REPORT NO. 313

000

136001

MICROFILMED

DIGHEM^{II} SURVEY

OF

BIRCH INLET AREA, TASMANIA

FOR

GEOPEKO LIMITED

BY

DIGHEM LIMITED

TORONTO, CANADA
JANUARY 7, 1981

D.C. FRASER
PRESIDENT

Z. DVORAK
GEOPHYSICIST

001

136002

SUMMARY

DIGHEM^{II} electromagnetic/resistivity/magnetic surveys were flown in November and December, 1980, for Geopeko Limited, in the Birch Inlet and Mt. Lyell Mine areas in Tasmania.

The geologic environment in both survey areas was mostly resistive. Several low resistivity lows were located in the Birch Inlet area which may reflect bedrock sources. In the Mt. Lyell Mine area the survey identified two moderately strong conductive zones which coincide with known ore bodies.

LOCATION MAP

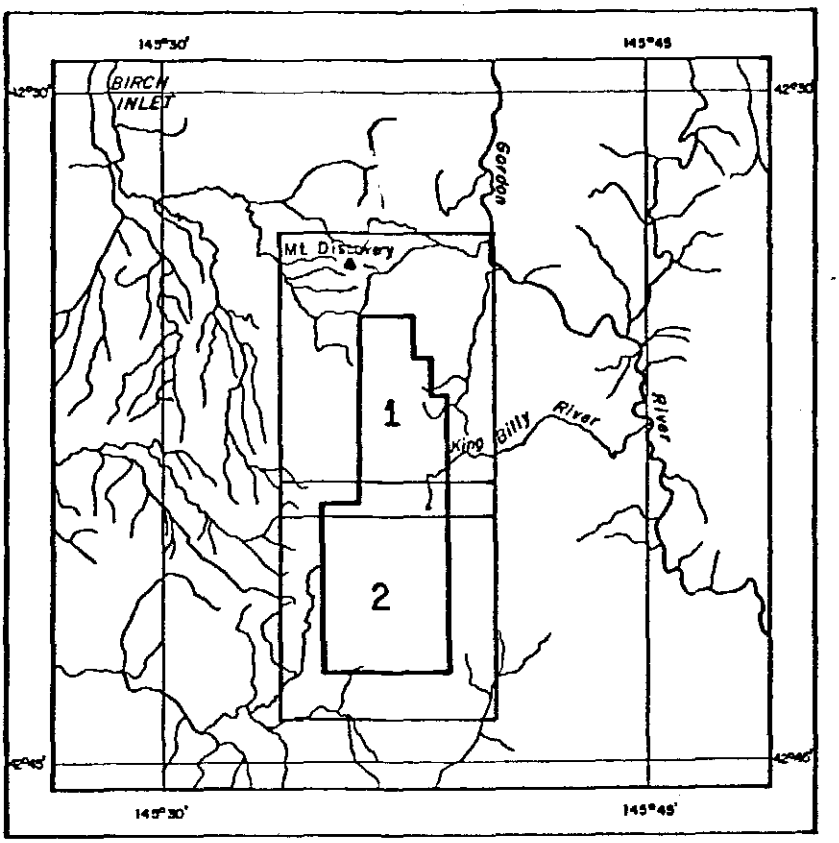


Figure 1a: Birch Inlet

LOCATION MAP

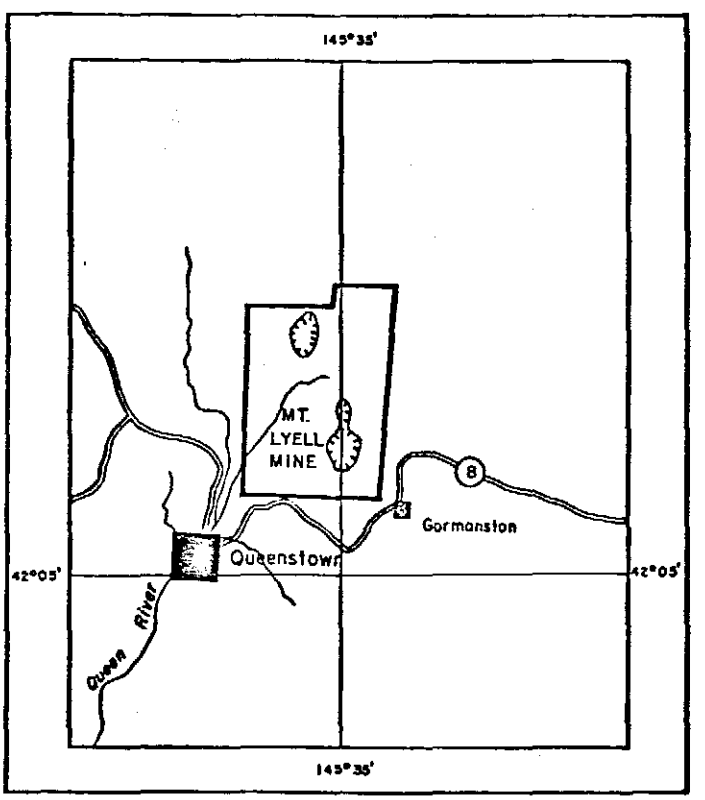


Figure 1b: Mt. Lyell

003

136004

CONTENTS

INTRODUCTION..... 1

ELECTROMAGNETICS..... 2

Discrete conductor analysis..... 3

X-type electromagnetic responses..... 11

The thickness parameter..... 11

Resistivity mapping..... 12

Interpretation in conductive environments.... 15

Reduction of geologic noise..... 18

MAGNETICS..... 19

CONDUCTORS IN THE SURVEY AREA..... 22

Birch Inlet area..... 23

Mt. Lyell Mine test..... 24

APPENDIX A: The Flight Record and Path Recovery

APPENDIX B: EM Anomaly List

004

136005

INTRODUCTION

DIGHEM^{II} surveys of 585 line-km were flown with a 150 m line-spacing for Geopeko Limited between November 30 and December 7, 1980, in the Birch Inlet and Mt. Lyell Mine areas of Tasmania (Figures 1a, 1b).

The Lama VH-PDU jet helicopter flew with an average airspeed of 119 km/h and EM bird height of 41 m. Ancillary equipment consisted of a Geometrics 803 magnetometer with its bird at an average height of 56 m, a Sperry radio altimeter, Geocam sequence camera, Barringer 8-channel hot pen analog recorder, and a Geometrics G-714 digital data acquisition system with a Kennedy 9700 9-track 800 bpi magnetic tape recorder. The analog equipment recorded four channels of EM data at approximately 900 Hz, two ambient EM noise channels (for the coaxial and coplanar receivers), and one channel each of magnetics and radio altitude. The digital equipment recorded the EM data with a sensitivity of 0.25 ppm/bit and the magnetic field to one gamma/bit.

The Appendix provides details on the data channels, their respective noise levels, and the data reduction

005

procedure. The quoted noise levels are generally valid for wind speeds up to 35 km/h. Higher winds may cause the system to be grounded because excessive bird swinging produces difficulties in flying the helicopter. The swinging results from the 5 m^2 of area which is presented by the bird to broadside gusts. The DIGHEM system nevertheless can be flown under wind conditions that seriously degrade other AEM systems.

ELECTROMAGNETICS

DIGHEM electromagnetic responses fall into two general classes, discrete and broad. The discrete class consists of sharp, well defined anomalies from discrete conductors such as sulfide lenses and steeply dipping sheets of graphite and sulfides. The broad class consists of wide anomalies from conductors having a large horizontal surface such as flatly dipping graphite or sulfide sheets, saline water-saturated sedimentary formations, conductive overburden and rock, and geothermal zones. A vertical conductive slab with a width of 100 m would straddle these two classes.

The vertical sheet (half plane) is the most common model used for the analysis of discrete conductors. All anomalies plotted on the electromagnetic map are interpreted according to this model. The following section entitled Discrete conductor analysis describes this model in detail, including the effect of using it on anomalies caused by broad conductors such as conductive overburden.

The conductive earth (half space) model is suitable for broad conductors. Resistivity contour maps result from the use of this model. A later section entitled Resistivity mapping describes the method further, including the effect of using it on anomalies caused by discrete conductors such as sulfide bodies.

Discrete conductor analysis

The EM anomalies appearing on the electromagnetic map are interpreted by computer to give the conductance (i.e., conductivity-thickness product) in mhos of a vertical sheet model. DIGHEM anomalies are divided into six grades of conductance, as shown in Table I. The conductance in mhos is the reciprocal of resistance in ohms.

Table I. EM Anomaly Grades

Anomaly Grade	Mho Range
6	greater than 99
5	50 - 99
4	20 - 49
3	10 - 19
2	5 - 9
1	less than 5

The mho value is a geological parameter because it is a characteristic of the conductor alone; it generally is independent of frequency, and of flying height or depth of burial apart from the averaging over a greater portion of the conductor as height increases.[1] Small anomalies from deeply buried strong conductors are not confused with small anomalies from shallow weak conductors because the former will have larger mho values.

Conductive overburden generally produces broad EM responses which are not plotted on the EM maps. However, patchy conductive overburden in otherwise resistive areas

[1]This statement is an approximation. DIGHEM, with its short coil separation, tends to yield larger and more accurate mho values than airborne systems having a larger coil separation.

can yield discrete-like anomalies with a conductance grade (cf. Table I) of 1, or even of 2 for conducting clays which have resistivities as low as 50 ohm-m. In areas where ground resistivities can be as low as 1 ohm-m, anomalies caused by weathering variations and similar causes can have conductance grades as high as 4. The anomaly shapes from the multiple coils often allow such surface conductors to be recognized, and these are indicated by the letter S on the map. The remaining anomalies in such areas could be bedrock conductors. The higher grades indicate increasingly higher conductances. Examples: DIGHEM's New Insco copper discovery (Noranda, Quebec, Canada) yielded a grade 4 anomaly, as did the neighbouring copper-zinc Magusi River ore body; Mattabi (copper-zinc, Sturgeon Lake, Ontario, Canada) and Whistle (nickel, Sudbury, Ontario, Canada) gave grade 5; and DIGHEM's Montcalm nickel-copper discovery (Timmins, Ontario, Canada) yielded a grade 6 anomaly. Graphite and sulfides can span all grades but, in any particular survey area, field work may show that the different grades indicate different types of conductors.

Strong conductors (i.e., grades 5 and 6) are characteristic of massive sulfides or graphite. Moderate conductors (grades 3 and 4) typically reflect sulfides of a less

009

136010

massive character or graphite, while weak bedrock conductors (grades 1 and 2) can signify poorly connected graphite or heavily disseminated sulfides. Grade 1 conductors may not respond to ground EM equipment using frequencies less than 2000 Hz.

The presence of sphalerite or gangue can result in ore deposits having weak to moderate conductances. As an example, the three million ton lead-zinc deposit of Restigouche Mining Corporation near Bathurst, New Brunswick, Canada, yielded a well defined grade 1 conductor. The 10 percent by volume of sphalerite occurs as a coating around the fine grained massive pyrite, thereby inhibiting electrical conduction.

Faults, fractures and shear zones may produce anomalies which typically have low conductances (e.g., grade 1 and 2). Conductive rock formations can yield anomalies of any conductance grade. The conductive materials in such rock formations can be salt water, weathered products such as clays, original depositional clays, and carbonaceous material.

On the electromagnetic map, the actual mho value and a letter are plotted beside the EM grade symbol. The letter is the anomaly identifier. The horizontal rows of dots, beside each anomaly symbol, indicate the anomaly amplitude on the flight record. The vertical column of dots gives the estimated depth. In areas where anomalies are crowded, the identifiers, dots and mho values may be obliterated. The EM grade symbols, however, will always be discernible, and the obliterated information can be obtained from the anomaly listing appended to this report.

The purpose of indicating the anomaly amplitude by dots is to provide an estimate of the reliability of the conductance calculation. Thus, a conductance value obtained from a large ppm anomaly (3 or 4 dots) will be accurate whereas one obtained from a small ppm anomaly (no dots) could be inaccurate. The absence of amplitude dots indicates that the anomaly from the coaxial coil-pair is 5 ppm or less on both the inphase and quadrature channels. Such small anomalies could reflect a weak conductor at the surface or a stronger conductor at depth. The mho value and depth estimate will illustrate which of these possibilities fits the recorded data best.

Flight line deviations occasionally yield cases where two anomalies, having similar mho values but dramatically different depth estimates, occur close together on the same conductor. Such examples illustrate the reliability of the conductance measurement while showing that the depth estimate can be unreliable. There are a number of factors which can produce an error in the depth estimate, including the averaging of topographic variations by the altimeter, overlying conductive overburden, and the location and attitude of the conductor relative to the flight line. Conductor location and attitude can provide an erroneous depth estimate because the stronger part of the conductor may be deeper or to one side of the flight line, or because it has a shallow dip. A heavy tree cover can also produce errors in depth estimates. This is because the depth estimate is computed as the distance of bird from conductor, minus the altimeter reading. The altimeter can lock on the top of a dense forest canopy. This situation yields an erroneously large depth estimate but does not affect the conductance estimate.

Dip symbols are used to indicate the direction of dip of conductors. These symbols are used only when the anomaly shapes are unambiguous, which usually requires a fairly resistive environment.

A further interpretation is presented on the EM map by means of the line-to-line correlation of anomalies, which is based on a comparison of anomaly shapes on adjacent lines. This provides conductor axes which may define the geological structure over portions of the survey area. The absence of conductor axes in an area implies that anomalies could not be correlated from line to line with reasonable confidence.

DIGHEM electromagnetic maps are designed to provide a correct impression of conductor quality by means of the conductance grade symbols. The symbols can stand alone with geology when planning a follow-up program. The actual mho values are plotted for those who wish quantitative data. The anomaly ppm and depth are indicated by inconspicuous dots which should not distract from the conductor patterns, while being helpful to those who wish this information. The map provides an interpretation of conductors in terms of length, strike direction, conductance, depth, thickness (see below), and dip. The accuracy is comparable to an interpretation from a ground EM survey having the same line spacing.

An EM anomaly list attached to each survey report provides a tabulation of anomalies in ppm, and in mhos and

estimated depth for the vertical sheet model. The EM anomaly list also shows the conductance in mhos and the depth for a thin horizontal sheet (whole plane) model, but only the vertical sheet parameters appear on the EM map. The horizontal sheet model is suitable for a flatly dipping thin bedrock conductor such as a sulfide sheet having a thickness less than 15 m. The list also shows the resistivity and depth for a conductive earth (half space) model, which is suitable for thicker slabs such as thick conductive overburden. In the EM anomaly list, a depth value of zero for the conductive earth model, in an area of thick cover, warns that the anomaly may be caused by conductive overburden.

Since discrete bodies normally are the targets of EM surveys, local base (or zero) levels are used to compute local anomaly amplitudes. This contrasts with the use of true zero levels which are used to compute true EM amplitudes. Local anomaly amplitudes are shown in the EM anomaly list and these are used to compute the vertical sheet parameters of conductance and depth. Not shown in the EM anomaly list are the true amplitudes which are used to compute the horizontal sheet and conductive earth parameters.

014

136015

X-type electromagnetic responses

DIGHEM^{II} maps contain x-type EM responses in addition to EM anomalies. An x-type response is below the noise threshold of 2 ppm, and reflects one of the following: a weak conductor near the surface, a strong conductor at depth (e.g., 100 to 120 m below surface) or to one side of a flight line, or aerodynamic noise. Those responses that have the appearance of valid bedrock anomalies on the flight profiles are mentioned in the report. The others should not be followed up unless their locations are of considerable geological interest.

The thickness parameter

DIGHEM^{II} can provide an indication of the thickness of a steeply dipping conductor. The ratio of the anomaly amplitude of channel 24/channel 22 generally increases as the apparent thickness increases, i.e., the thickness in the horizontal plane. This thickness is equal to the conductor width if the conductor dips at 90 degrees and strikes at right angles to the flight line. This report refers to a conductor as thin when the thickness is likely to be less than 3m, and thick when in excess of 10 m. In base metal

exploration applications, thick conductors can be high priority targets because most massive sulfide ore bodies are thick, whereas non-economic bedrock conductors are usually thin. An estimate of thickness cannot be obtained when the strike of the conductor is subparallel to the flight line,when the conductor has a shallow dip, when the anomaly amplitudes are small, or when the resistivity of the environment is below 100 ohm-m.

Resistivity mapping

Areas of widespread conductivity are commonly encountered during surveys. In such areas, anomalies can be generated by decreases of only 5 m in survey altitude as well as by increases in conductivity. The typical flight record in conductive areas is characterized by inphase and quadrature channels which are continuously active; local peaks reflect either increases in conductivity of the earth or decreases in survey altitude. For such conductive areas, apparent resistivity profiles and contour maps are necessary for the interpretation of the airborne data. The advantage of the resistivity parameter is that anomalies caused by altitude changes are virtually eliminated, so the resistivity data reflect only those anomalies caused by conductivity changes. This helps the interpreter to differentiate

016

136017

between conductive trends in the bedrock and those patterns typical of conductive overburden. Discrete conductors will generally appear as narrow lows on the contour map and broad conductors will appear as wide lows.

Channel 40 (see Appendix) and the resistivity contour map present the apparent resistivity using the so-called pseudo-layer (or buried) half space model defined in Fraser (1978)[2]. This model consists of a resistive layer overlying a conductive half space. Channel 41 gives the apparent depth below surface of the conductive material. The apparent depth therefore is simply the apparent thickness of the overlying resistive layer. The apparent depth (or thickness) parameter will be positive when the upper layer is more resistive than the underlying material, in which case the apparent depth may be quite close to the true depth.

The apparent depth will be negative when the upper layer is more conductive than the underlying material, and will be zero when a homogeneous half space exists.

---

[2]Resistivity mapping with an airborne multicoil electromagnetic system: Geophysics, v 43, p. 144-172.

The apparent depth parameter must be interpreted cautiously because it will contain any errors which may exist in the measured altitude of the EM bird (e.g., as caused by a dense tree cover). The inputs to the resistivity algorithm are the inphase and quadrature components of the coplanar coil-pair. The outputs are the apparent resistivity of the conductive half space (the source) and the sensor-source distance. The flying height is not an input variable, and the output resistivity and sensor-source distance are independent of the flying height. The apparent depth, discussed above, is simply the sensor-source distance minus the measured altitude or flying height. Consequently, errors in the measured altitude will affect the apparent depth parameter but not the apparent resistivity parameter.

The apparent depth parameter is a useful indicator of simple layering in areas lacking a heavy tree cover. The DIGHEM^{II} system has been flown for the purpose of permafrost mapping, where positive apparent depths were used as a measure of permafrost thickness. However, little quantitative use has been made of negative apparent depths because the absolute value of the negative depth is not a measure of the thickness of the conductive upper layer and, therefore, is not meaningful physically. Qualitatively, a negative

apparent depth estimate usually shows that the EM anomaly is caused by conductive overburden. Consequently, the apparent depth channel 41 can be of significant help in distinguishing between overburden and bedrock conductors.

Interpretation in conductive environments

Environments having background resistivities below 30 ohm-m cause all airborne EM systems to yield very large responses from the conductive ground. This usually prohibits the recognition of bedrock conductors. The processing of DIGHEM^{II} data, however, produces four channels which contribute significantly to the recognition of bedrock conductors. These are the inphase and quadrature difference channels (number 33 and 34), and the resistivity and depth channels (40 and 41). The EM difference channels eliminate up to 99% of the response of conductive ground, leaving responses from bedrock conductors, cultural features (e.g., telephone lines, fences, etc.) and edge effects. An edge effect arises when the conductivity of the ground suddenly changes, and this is a source of geologic noise. While edge effects yield anomalies on the EM difference channels, they do not produce resistivity anomalies. Consequently, the resistivity channel aids in eliminating

anomalies due to edge effects. On the other hand, resistivity anomalies will coincide with the most highly conductive sections of conductive ground, and this is another source of geologic noise. The recognition of a bedrock conductor in a highly conductive environment therefore is based on the anomalous responses of the two difference channels (33 and 34) and the resistivity channel (40). The most favourable situation is where anomalies coincide on all 3 channels.

Channel 41, which is the apparent depth to the conductive material, also helps determine whether a conductive response arises from surficial material or from a conductive zone in the bedrock. When this channel rides above the zero level on the orange profile paper (i.e., it is negative), it implies that the EM and resistivity profiles are responding primarily to a conductive upper layer, i.e., conductive overburden. If channel 41 is below the zero level, it indicates that a resistive upper layer exists, and this usually implies the existence of a bedrock conductor.

Channels 35 and 36 are the anomaly recognition functions. They are used to trigger the conductance channel 37 which identifies discrete conductors. In highly conducting

environments, channel 36 may not be generated because it is subject to some corruption by highly conductive earth signals. Some of the automatically selected anomalies (channel 37) are discarded by the human interpreter. The automatic selection algorithm is intentionally oversensitive to assure that no meaningful responses are missed. The interpreter then classifies the anomalies according to their source and eliminates those that are not substantiated by the data, such as those rising from geologic or aerodynamic noise.

The resistivity map often yields more useful information on conductivity distributions than the EM map. In comparing the EM and resistivity maps, keep in mind the following:

(a) The resistivity map portrays the absolute value of the earth's resistivity.

(b) The EM map portrays anomalies in the earth's resistivity. An anomaly by definition is a change from the norm and so the EM map displays anomalies, (i) over narrow, conductive bodies and (ii) over the boundary zone

021

136022

between two wide formations of differing conductivity.

The resistivity map might be likened to a total field map and the EM map to a horizontal gradient in the direction of flight[3]. Because gradient maps are usually more sensitive than total field maps, the EM map therefore is to be preferred in resistive areas. However, in conductive areas, the absolute character of the resistivity map usually causes it to be more useful than the EM map.

Reduction of geologic noise

Geologic noise refers to unwanted geophysical responses. For purposes of airborne EM surveying, geologic noise refers to EM responses caused by conductive overburden and magnetic polarization. It was mentioned above that the EM difference channels (i.e., channel 33 for inphase and 34 for quadrature) tend to eliminate the response of conductive overburden. This marked a unique development in airborne EM

[3]The gradient analogy is only valid with regard to the identification of anomalous locations. The calculation of conductance is based on EM amplitudes relative to a local base level, rather than to an absolute zero level as for the resistivity calculation.

022

136023

technology, as DIGHEM^{II} is the only EM system which yields channels having an exceptionally high degree of immunity to conductive overburden.

Magnetite produces a form of geological noise on the inphase channels of all EM systems. Rocks containing less than 1% magnetite can yield negative inphase anomalies caused by magnetic polarization. When magnetite is widely distributed throughout a survey area, the inphase EM channels may continuously rise and fall reflecting variations in the magnetite percentage, flying height, and overburden thickness. This can lead to difficulties in recognizing deeply buried bedrock conductors, particularly if conductive overburden also exists. However, the response of broadly distributed magnetite generally vanishes on the inphase difference channel 33. This feature can be a significant aid in the recognition of conductors which occur in rocks containing accessory magnetite.

MAGNETICS

The existence of a magnetic correlation with an EM anomaly is indicated directly on the EM map. An EM anomaly

023

136024

with magnetic correlation has a greater likelihood of being produced by sulfides than one that is non-magnetic. However, sulfide ore bodies may be non-magnetic (e.g., the Kidd Creek deposit near Timmins, Ontario, Canada) as well as magnetic (e.g., the Mattabi deposit near Sturgeon Lake, Ontario).

The magnetometer data are digitally recorded in the aircraft to an accuracy of one gamma. The digital tape is processed by computer to yield a standard total field magnetic map which is usually contoured at 25 gamma intervals. The magnetic data also are treated mathematically to enhance the magnetic response of the near-surface geology, and an enhanced magnetic map is produced with a 100 gamma contour interval. The response of the enhancement operator in the frequency domain is shown in Figure 2. The 100 gamma contour interval is equivalent to a 5 gamma interval for the passband components of the airborne data. This is because these components are amplified 20 times by the operator of Figure 2.

The enhanced map, which bears a resemblance to a downward continuation map, is produced by digital bandpass filtering the total field data. The enhancement is

024

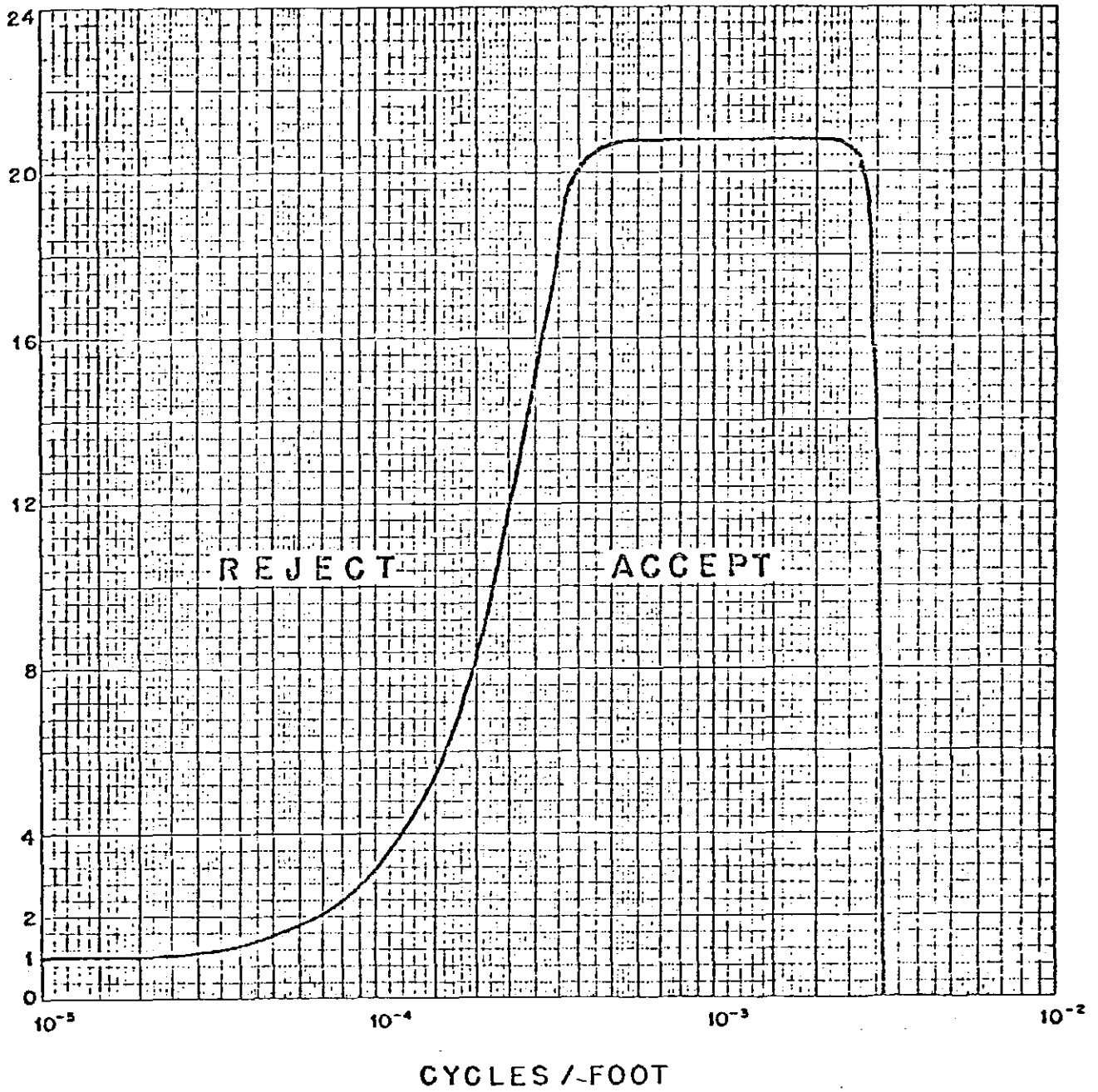


Figure 2 Frequency response of mognetic operator

025

136026

equivalent to continuing the field downward to a level (above the source) which is 1/20th of the actual sensor-source distance.

Because the enhanced magnetic map bears a resemblance to a ground magnetic map, it simplifies the recognition of trends in the rock strata and the interpretation of geological structure. The contour interval of 100 gammas is suitable for defining the near-surface local geology while de-emphasizing deep-seated regional features.

CONDUCTORS IN THE SURVEY AREA

The electromagnetic maps show the locations of conductors and their interpreted conductance (i.e., conductivity-thickness product), depth and, occasionally, dip. Their strike direction and length are also shown where anomalies can be correlated from line-to-line. When studying the maps for follow-up planning, consult the anomaly listings appended to this report to ensure that none of the conductors are overlooked.

The survey consisted of an east-west grid in the Birch Inlet area flown along lines spaced at 150 m, and an irregularly spaced grid in the Mt. Lyell Mine area flown in a northeasterly direction. The production statistics are as follows:

Area	Line-numbers	Line-km
Birch Inlet	1-112	568
Mt. Lyell Mine	201, 204-207, 301-303	17
		585

Birch Inlet Area

The survey area is characterized by background resistivities in excess of 1000 ohm-m. Several low resistivity zones of a limited areal extent, with values as low as 150 ohm-m, occurred due to locally conductive bedrock and overburden features. When evaluating the relative potential of these conductive zones, the apparent depth parameter (DP on the orange profiles) should be used as a guide. For example, the low resistivity zone centered at fiducial 279, line 44, appears to reflect a bedrock source because the depth parameter rides at or below the zero level.[4]

[4]For surface conductors, the DP channel rides above the zero level.

Similarly, the two low resistivity zones which occur along the southern boundary of the survey block reflect bedrock sources.

The survey area almost totally lacks well defined EM anomalies and responses which would be indicative of bedrock conductors. EM anomalies 93A and 95A, and x-type responses 86xA, 89xB, 91xD, 94xC, and 94xE possibly could reflect bedrock sources. Response 111xC definitely reflects a magnetic bedrock conductor which extends in a southerly direction beyond the survey boundary.

The total magnetic field map shows well defined north-northwesterly trends which are particularly well portrayed by the enhanced magnetics. Except for the bedrock conductor 111xC, no direct correlation exists between the magnetic and low resistivity anomalies.

Mt. Lyell Mine area

Eight irregularly spaced lines of variable flight direction were flown in the Mt. Lyell Mine area. Only computer generated profiles and an EM map were produced because of the difficulties which commonly are encountered in the machine contouring of narrow data sets.

028

136029

The background resistivities in this survey block are high, mostly in excess of 1000 ohm-m. Local low resistivity zones, however, exist due to bedrock conductors which are also indicated by EM anomalies and responses, e.g., 206xA-301A, 201D-302F, 302G.

Numerous cultural sources, such as power lines, pipe lines, metal buildings and the like, exist in this survey area. Occasionally, these sources have produced spurious EM and resistivity anomalies which, in most instances, can be readily identified. The cultural activity, however, caused serious problems on line 303. The electronic equipment was overdriven by signals from the mining equipment and, consequently, the EM responses must be regarded with caution.

Respectfully submitted,
DIGHEM LIMITED,

D.C. Fraser,
President.

Z. Dvorak,
Geophysicist.

02

136030

Nine map sheets accompany this report.

Electromagnetics	3 map sheets
Resistivity	2 map sheets
Magnetics	2 map sheets
Enhanced magnetics	2 map sheets

030

136031

A P P E N D I X A

THE FLIGHT RECORD AND PATH RECOVERY

Both analog and digital flight records are produced. The analog profiles are recorded on green chart paper in the aircraft during the survey. The digital profiles are generated later by computer and plotted on orange chart paper at a scale identical to the geophysical maps. The digital profiles, which may be displayed, are as follows:

Channel Label	Parameter	Scale units/mm	Noise
MAG	magnetometer	10 gamma	2 gamma
ALT	bird height	10 feet	5 feet
CXI	coaxial coil-pair inphase	1 ppm	1-2 ppm
CXQ	coaxial coil-pair quadrature	1 ppm	1-2 ppm
CPI	coplanar coil-pair inphase	1 ppm	1-2 ppm
CPQ	coplanar coil-pair quadrature	1 ppm	1-2 ppm
VLFT	VLF-EM total field	1 %	1-2 %
VLFQ	VLF-EM vertical quadrature	1 %	1-2 %
CXS	ambient noise monitor (coaxial coil)	1 ppm	1 ppm
CPS	ambient noise monitor (coplanar coil)	1 ppm	1 ppm
DIFI	difference function inphase	1 ppm	1-2 ppm
DIFQ	difference function quadrature	1 ppm	1-2 ppm
REC1	first anomaly recognition function	1 ppm	1-2 ppm
REC2	second anomaly recognition function	1 ppm	1-2 ppm
SIGT	conductance	1 mho	
RES	log resistivity at main frequency	.03 decade	
DP	apparent depth at main frequency	3 m	
RES2	log resistivity at secondary frequency	.03 decade	
DP2	apparent depth at secondary frequency	3 m	

Note: Channels CC and EXP2 are experimental.

031

136032

The log resistivity scale of 0.03 decade/mm means that the resistivity changes by an order of magnitude in 33 mm. The resistivities at 0, 33, 67 and 100 mm up from the bottom of the chart are respectively 1, 10, 100 and 1000 ohm-m.

The fiducial marks on the flight records represent points on the ground which were recognized by the aircraft navigator. Continuous photographic coverage allowed accurate photo-path recovery locations for the fiducials, which were then plotted on the geophysical maps to provide the track of the aircraft.

The fiducial locations on both the flight records and flight path maps were examined by a computer for unusual helicopter speed changes. Such changes may denote an error in flight path recovery. The resulting flight path locations therefore reflect a more stringent checking than is provided by standard flight path recovery techniques.

The following brief description of DIGHEM^{II} illustrates the information content of the various profiles*.

*For a detailed description, see D.C. Fraser, Geophysics, v.44, p.1367-1394.

032

136033

Single-frequency surveying

The DIGHEM^{II} system has two transmitter coils which are mounted at right angles to each other. Both coils transmit at approximately the same frequency. (This frequency is given in the Introduction.) Thus, the system provides two completely independent surveys at one pass. In addition, the digital flight chart profiles (generated by computer) include an inphase channel and a quadrature channel which essentially are free of the response of conductive overburden. Also, the EM channels may indicate whether the conductor is thin (e.g., less than 3 m), or has a substantial width (e.g., greater than 10 m). Further, the EM channels include channels of resistivity, apparent depth and conductance. A minimum of 11 EM channels are provided. The DIGHEM^{II} system therefore gives information in one pass which cannot be obtained by any other airborne or ground EM technique.

Figure A1 shows a DIGHEM^{II} flight profile over the massive pyrrhotite ore body in Montcalm Township, Ontario. It will serve to identify the majority of the available channels.

033

136034

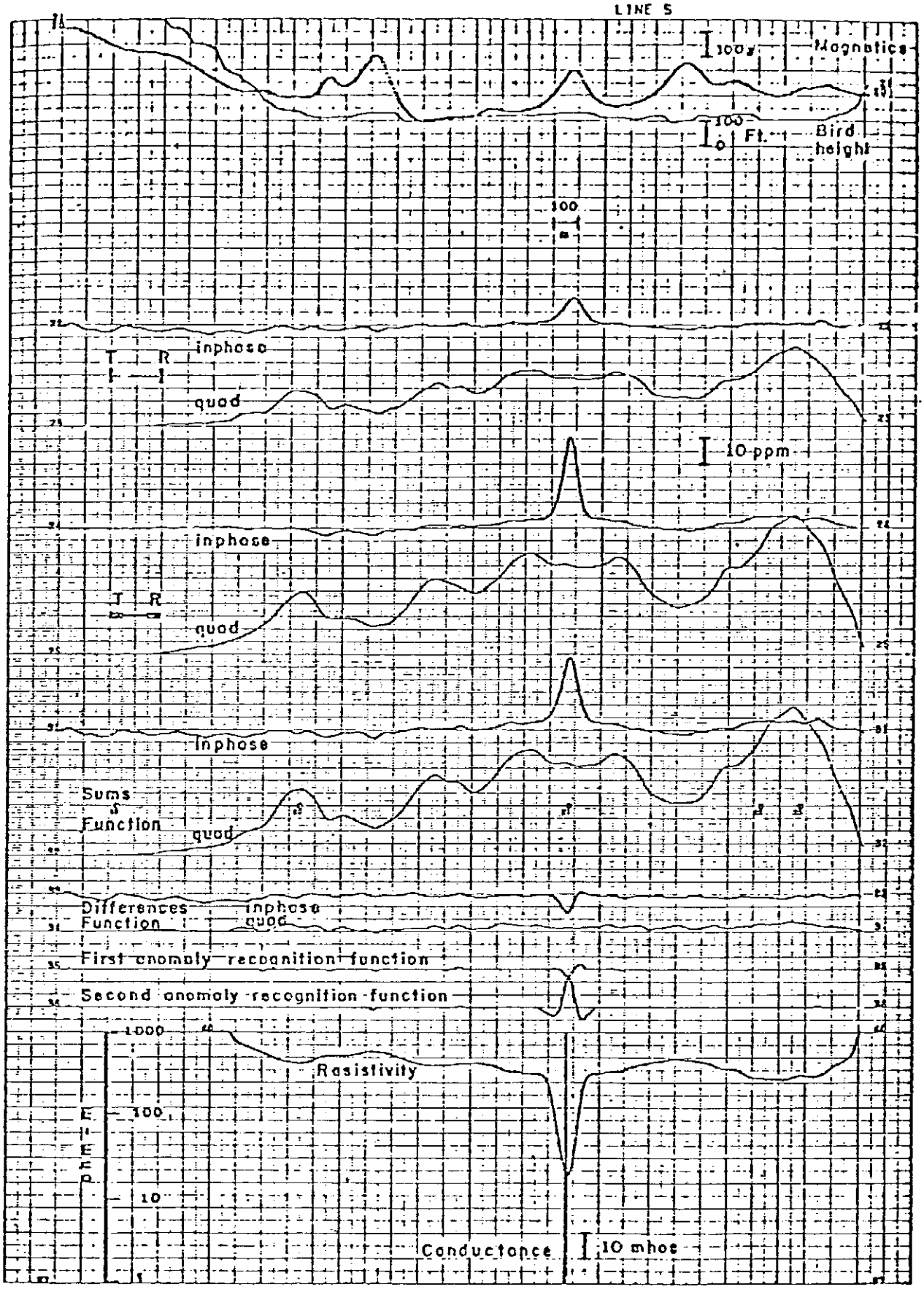


Fig. A1. Flight over Montcalm deposit, with line parallel to strike

The two upper channels (numbered 20 and 21) are respectively the magnetics and the radio altitude. Channels 22 and 23 are respectively the inphase and quadrature of the coaxial coil-pair, which is termed the standard coil-pair. This coil-pair is equivalent to the standard coil-pair of all inphase-quadrature airborne EM systems. Channels 24 and 25 are the inphase and quadrature of the additional coplanar coil-pair which is termed the whaletail coil-pair.

Channels 31 and 32 are inphase and quadrature sum functions of the standard and whaletail channels; they provide a condensed view of the four basic channels 22 to 25. The sum channels normally are not plotted.

Channels 33 and 34 are inphase and quadrature difference functions of the standard and whaletail channels. The difference channels are almost free from the response of conductive overburden. Channel 37 is the conductance. The conductance channel essentially is an automatic anomaly picker calibrated in conductance units of mhos; it is triggered by the anomaly recognition functions shown as channels 35 and 36.

Channel 40 is the resistivity, which is derived from the whaletail channels 24 and 25. The resistivity channel 40 yields data which can be contoured, and so the DIGHEM^{II} system yields a resistivity contour map in addition to an electromagnetic map, a magnetic contour map, and an enhanced magnetic contour map. The enhanced magnetic contour map is similar to the filtered magnetic map discussed by Fraser.*

Figure A2 presents the DIGHEM^{II} results for a line flown perpendicularly to the Montcalm ore body. Channel 20 shows the 175 gamma magnetic anomaly caused by the massive pyrrhotite deposit. For the EM channels, the following points are of interest:

1. On channels 22-25 and 31-34, the ore body essentially yields only an inphase response. The quadrature response is almost completely caused by conductive overburden (which also gives a small inphase response). The hachures show the EM response from the overburden. The overburden response vanishes on the

---

*Cdn. Inst. Mng., Bull., April 1974.

136037

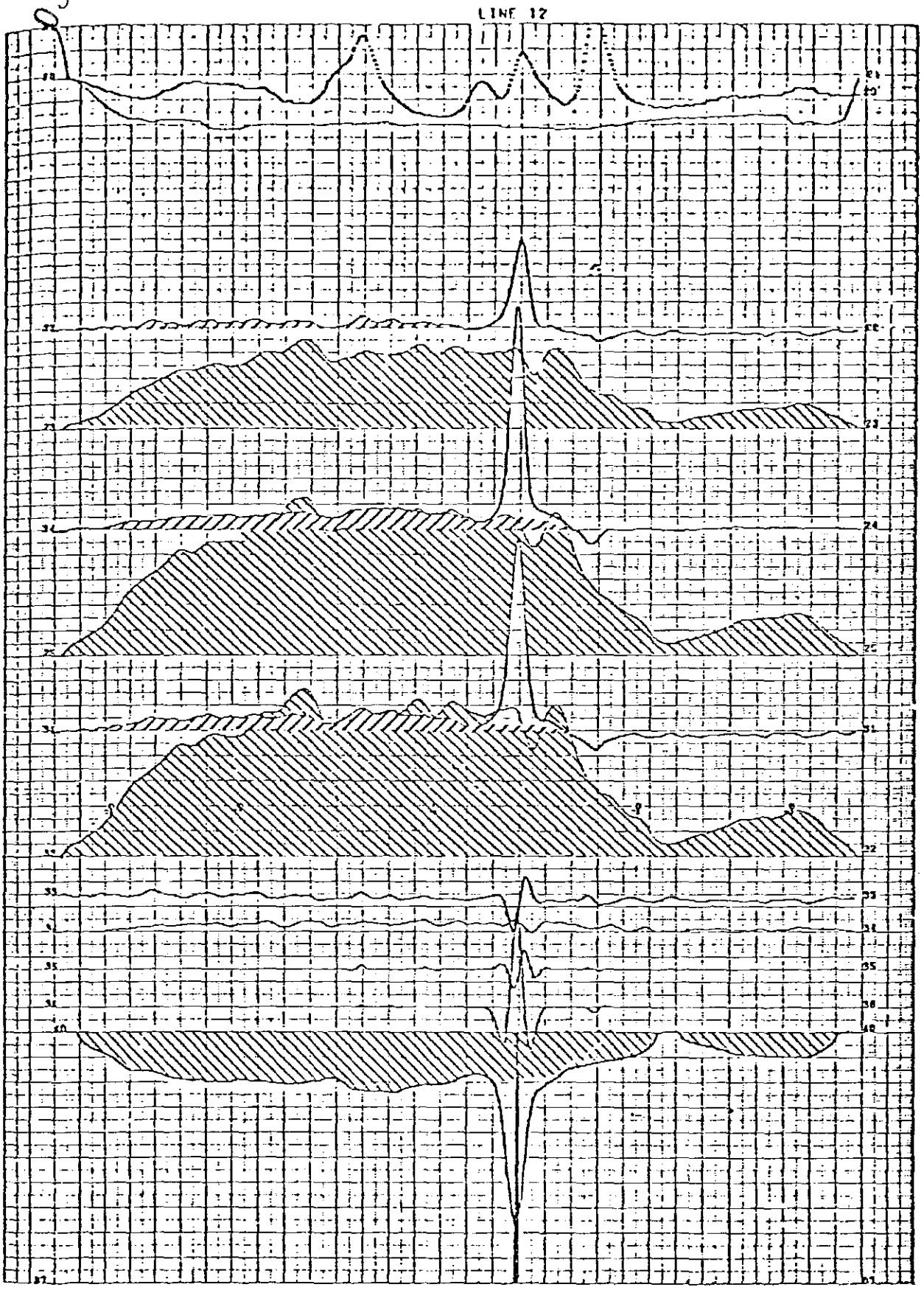


Fig. A2. Flight over Montcalm deposit, with line perpendicular to strike.

difference EM channels, as can be seen by comparing the quadrature channels 25 and 34. This is an important point to note because DIGHEM^{II} is the only EM system which provides an inphase channel and a quadrature channel which are essentially free of conductive overburden response.

2. The whaletail anomaly of channel 24 has a single peak. This shows that the conductor has a substantial width. If the width had been under 3 m, the conductor would have produced a weak m-shaped anomaly on channel 24.

3. The ore body yields a resistivity of 5 ohm-m in a background of about 200 ohm-m (cf. channel 40). A dipole-dipole ground resistivity survey with an a-spacing of 50 m showed a similar background, but the ore body gave a low of only 53 ohm-m because of the averaging effect inherent in the ground technique.

4. The ore body has a conductance of 330 mhos according to its EM response on this particular flight line. The conductance channel 37 saturates at 100 mhos, and so the deposit is indicated by a 100-mho spike.

Figure A1 illustrates the DIGHEM^{II} results for a line flown subparallel to the ore body. The ore body anomaly is small on the standard coil-pair (channel 22) but shows up strongly on the whaletail coil-pair (channel 24).

Dual-frequency surveying

For surveys flown primarily for resistivity mapping, as opposed to EM surveying, the two transmitter coils may be energized at two well-separated frequencies (e.g., 900 and 3600 Hz). Apparent resistivity and apparent depth maps can be made independently for each frequency. The interpretation procedure involves comparing the apparent resistivities and apparent depths at the two frequencies.

The use of two different coil-pair orientations (i.e., standard and whaletail) for dual-frequency resistivity mapping is an unorthodox procedure. However, as long as the current flow patterns are primarily horizontal, the different coil orientations do not influence the results, according to superposed dipole theory. Wire fences and other cultural features will produce local deviations,

039

136040

because they usually respond preferentially to one or the other of the coil-pairs.

The difference channels 33 and 34 are not produced because the divergent frequencies of the two coil-pairs renders them meaningless. In addition, channels 35 to 37 also are not produced.

040

136041

APPENDIX B

EM ANOMALY LIST

041

136042

SH 2 GEOPEKO TASMANIA DEC/80

LINE & ANOMALY	COAXIAL COIL REAL PPM	COAXIAL COIL QUAD PPM	COPLANAR COIL REAL PPM	COPLANAR COIL QUAD PPM	VERTICAL DIKE COND MHOS	VERTICAL DIKE DEPTH* FEET	HORIZONTAL SHEET COND MHOS	HORIZONTAL SHEET DEPTH FEET	CONDUCTIVE EARTH RESIS OHM-M	CONDUCTIVE EARTH DEPTH FEET
5B	6	2	0	2	19	200	1	536	1012	86
5A	3	2	0	1	5	211	1	440	1035	0
5A	4	2	0	0	12	230	1	625	1035	0

+ PROBABLE BEDROCK CONDUCTOR (SEE TITLE PAGE OF APPENDIX B)

* ESTIMATED DEPTH MAY BE UNRELIABLE BECAUSE THE STRONGER PART OF THE CONDUCTOR MAY BE DEEPER OR TO ONE SIDE OF THE FLIGHT LINE, OR BECAUSE OF A SHALLOW DIP OR OVERBURDEN EFFECTS.

042

136043

313-TEST AREA GEORGE,TASMANIA DEC/80

LINE & ANOMALY	COAXIAL COIL REAL PPM	COAXIAL COIL QUAD PPM	COPLANAR COIL REAL PPM	COPLANAR COIL QUAD PPM	VERTICAL DIKE COND MHOS	VERTICAL DIKE DEPTH* FEET	HORIZONTAL SHEET COND MHOS	HORIZONTAL SHEET DEPTH FEET	CONDUCTIVE EARTH RESIS OHM-M	CONDUCTIVE EARTH DEPTH FEET
201A	12	1	0	0	13	0	1	425	1035'	0
201C	2	2	1	0	4	53	1	607	1035	0
201E	2	3	0	1	3	0	1	533	1035	0
201F	6	5	0	3	7	0	1	467	1035	0
201G	5	3	1	0	5	0	1	425	1035	0
201H	5	5	7	3	9	0	2	238	52	107
201I	5	1	1	0	15	0	1	374	645	0
304A	10	11	13	21	7	0	1	141	76	21
301A	28	36	31	67	10	0	2	125	27	44
301B	5	2	0	2	7	80	1	464	476	128
302C	0	0	0	3	9	21	1	676	1035	0
302F	16	25	25	28	8	4	2	176	28	85
302G	6	12	9	22	3	0	1	111	143	0
303A	0	0	6	4	8	188	5	576	10	476
303C	27	31	0	4	13	42	1	366	1035	0
303F	2	0	12	0	257	0	4	188	10	104
303H	2	6	3	6	2	0	1	242	148	71

.+ PROBABLE BEDROCK CONDUCTOR (SEE TITLE PAGE OF APPENDIX B)

.* ESTIMATED DEPTH MAY BE UNRELIABLE BECAUSE THE STRONGER PART OF THE CONDUCTOR MAY BE DEEPER OR TO ONE SIDE OF THE FLIGHT LINE, OR BECAUSE OF A SHALLOW DIP OR OVERBURDEN EFFECTS.

3457

DIGHEM^{II} SURVEY

BIRCH INLET AREA, TASMANIA

ELECTROMAGNETICS

FOR

GEOPEKO LIMITED

LOCATION MAP



Scale 1 250,000

5 cm

SCALE 1:10,000

1/2 0 1/2 1 Kilometres

1/4 0 1/4 1/2 Miles

3457

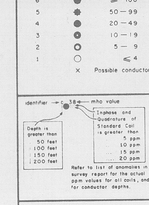
Sheet 1

Flight line

Fiducials and numbers

ANOMALY GRADE	EM GRADE SYMBOL	MHO RANGE
6	●	≥ 100
5	◕	50 — 99
4	●	20 — 49
3	◔	10 — 19
2	○	5 — 9
1	○	≤ 4
	×	Possible conductor

DIGHEM anomalies are divided into six grades of conductivity - thickness product. This product in mhos is the reciprocal of resistance in ohms. The mho is a measure of conductance, and is a geologic parameter. Most swamps yield Grade 1 anomalies but highly conducting clays can give Grade 2 anomalies. The multi-coil anomaly shapes often allow surface conductors to be recognized, and these are indicated by the letter S on this map. The remaining Grade 1 and 2 anomalies could be weak bedrock conductors. The higher grades indicate increasingly higher conductances. Examples: The ore bodies of the Magusi River camp yield Grade 4 anomalies, while Matagi and Whistle give Grade 5. Graphite and sulphides can span all grades but, in this survey area, field work may show that the different grades indicate different types of conductors.



The actual mho value is plotted beside the E.M. grade symbol. The letter is the anomaly identifier. The horizontal rows of dots indicate anomaly amplitude on the flight record, and the vertical column gives the estimated depth. This depth may be unreliable because the stronger part of the conductor may be deeper or to one side of the flight line, or because of a shallow dip or conductive overburden effects.

	Conductor axis
S	Probable surface response
S?	Possible surface response
L	Probable line (power, telephone, pipe, or fence)
L?	Possible line
?	Questionable anomaly
○	Apparent thickness >10 m
>	Dip
100 ℓ	Direct magnetic correlation of 100 gammas

DIGHEM maps are designed to provide a correct impression of conductor quality by means of the conductance grade symbols. The symbols can stand alone with geology when planning a follow-up program. The actual mho values are plotted for those who wish quantitative data. The anomaly ppm and depth are indicated by inconspicuous dots which should not distract from the conductor patterns, while being helpful to those who wish this information. The map provides an interpretation of all conductors in terms of length, strike direction, conductance and depth. The accuracy is comparable to an interpretation from a ground E.M. survey having the same line spacing.

REGISTERED PROFESSIONAL ENGINEER
D. C. FRASER
PROVINCE OF ONTARIO

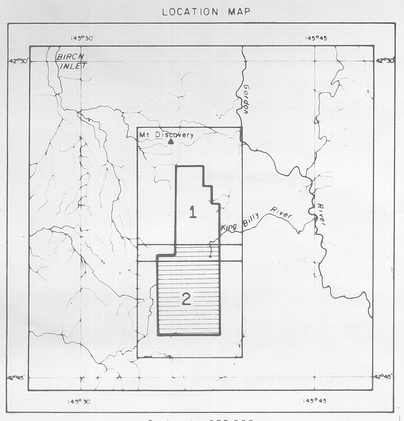
136041

85-2436

3458



LOCATION MAP



Scale 1 : 250,000

5 cm

REGISTERED PROFESSIONAL ENGINEER
D. C. FRASER
PROVINCE OF ONTARIO

DIGHEM^{II} SURVEY

BIRCH INLET AREA, TASMANIA

ELECTROMAGNETICS

FOR

GEOPEKO LIMITED

136045

SCALE 1 : 10,000

1/2 0 1/2 1 Kilometres

1/4 0 1/4 1/2 Miles

3458

Sheet 2

85-2436

Flight line

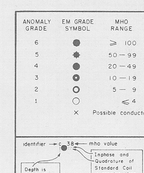
1250'

Fiducials and numbers

1250'

ANOMALY GRADE	EM GRADE SYMBOL	MHO RANGE
6	●	≥ 100
5	◉	50 — 99
4	●	20 — 49
3	◎	10 — 19
2	○	5 — 9
1	○	≤ 4
	×	Possible conductor

DIGHEM anomalies are divided into six grades of conductivity – thickness product. This product in mhos is the reciprocal of resistance in ohms. The mho is a measure of conductance, and is a geologic parameter. Most swamps yield Grade 1 anomalies but highly conducting clays can give Grade 2 anomalies. The multi - coil anomaly shapes often allow surface conductors to be recognized, and these are indicated by the letter S on this map. The remaining Grade 1 and 2 anomalies could be weak bedrock conductors. The higher grades indicate increasingly higher conductances. Examples: The ore bodies of the Mogul River camp yield Grade 4 anomalies, while Mattabi and Whistle give Grade 5. Graphite and sulphides can span all grades but, in this survey area, field work may show that the different grades indicate different types of conductors.



The actual mho value is plotted beside the EM grade symbol. The letter is the anomaly identifier. The horizontal rows of dots indicate anomaly amplitude on the flight record, and the vertical column gives the estimated depth. This depth may be unreliable because the stronger part of the conductor may be deeper or to one side of the flight line, or because of a shallow dip or conductive overburden effects.

	Conductor axis
S	Probable surface response
S?	Possible surface response
L	Probable line (power, telephone, pipe or fence)
L?	Possible line
?	Questionable anomaly
○	Apparent thickness > 10 m
>	Dip
100 γ	Direct magnetic correlation of 100 gammas

DIGHEM maps are designed to provide a correct impression of conductor quality by means of the conductance grade symbols. The symbols can stand alone with geology when planning a follow-up program. The actual mho values are plotted for those who wish quantitative data. The anomaly ppm and depth are indicated by inconspicuous dots which should not distract from the conductor patterns, while being helpful to those who wish this information. The map provides an interpretation of all conductors in terms of length, strike direction, conductance and depth. The accuracy is comparable to an interpretation from a ground EM survey having the same line spacing.

3459

DIGHEM^{II} SURVEY

BIRCH INLET AREA, TASMANIA

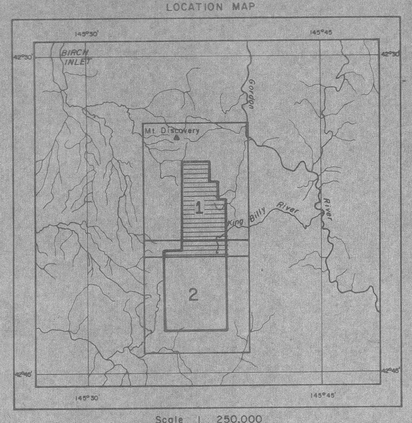
RESISTIVITY

136046

FOR

GEOPEKO LIMITED

LOCATION MAP



Scale 1 250,000

5 cm

SCALE 1 : 10,000

1/2 0 1/2 1 Kilometres

1/4 0 1/4 1/2 Miles

3459

Sheet 1

85-2436

Flight line

Fiducials and numbers

LEGEND

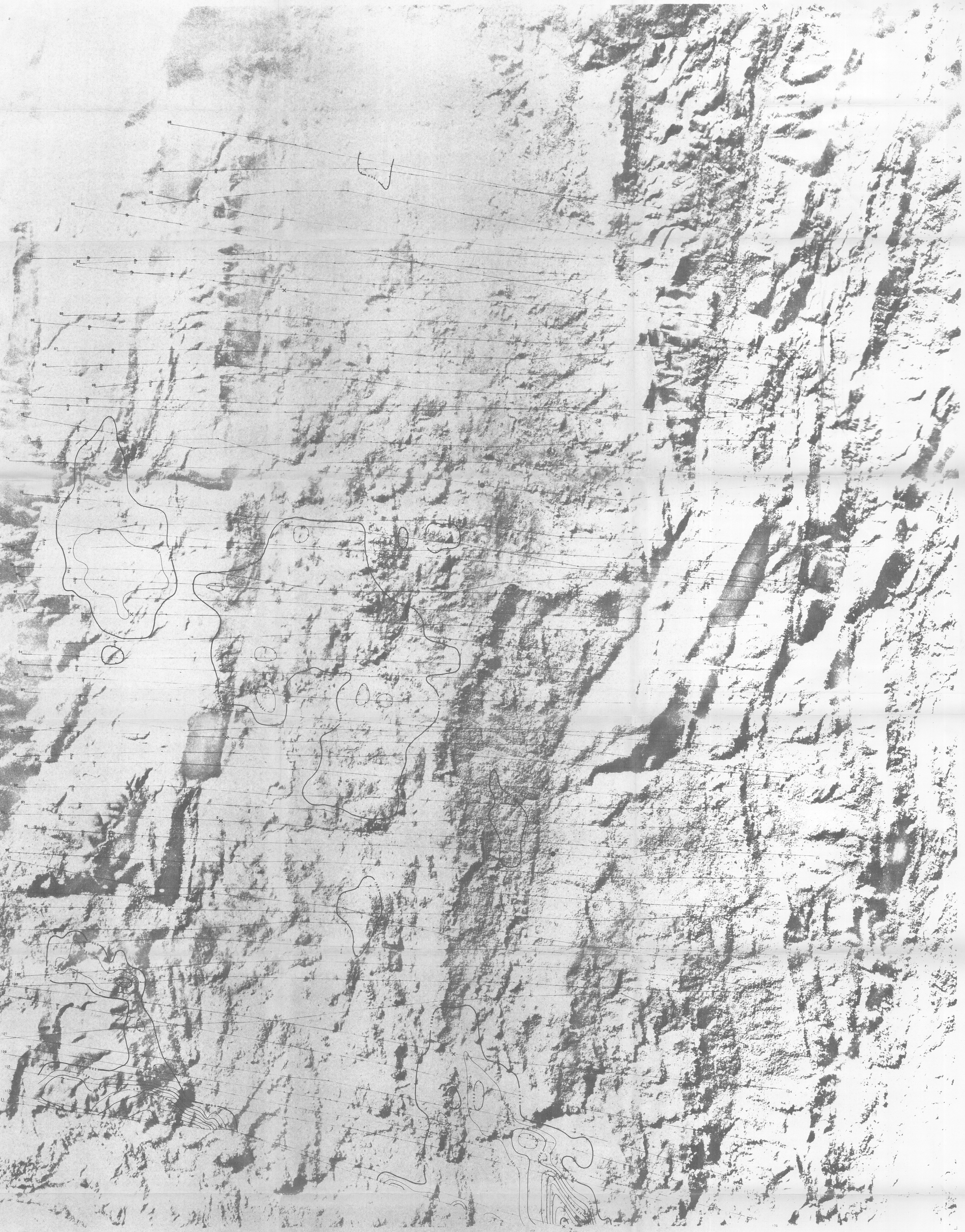
Contours in ohm-m at eight intervals per decade

100
75
56
42
31
23
17
13
10

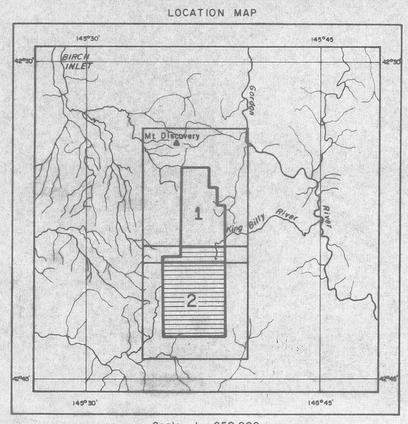
Note

The numbers face in the direction of increasing value.

3460



LOCATION MAP



Scale 1 : 250,000

5 cm

DIGHEM^{II} SURVEY

BIRCH INLET AREA, TASMANIA

RESISTIVITY

FOR

GEOPEKO LIMITED

136047

SCALE 1 : 10,000

1/2 0 1/2 1 Kilometres

1/4 0 1/4 1/2 Miles

3460

Sheet 2

85-2436

REGISTERED PROFESSIONAL ENGINEER
D. C. FRASER
PROVINCE OF ONTARIO

Flight line

1200

Fiducials and numbers

9431

LEGEND

Contours in ohm-m at eight intervals per decade

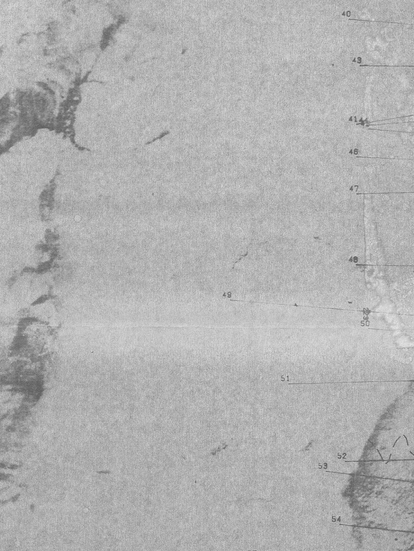
100
75
56
42
31
23
17
13
10

Note

The numbers face in the direction of increasing value.

3461

LOCATION MAP



Scale 1 250,000

5 cm

DIGHEM^{II} SURVEY

BIRCH INLET AREA, TASMANIA

MAGNETICS

FOR

GEOPEKO LIMITED

136048

SCALE 1:10,000

1/2 0 1/2 1 Kilometres

1/4 0 1/4 1/2 Miles

3461

Sheet 1

85-2436

REGISTERED PROFESSIONAL ENGINEER
D. C. FRASER
PROVINCE OF ONTARIO

Flight line

1250

Fiducials and numbers

9521

ISOMAGNETIC LINES

(total field)

1000 ..... 1000 gammas

200 ..... 200 gammas

..... 50 gammas

..... 25 gammas

..... magnetic depression

Magnetic Inclination within the survey area: 72°

3462

DIGHEM^{II} SURVEY

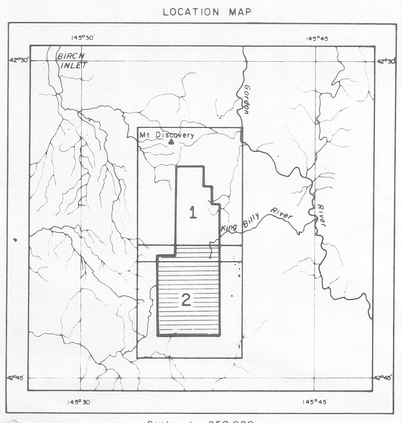
BIRCH INLET AREA, TASMANIA

MAGNETICS

FOR 136049

GEOPEKO LIMITED

LOCATION MAP



Scale 1 250,000

5 cm

SCALE 1:10,000

1/2 0 1/2 1 Kilometres

1/4 0 1/4 1/2 Miles

3462

Sheet 2

85-2436

Flight line

Fiducials and numbers

ISOMAGNETIC LINES

(total field)

1000 ..... 1000 gammas

200 ..... 200 gammas

..... 50 gammas

..... 25 gammas

..... magnetic depression

Magnetic Inclination within the survey area: 72°

3464

DIGHEM^{II} SURVEY

BIRCH INLET AREA, TASMANIA

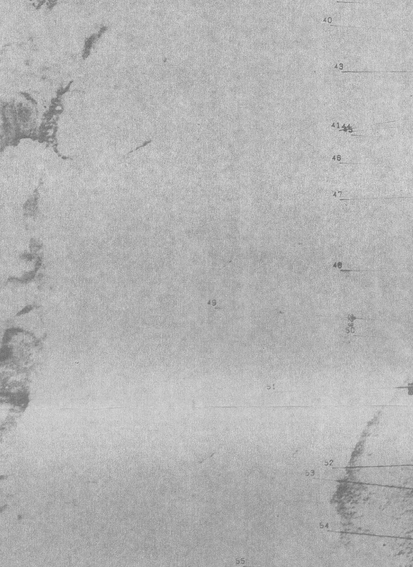
ENHANCED MAGNETICS

FOR

GEOPEKO LIMITED

126050

LOCATION MAP



Scale 1 : 250,000

5 cm

SCALE 1 : 10,000

1/2 0 1/2 1 Kilometres

1/4 0 1/4 1/2 Miles

3464

Sheet 1

85-2436

Flight line

3321

Fiducials and numbers

3281

ISOMAGNETIC LINES

(enhanced field)

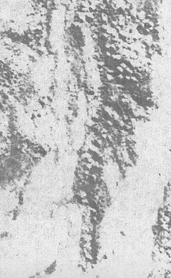
5000 ..... 5000 gammas

1000 ..... 1000 gammas

200 ..... 200 gammas

100 ..... 100 gammas

..... magnetic depression



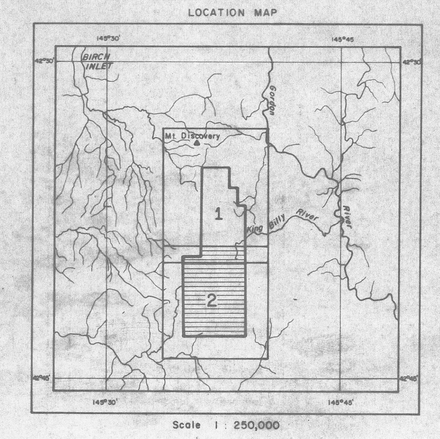
Frequency response of magnetic operator

REGISTERED PROFESSIONAL ENGINEER
D. FRASER
PROVINCE OF ONTARIO

3463



LOCATION MAP



Scale 1 : 250,000

DIGHEM^{II} SURVEY

BIRCH INLET AREA, TASMANIA

ENHANCED MAGNETICS

FOR

GEOPEKO LIMITED

136051

REGISTERED PROFESSIONAL ENGINEER
D. FRASER
PROVINCE OF ONTARIO

SCALE 1 : 10,000

1/2 0 1/2 1 Kilometres

1/4 0 1/4 1/2 Miles

3463

Sheet 2

85-2436

Flight line

Fiducials and numbers

ISOMAGNETIC LINES

(enhanced field)

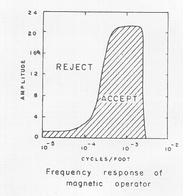
5000 ..... 5000 gammas

1000 ..... 1000 gammas

..... 200 gammas

..... 100 gammas

..... magnetic depression



Frequency response of magnetic operator