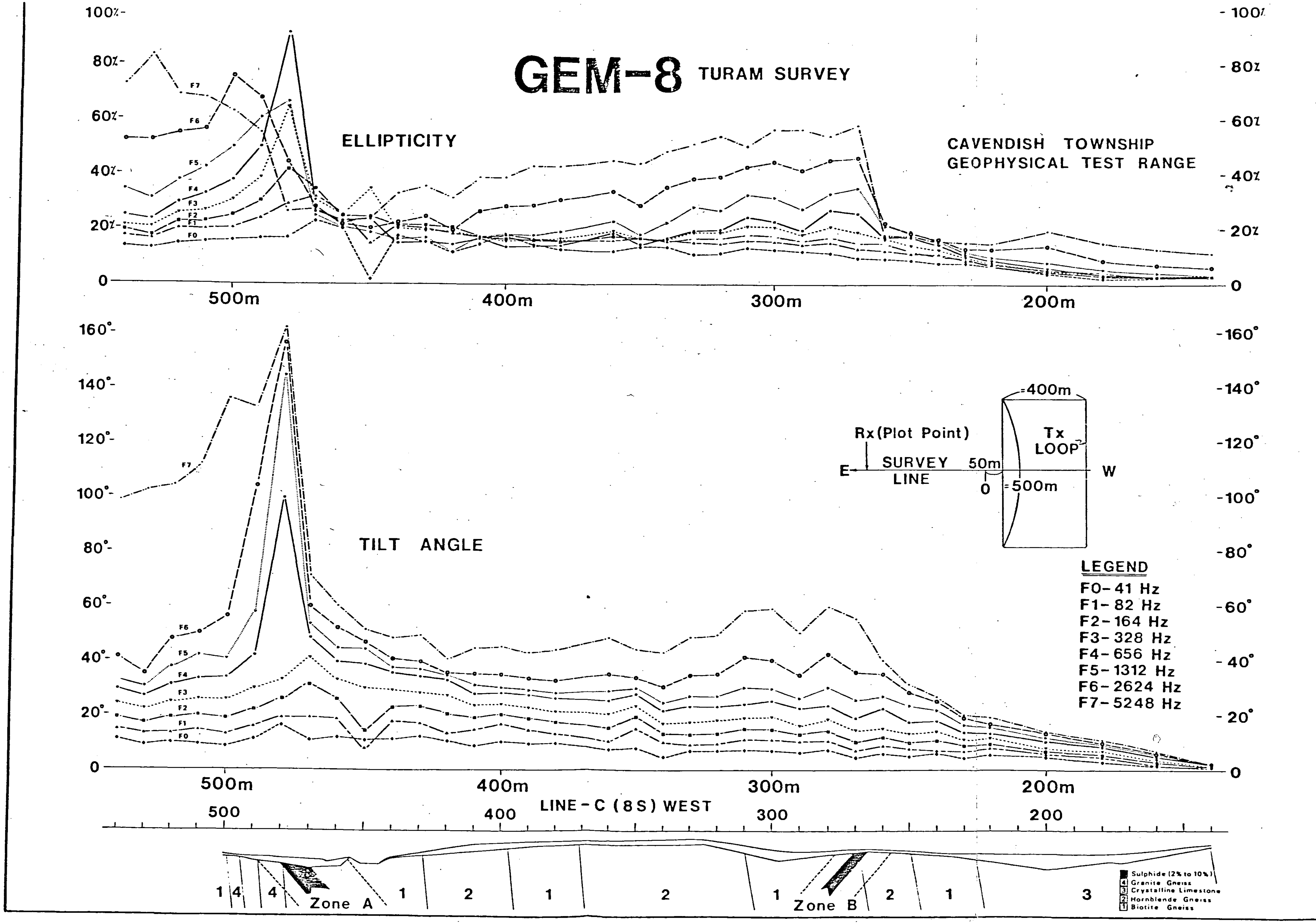


Fig G

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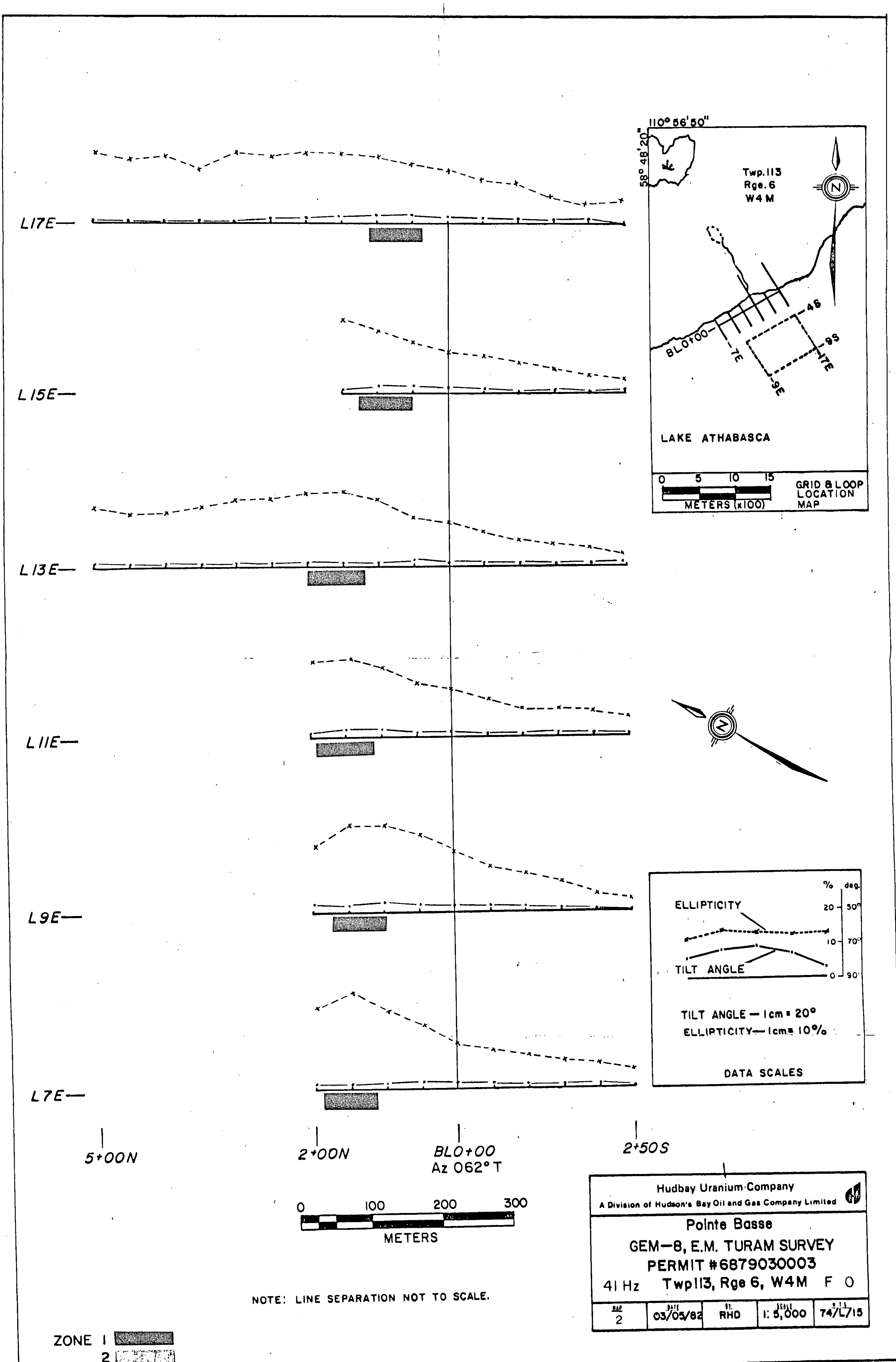
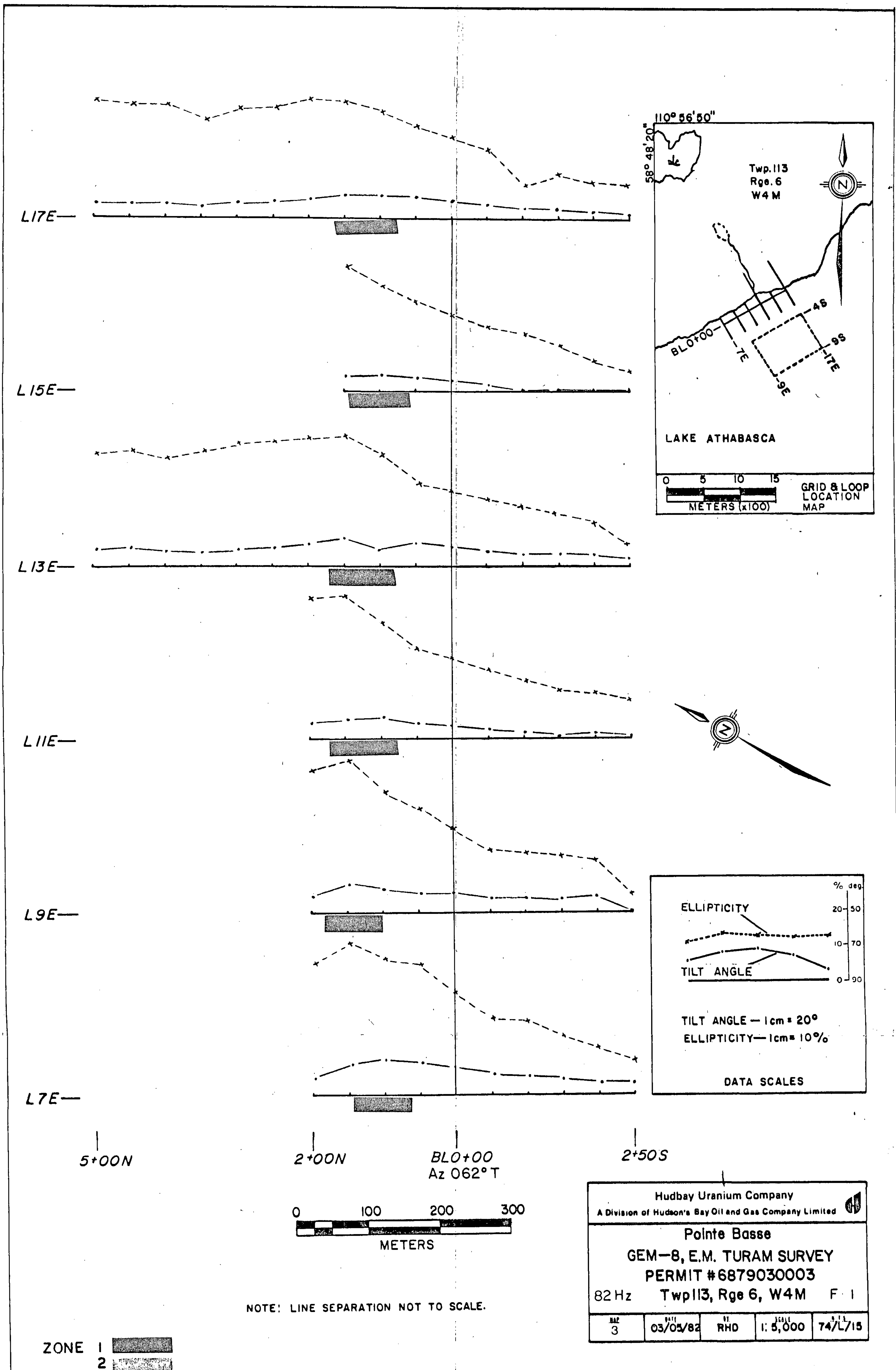
APPENDIX IV

FIGURES 2 - 12 INCLUSIVE



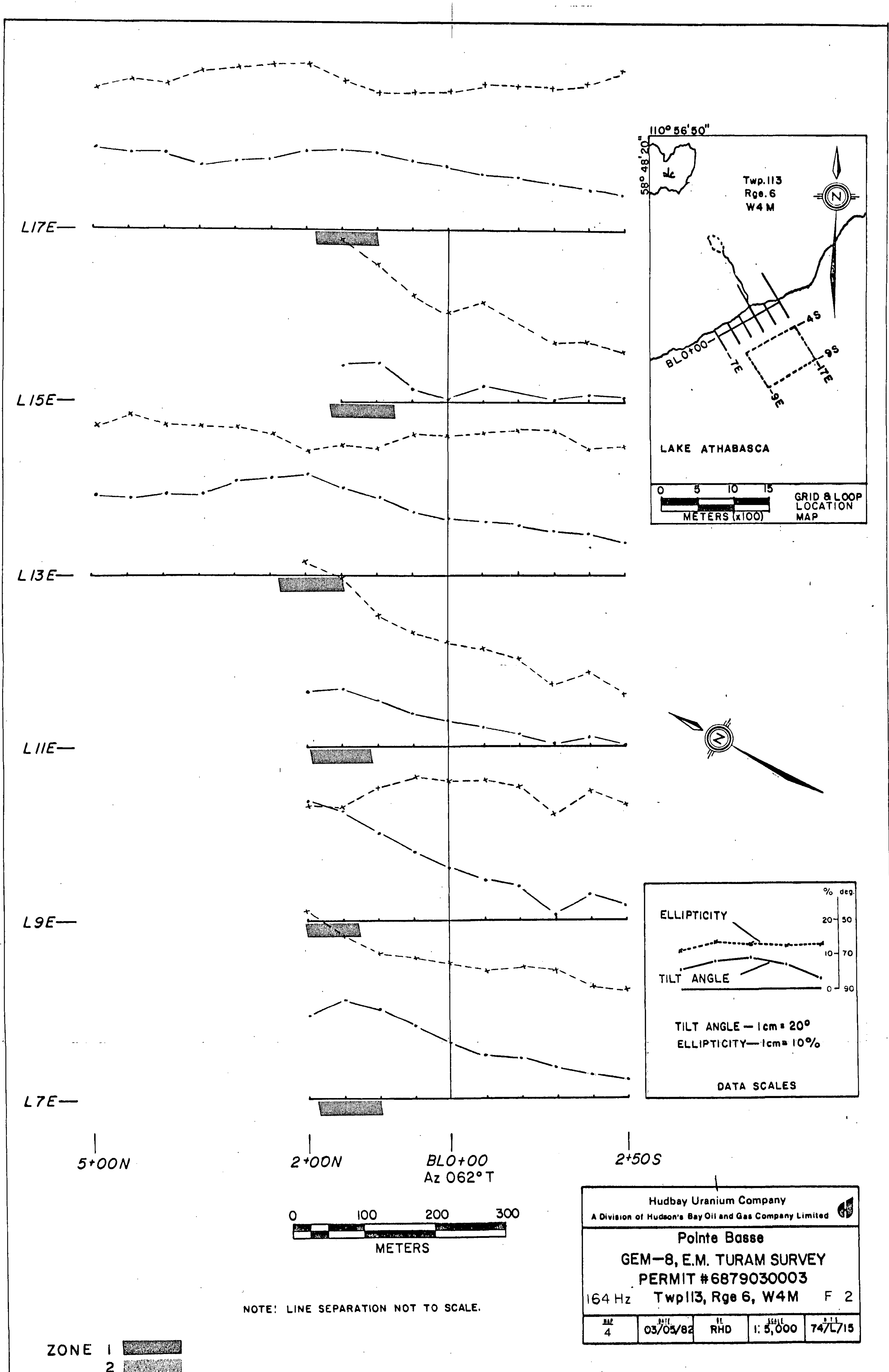
L17E
L15E
L13E
L11E
L9E
L7E
5+00N
2+00N
BL0+00
Az 062° T
2+50S
0 100 200 300
METERS
NOTE: LINE SEPARATION NOT TO SCALE.
ZONE 1
2
110° 56'50"
58° 48'20"
Twp. 113
Rge. 6
W4 M
N
BL0+00
7E
9E
4S
9S
17E
LAKE ATHABASCA
0 5 10 15
METERS (x100)
GRID & LOOP LOCATION MAP
ELLIPTICITY
TILT ANGLE
% deg.
20 50°
10 70°
0 90°
TILT ANGLE — 1cm = 20°
ELLIPTICITY — 1cm = 10%
DATA SCALES
Hudbay Uranium Company
A Division of Hudson's Bay Oil and Gas Company Limited
Pointe Bosse
GEM—8, E.M. TURAM SURVEY
PERMIT #6879030003
41 Hz Twp113, Rge 6, W4M F 0
MAP 2
DATE 03/05/82
BY RHD
SCALE 1: 5,000
N.T.S. 74/L/15

19820001



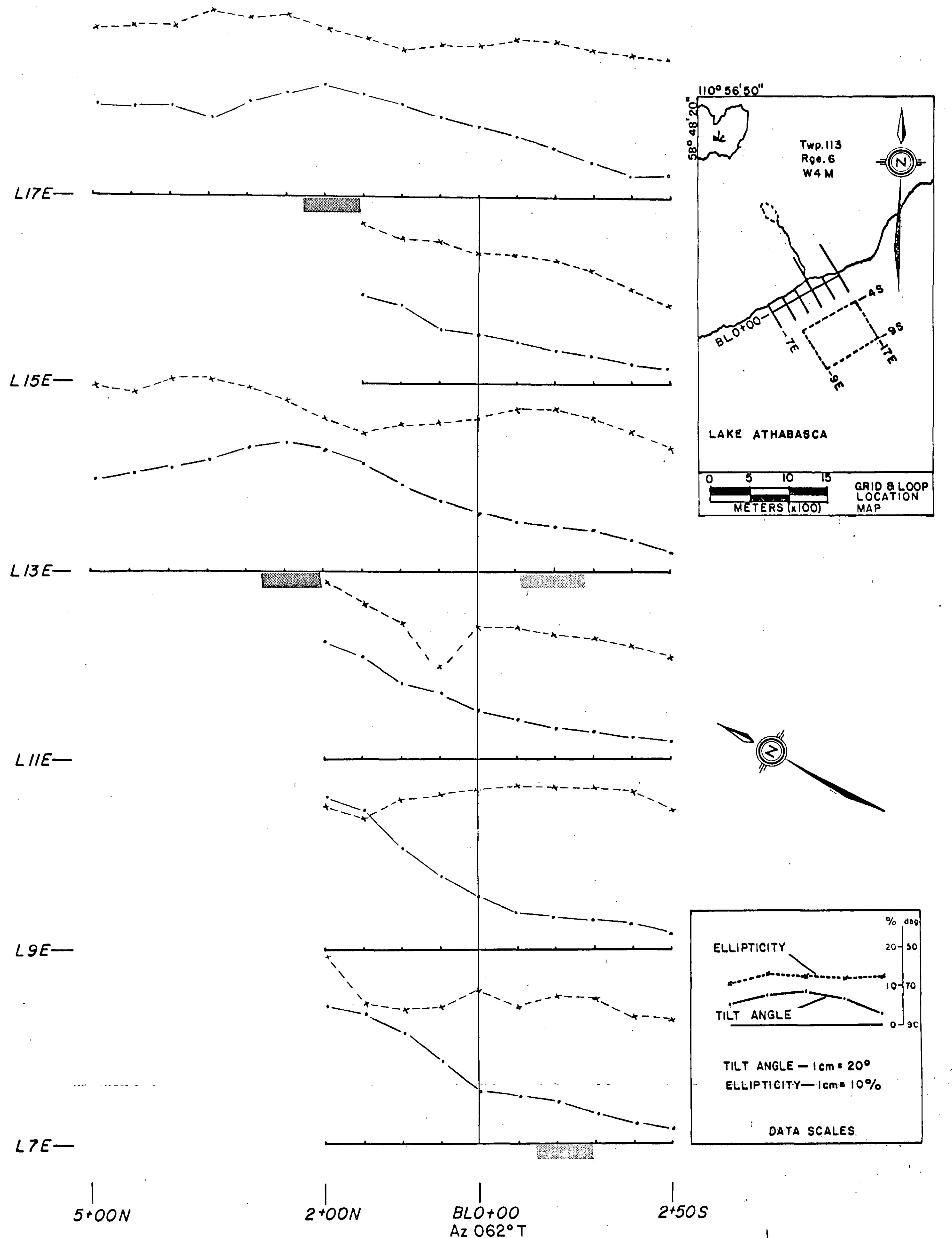
L17E
L15E
L13E
L11E
L9E
L7E
5+00N
2+00N
BL0+00
Az 062° T
2+50S
0
100
200
300
METERS
NOTE: LINE SEPARATION NOT TO SCALE.
ZONE 1
2
110° 56'50"
58° 48'20"
Twp.113
Rge.6
W4M
N
BL0+00
7E
9E
4S
9S
17E
LAKE ATHABASCA
0
5
10
15
METERS (x100)
GRID & LOOP LOCATION MAP
N
% deg.
20 50
10 70
0 90
ELLIPTICITY
TILT ANGLE
TILT ANGLE — 1cm = 20°
ELLIPTICITY— 1cm = 10%
DATA SCALES
Hudbay Uranium Company
A Division of Hudson's Bay Oil and Gas Company Limited
Pointe Basse
GEM—8, E.M. TURAM SURVEY
PERMIT # 6879030003
82 Hz
Twp 113, Rge 6, W4M
F 1
MAP 3
DATE 03/05/82
BY RHD
SCALE 1: 5,000
N.T.S. 74/L/15

19820001



L17E
L15E
L13E
L11E
L9E
L7E
5+00N
2+00N
BL0+00
Az 062° T
2+50S
0
100
200
300
METERS
NOTE: LINE SEPARATION NOT TO SCALE.
ZONE 1
2
110° 56' 50"
58° 48' 20"
Twp. 113
Rge. 6
W4 M
N
BL0+00
4S
9S
7E
17E
9E
LAKE ATHABASCA
0 5 10 15
METERS (x100)
GRID & LOOP LOCATION MAP
ELLIPTICITY
TILT ANGLE
% deg.
20 50
10 70
0 90
TILT ANGLE — 1cm = 20°
ELLIPTICITY — 1cm = 10%
DATA SCALES
Hudbay Uranium Company
A Division of Hudson's Bay Oil and Gas Company Limited
Pointe Basse
GEM—8, E.M. TURAM SURVEY
PERMIT #6879030003
164 Hz
Twp 113, Rge 6, W4M
F 2
MAP 4
DATE 03/05/82
BY RHD
SCALE 1: 5,000
NTS 74/L/15

19820001



0 100 200 300

METERS

NOTE: LINE SEPARATION NOT TO SCALE.

ZONE 1

2

Hudbay Uranium Company

A Division of Hudson's Bay Oil and Gas Company Limited

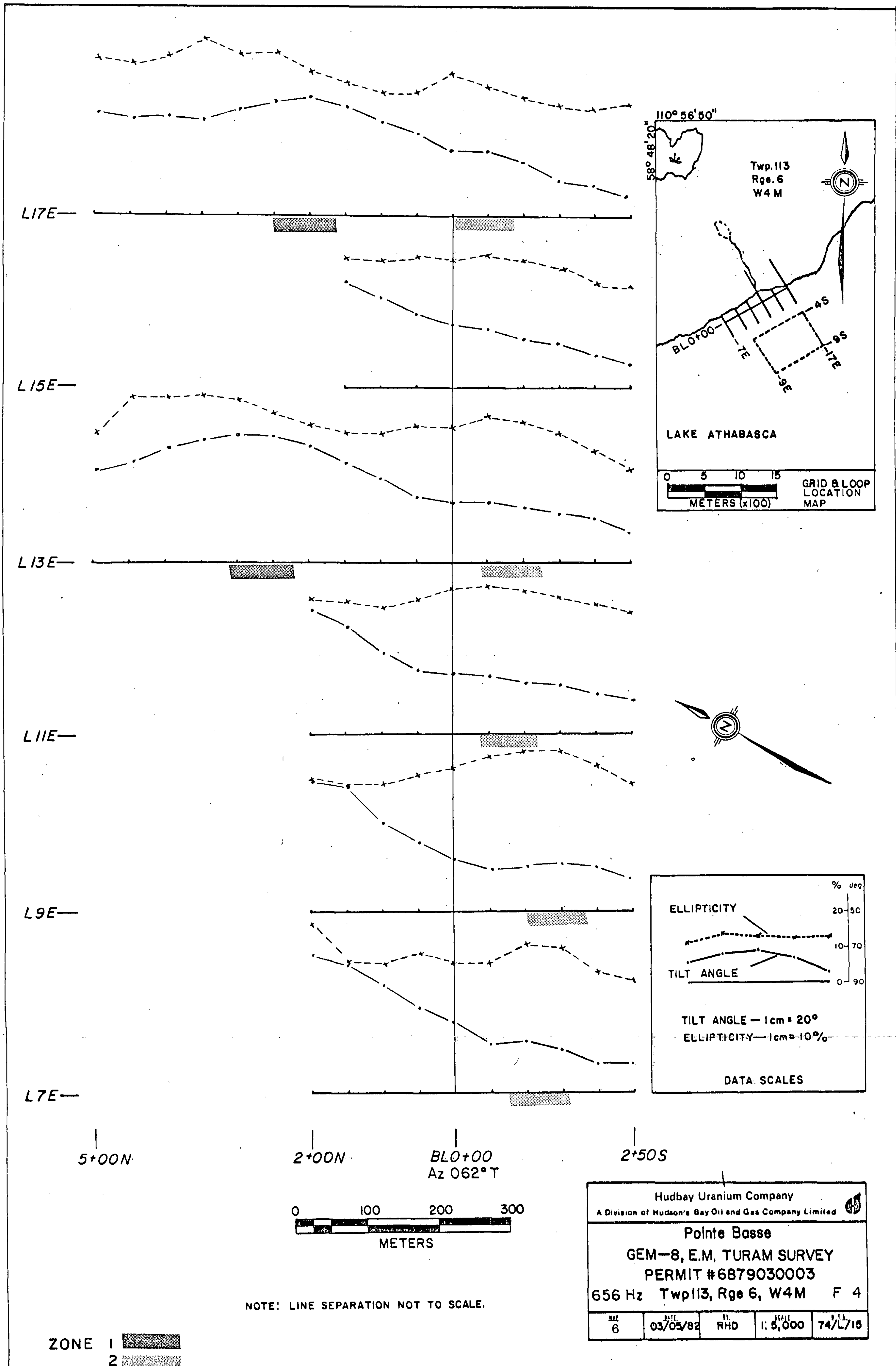
Pointe Basse

GEM-8, E.M. TURAM SURVEY

PERMIT #6879030003

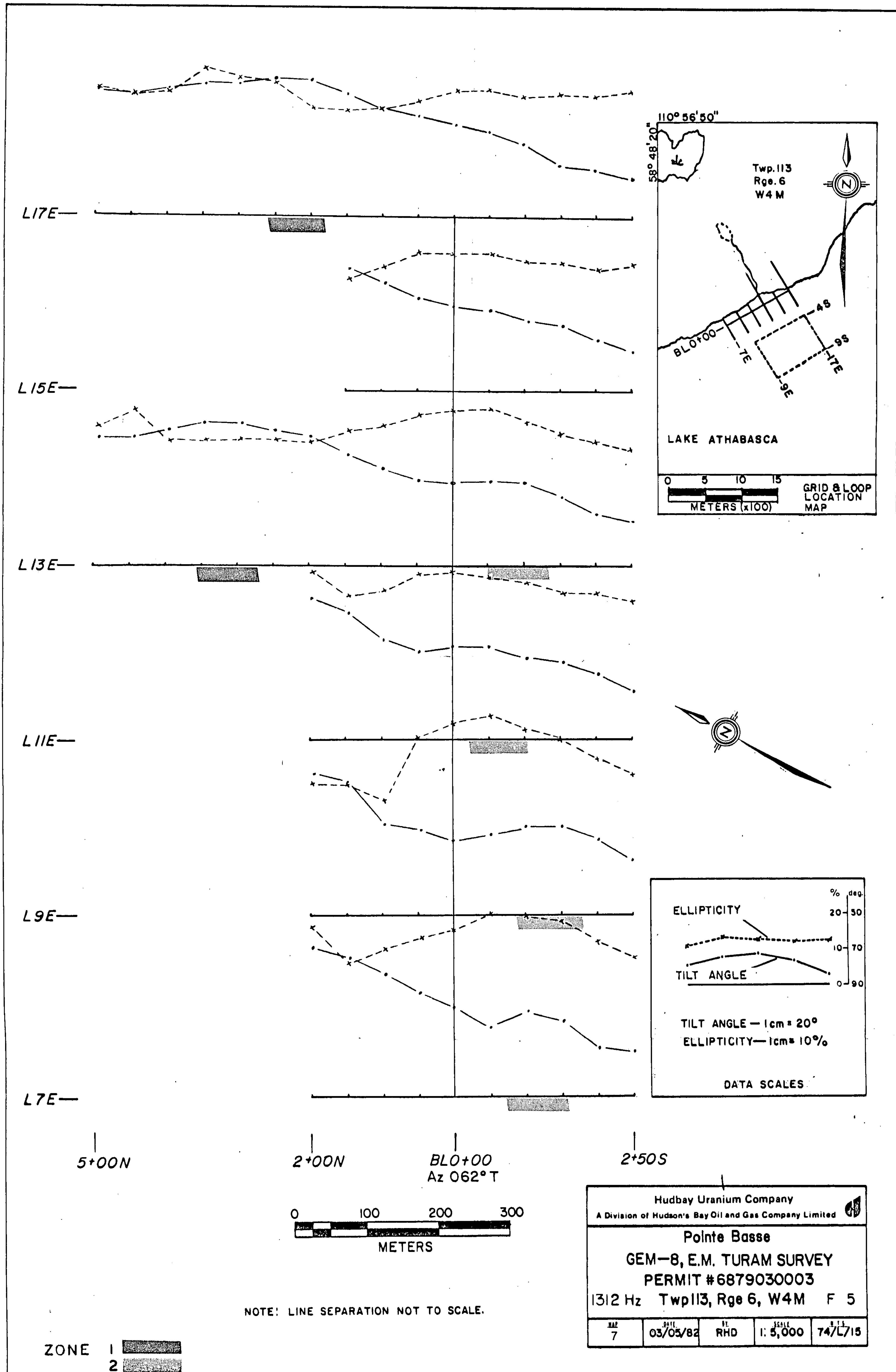
328 Hz Twp 113, Rge 6, W4M F. 3

MAP	DATE	BY	SCALE	N.T.S.
5	03/05/82	RHD	1: 5,000	74/L/15



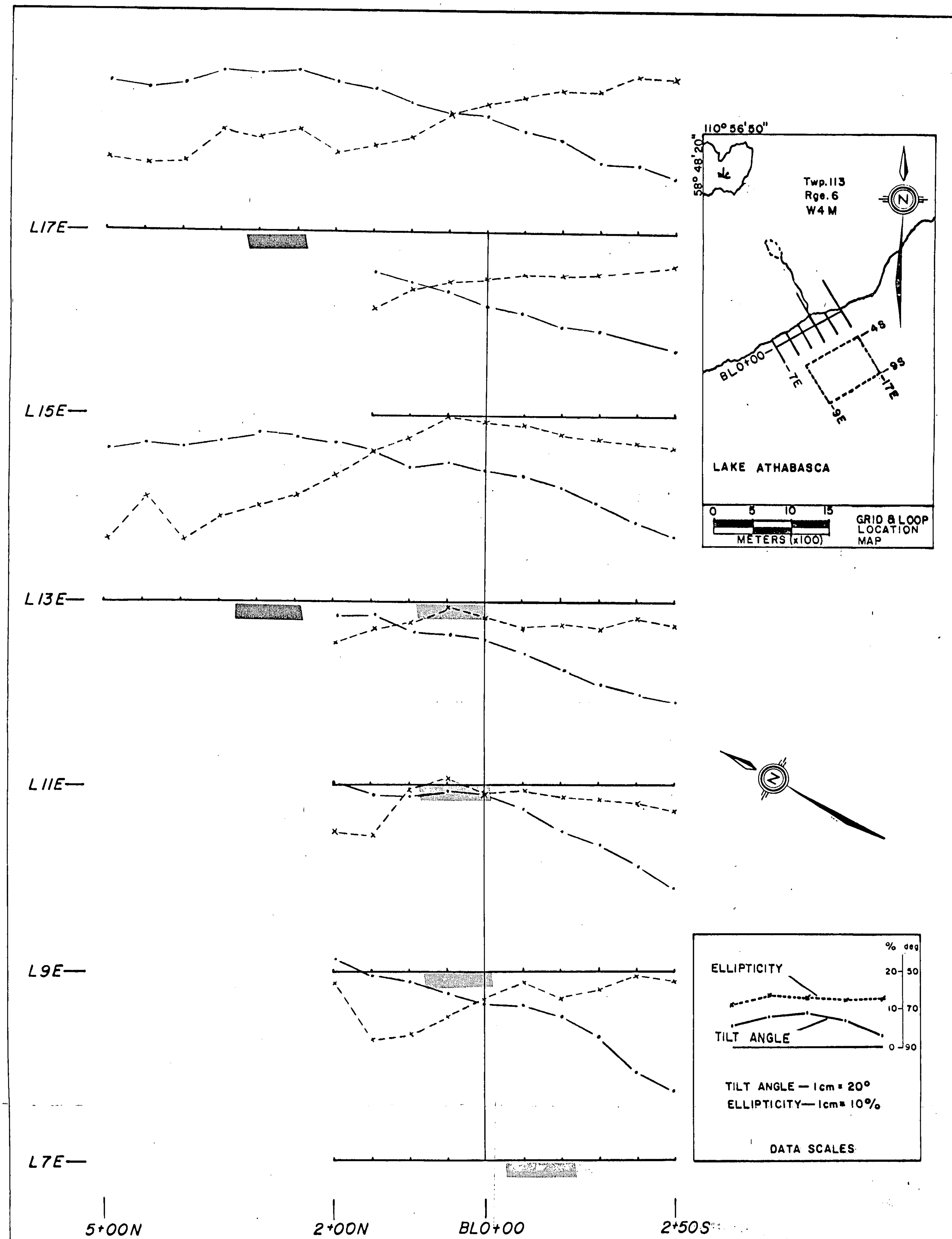
L17E
L15E
L13E
L11E
L9E
L7E
5+00N
2+00N
BL0+00
Az 062° T
2+50S
0 100 200 300
METERS
NOTE: LINE SEPARATION NOT TO SCALE.
ZONE 1
2
110° 56' 50"
58° 48' 20"
Twp. 113
Rge. 6
W4 M
N
BL0+00
7E
4S
9S
17E
9E
LAKE ATHABASCA
0 5 10 15
METERS (x100)
GRID & LOOP LOCATION MAP
% deg
ELLIPTICITY
20 50
10 70
0 90
TILT ANGLE
TILT ANGLE — 1cm = 20°
ELLIPTICITY — 1cm = 10%
DATA SCALES
Hudbay Uranium Company
A Division of Hudson's Bay Oil and Gas Company Limited
Pointe Basse
GEM—8, E.M. TURAM SURVEY
PERMIT # 6879030003
656 Hz Twp 113, Rge 6, W4M F 4
MAP 6
DATE 03/05/82
BY RHD
SCALE 1: 5,000
N.T.S. 74/L7/15

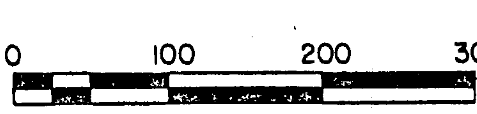
19820001



L17E
L15E
L13E
L11E
L9E
L7E
5+00N
2+00N
BL0+00
Az 062° T
2+50S
110° 56'50"
58° 48'20"
Twp.113
Rge.6
W4M
N
BL0+00
7E
4S
9S
17E
9E
LAKE ATHABASCA
0 5 10 15
METERS (x100)
GRID & LOOP LOCATION MAP
ELLIPTICITY
TILT ANGLE
% deg.
20 30
10 70
0 90
TILT ANGLE — 1cm = 20°
ELLIPTICITY— 1cm = 10%
DATA SCALES
0 100 200 300
METERS
NOTE: LINE SEPARATION NOT TO SCALE.
ZONE 1
2
Hudbay Uranium Company
A Division of Hudson's Bay Oil and Gas Company Limited
Pointe Basse
GEM—8, E.M. TURAM SURVEY
PERMIT #6879030003
1312 Hz Twp113, Rge 6, W4M F 5
MAP 7
DATE 03/05/82
BY RHD
SCALE 1: 5,000
N.T.S. 74/L/15

19820001





NOTE: LINE SEPARATION NOT TO SCALE.

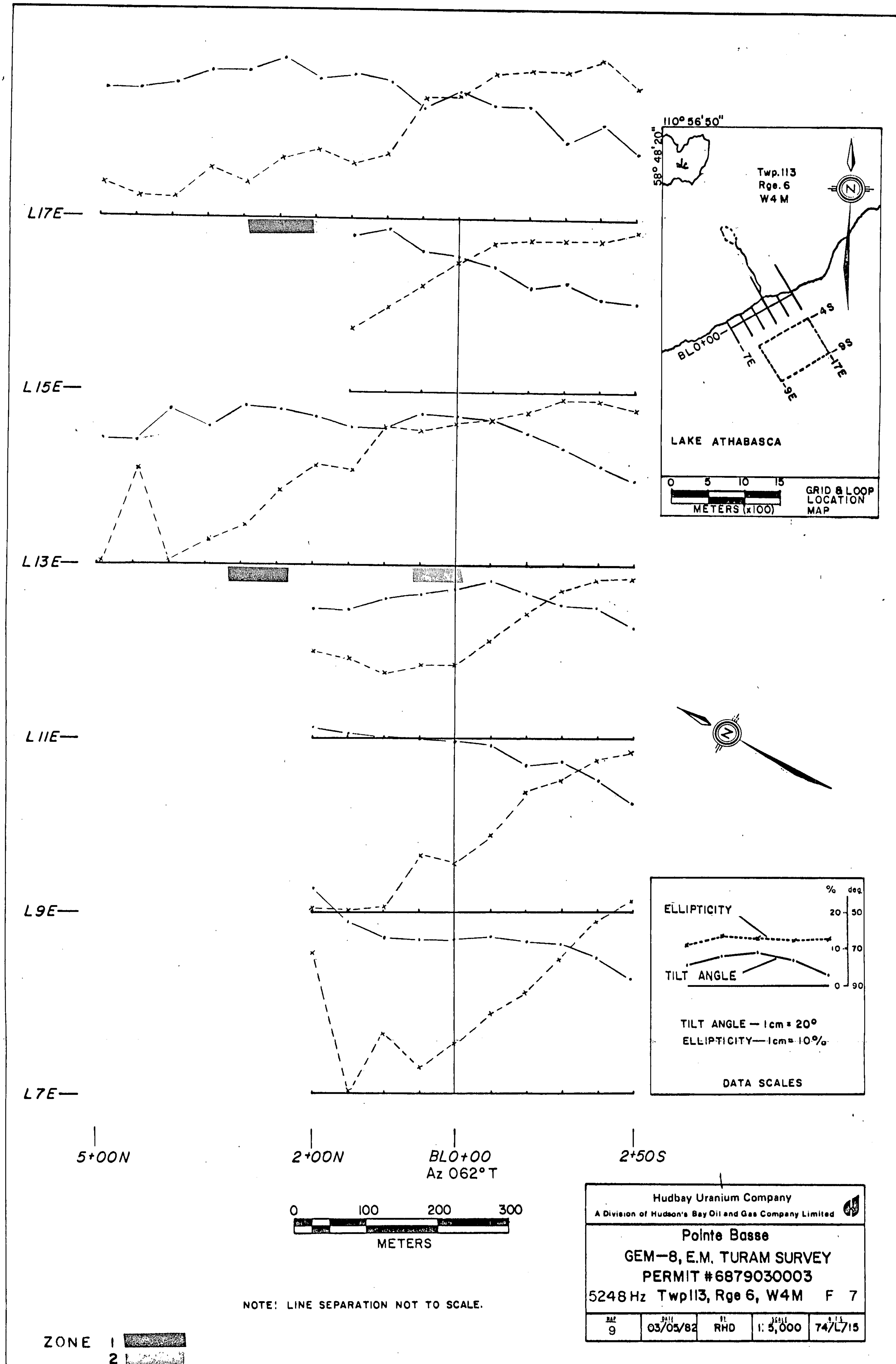
ZONE 1
2

Hudbay Uranium Company
A Division of Hudson's Bay Oil and Gas Company Limited

Pointe Basse
GEM—8, E.M. TURAM SURVEY
PERMIT #6879030003
2624Hz Twp113, Rge 6, W4M F 6

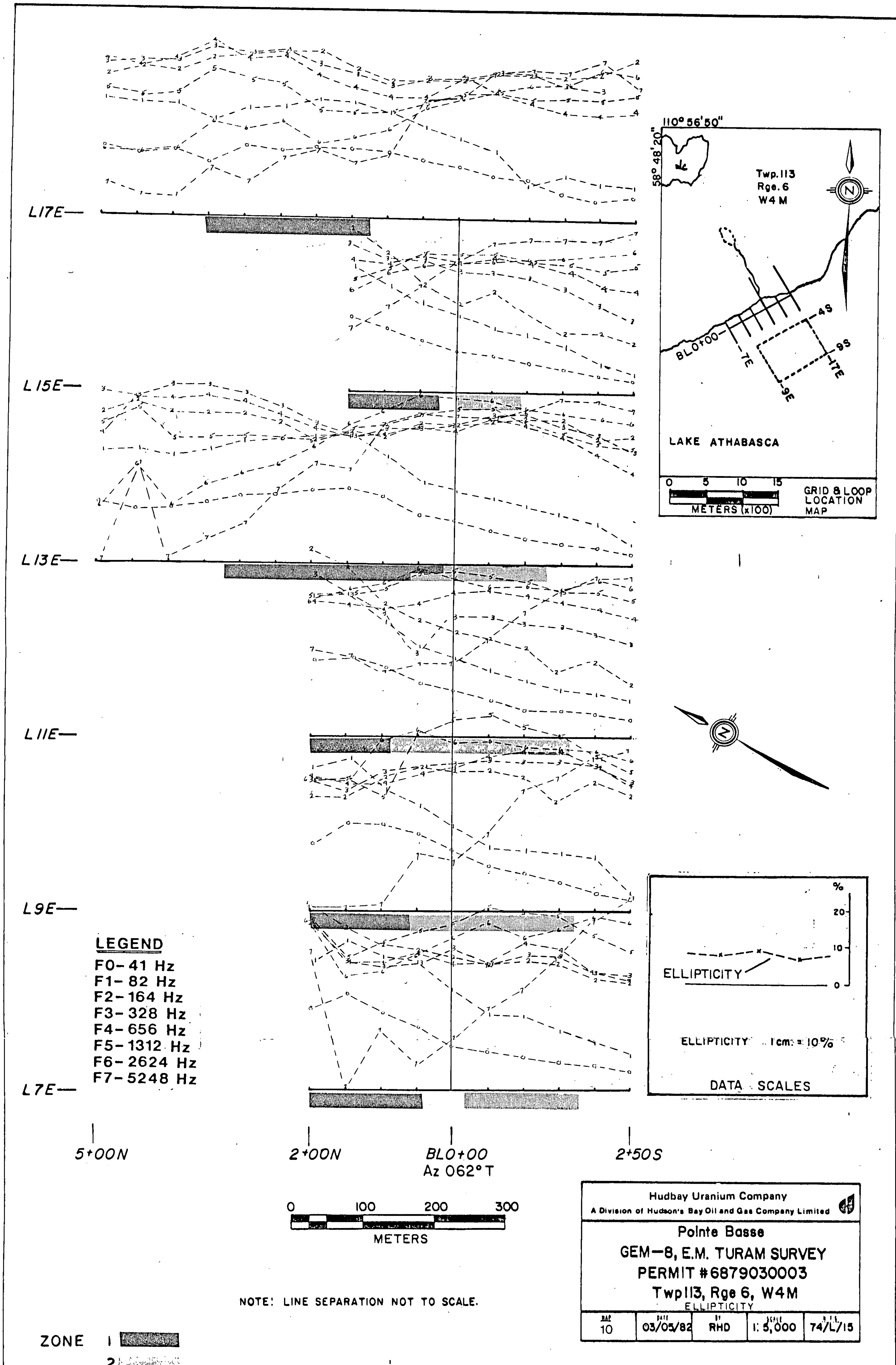
MAP	DATE	BY	SCALE	NTS
8	03/05/82	RHD	1: 5,000	74/L/15

19820001

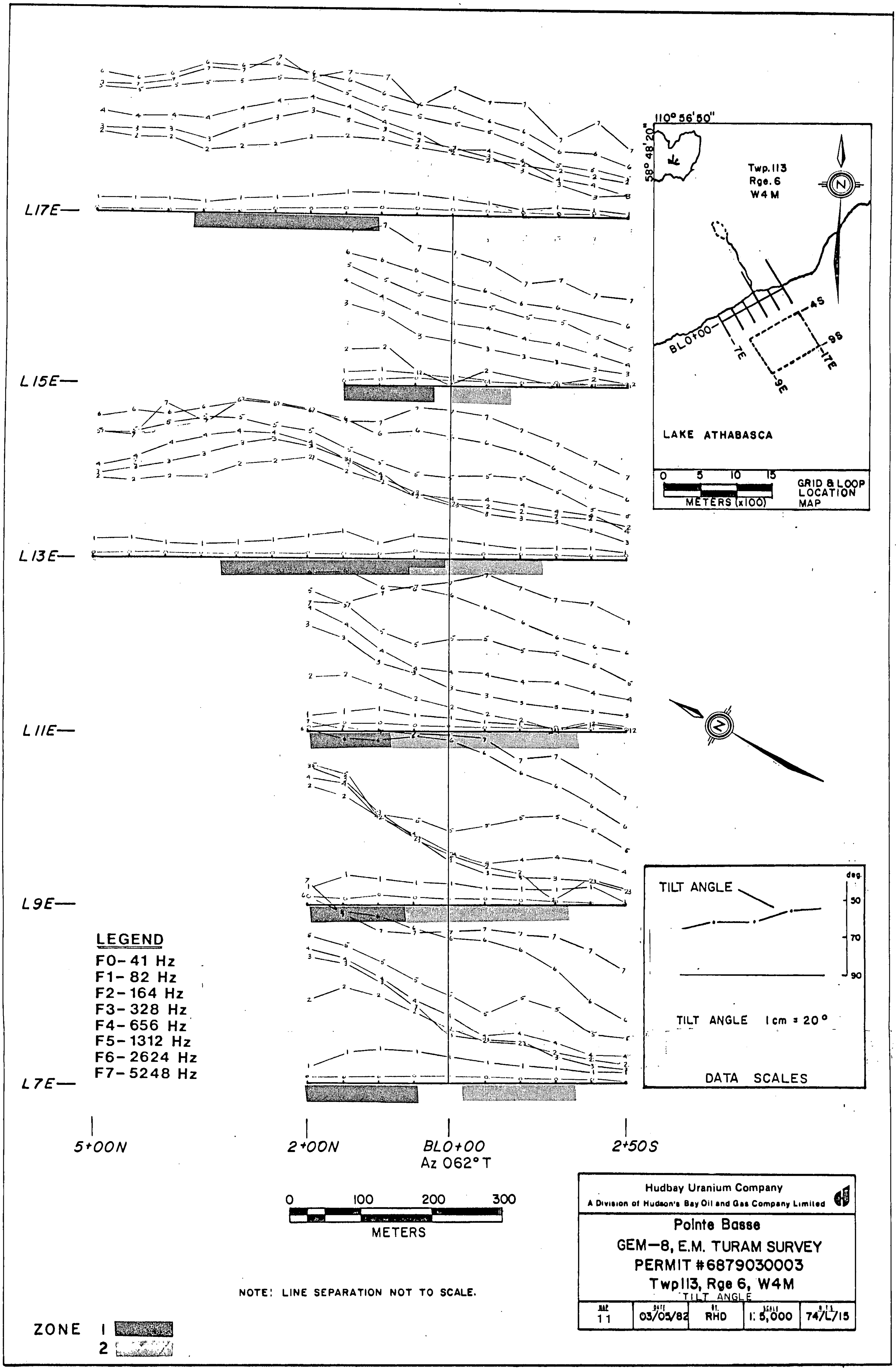


L17E
L15E
L13E
L11E
L9E
L7E
5+00N
2+00N
BL0+00
Az 062° T
2+50S
110° 56'50"
58° 48'20"
Twp.113
Rge.6
W4M
BL0+00
4S
9S
7E
17E
9E
LAKE ATHABASCA
0 5 10 15
METERS (x100)
GRID & LOOP LOCATION MAP
%
deg.
ELLIPTICITY
20 50
10 70
0 90
TILT ANGLE
TILT ANGLE — 1cm = 20°
ELLIPTICITY — 1cm = 10%
DATA SCALES
0 100 200 300
METERS
NOTE: LINE SEPARATION NOT TO SCALE.
ZONE 1
2
Hudbay Uranium Company
A Division of Hudson's Bay Oil and Gas Company Limited
Pointe Basse
GEM—8, E.M. TURAM SURVEY
PERMIT #6879030003
5248 Hz Twp113, Rge 6, W4M F 7
9
03/05/82
RHD
1: 5,000
74/L/15

19820001

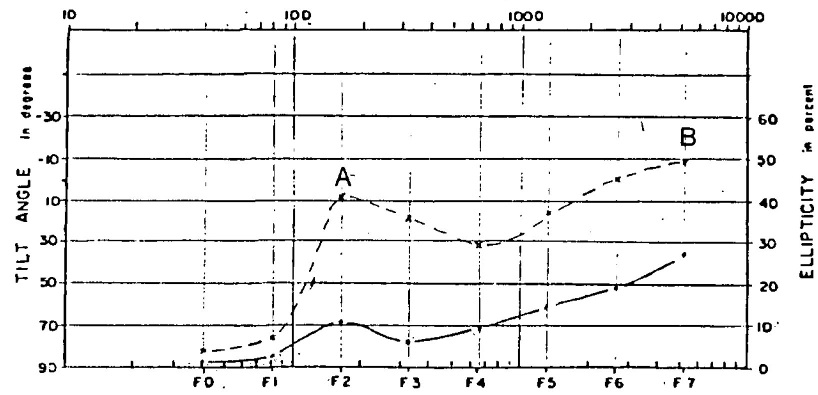

L17E
L15E
L13E
L11E
L9E
L7E
5+00N
2+00N
BL0+00
Az 062° T
2+50S
LEGEND
F0- 41 Hz
F1- 82 Hz
F2- 164 Hz
F3- 328 Hz
F4- 656 Hz
F5- 1312 Hz
F6- 2624 Hz
F7- 5248 Hz
0 100 200 300
METERS
NOTE: LINE SEPARATION NOT TO SCALE.
ZONE 1
2
110° 56'50"
58° 48'20"
Twp. 113
Rge. 6
W4 M
N
BL0+00
7E
9E
4S
9S
17E
LAKE ATHABASCA
0 5 10 15
METERS (x100)
GRID & LOOP LOCATION MAP
%
20
10
0
ELLIPTICITY
ELLIPTICITY 1cm = 10%
DATA SCALES
Hudbay Uranium Company
A Division of Hudson's Bay Oil and Gas Company Limited
Pointe Basse
GEM—8, E.M. TURAM SURVEY
PERMIT #6879030003
Twp113, Rge 6, W4M
ELLIPTICITY
10
03/05/82
RHD
1: 5,000
74/L/15

19820001


L17E
L15E
L13E
L11E
L9E
L7E
110° 56' 50"
58° 48' 20"
Twp.113
Rge. 6
W4M
N
BL0+00
4S
9S
7E
17E
9E
LAKE ATHABASCA
0 5 10 15
METERS (x100)
GRID & LOOP LOCATION MAP
TILT ANGLE
deg.
50
70
90
TILT ANGLE 1 cm = 20°
DATA SCALES
LEGEND
F0- 41 Hz
F1- 82 Hz
F2- 164 Hz
F3- 328 Hz
F4- 656 Hz
F5- 1312 Hz
F6- 2624 Hz
F7- 5248 Hz
5+00N
2+00N
BL0+00
Az 062° T
2+50S
0 100 200 300
METERS
NOTE: LINE SEPARATION NOT TO SCALE.
ZONE 1
2
Hudbay Uranium Company
A Division of Hudson's Bay Oil and Gas Company Limited
Pointe Basse
GEM—8, E.M. TURAM SURVEY
PERMIT #6879030003
Twp113, Rge 6, W4M
TILT ANGLE
MAP 11
DATE 03/05/82
BY RHD
SCALE 1: 5,000
N.T.S. 74/L/15

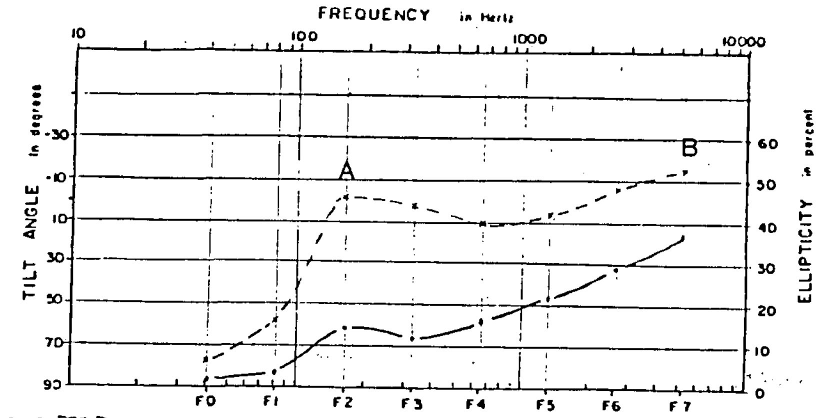
19820001

GEM-8
FREQUENCY vs AMPLITUDE



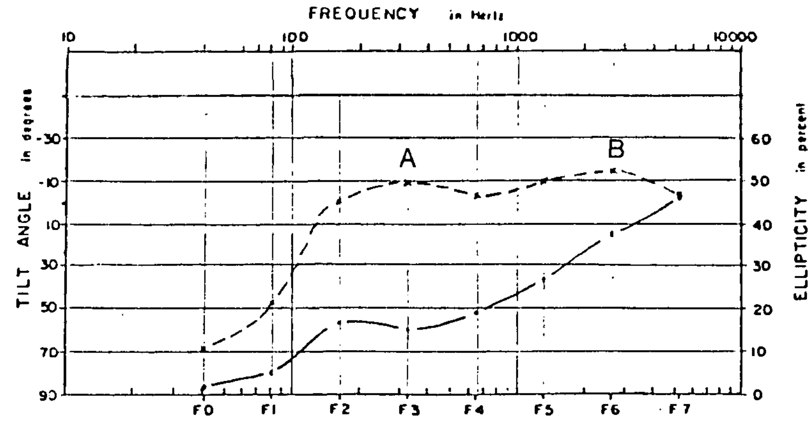
GRID PTE BASSE
LINE 13E
STA. 2+50S

GEM-8
FREQUENCY vs AMPLITUDE



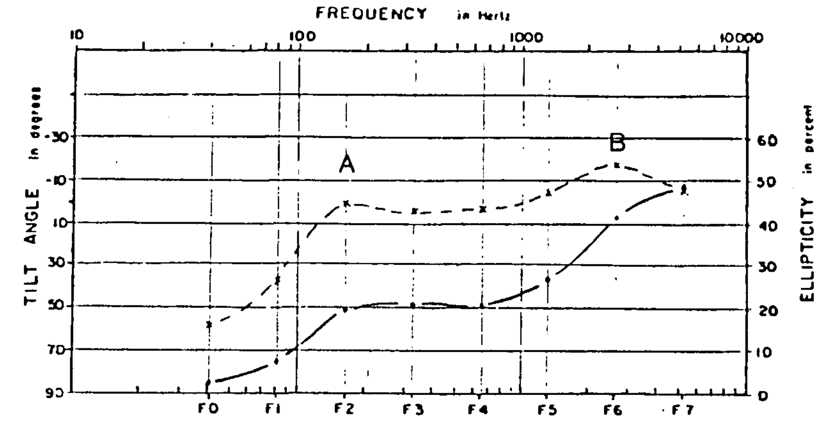
GRID PTE BASSE
LINE 13E
STA. 1+50S

GEM-8
FREQUENCY vs AMPLITUDE



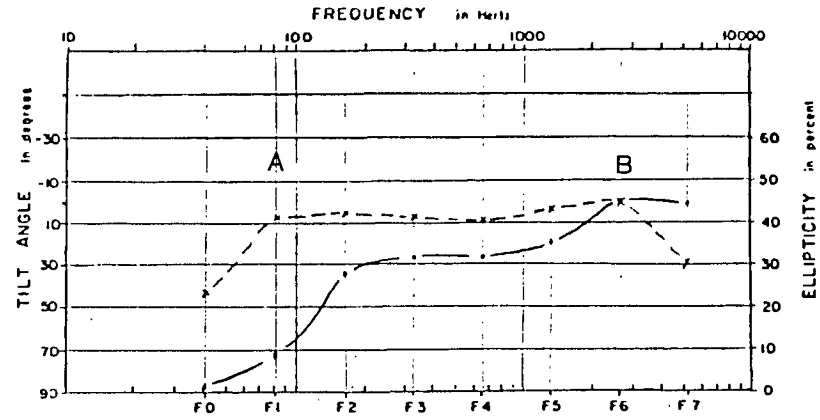
GRID PTE BASSE
LINE 13E
STA. 0+50S

GEM-8
FREQUENCY vs AMPLITUDE



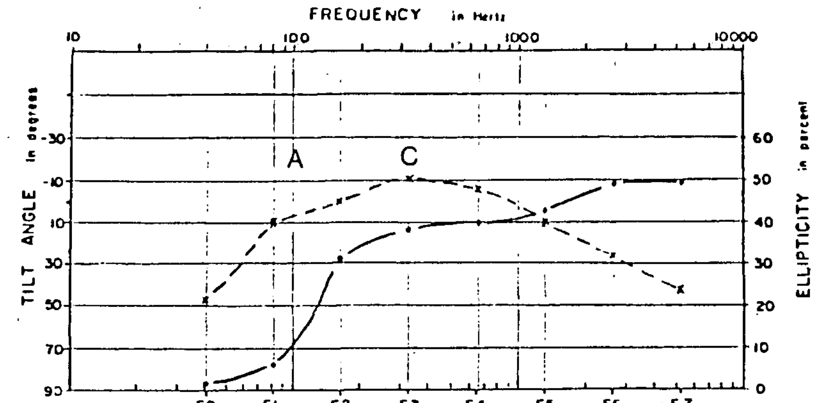
GRID PTE BASSE
LINE 13E
STA. 0+50N

GEM-8
FREQUENCY vs AMPLITUDE



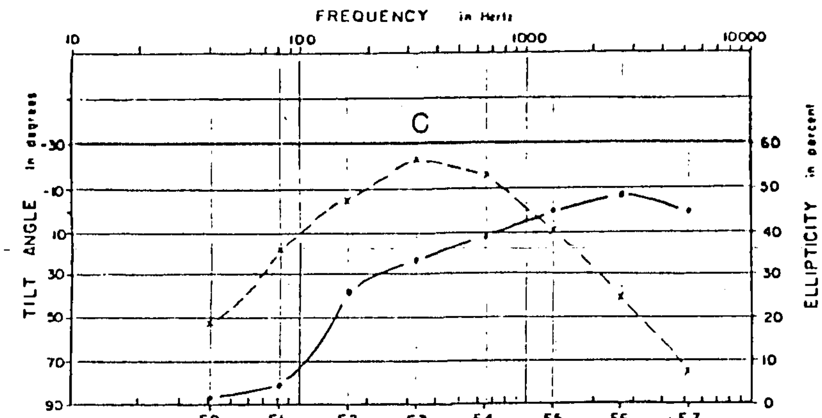
GRID PTE BASSE
LINE 13E
STA. 1+50N

GEM-8
FREQUENCY vs AMPLITUDE



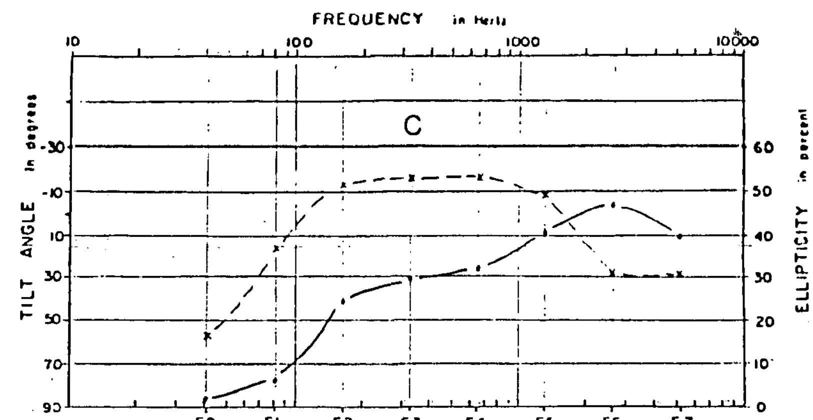
GRID PTE BASSE
LINE 13E
STA. 2+50N

GEM-8
FREQUENCY vs AMPLITUDE



GRID PTE BASSE
LINE 13E
STA. 2+50N

GEM-8
FREQUENCY vs AMPLITUDE



GRID PTE BASSE
LINE 13E
STA. 4+50N

ELLIPTICITY— x - - - - x

TILT ANGLE — • ——— •

A,B,C Response Feature

Hudbay Uranium Company
A Division of Hudson's Bay Oil and Gas Company Limited

Pointe Basse
GEM—8, E.M. TURAM SURVEY
PERMIT #6879030003
Twp113, Rge 6, W4M
FREQUENCY vs AMPLITUDE
LINE 13E

MAP	DATE	BY	SCALE	N.T.S.
12		RHD		

19820001