REPORT NO. 267

DIGHEM^{III} SURVEY
OF THE
WAWA AREA,
ONTARIO

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MINING LANDS SECTION

FOR

CITADEL GOLD MINES, INC.

BY

DIGHEM SURVEYS & PROCESSING INC.

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MISSISSAUGA, ONTARIO
December 17, 1986

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AD-SK-458

SUMMARY AND RECOMMENDATIONS

A total of 454 km (282 miles) of survey was flown with the DIGHEM^{III} system in October 1986, for Citadel Gold Mines, Inc., over a property near Wawa, Ontario.

The survey outlined several discrete bedrock conductors associated with areas of low resistivity. Many of these anomalies appear to warrant further investigation using appropriate surface exploration techniques. Areas of interest may be assigned priorities for follow-up work on the basis of supporting geological and/or geochemical information. Due to the several cultural features in the survey area, any interpreted bedrock conductors, which occur close to cultural sources, should be confirmed as bedrock conductors prior to drilling.

The area of interest contains several anomalous features, many of which are considered to be of moderate to high priority as exploration targets.

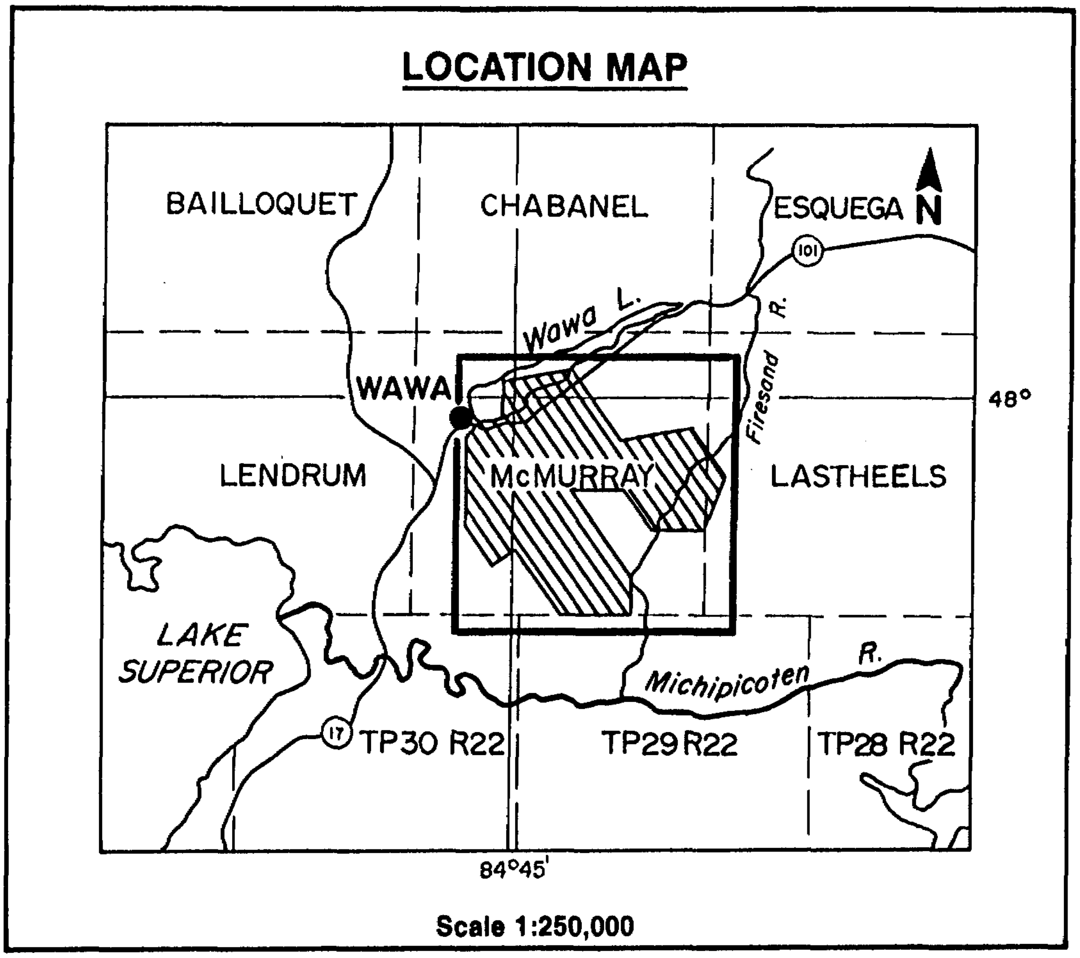

FIGURE 1

THE SURVEY AREA

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INTRODUCTION

A DIGHEM^{III} electromagnetic/resistivity/magnetic/VLF survey totalling 446 line-km (277 line-miles) was flown with a 100 m line-spacing for Citadel Gold Mines Inc., from October 20 to 28, 1986, in the Wawa area of Ontario (Figure 1). In addition, one tie line was flown totalling eight line-km.

The Aerospatiale 350B turbine helicopter flew at an average airspeed of 100 km/h with an EM bird height of approximately 30 m. Ancillary equipment consisted of a Sonotek PMH5010 magnetometer with its bird at an average height of 45 m, a Sperry radio altimeter, a Geocam sequence camera, an RMS GR33 digital graphics recorder, a Scintrex CDI 6 digital data acquisition system and a DigiData 9-track 800-bpi magnetic tape recorder. The analog equipment recorded four channels of EM data at approximately 900 Hz, two channels of EM data at approximately 7200 Hz, two ambient EM noise channels (for the coaxial and coplanar receivers), two channels of magnetics (coarse and fine count), and a channel of radio altitude. The digital equipment recorded the above parameters, with the EM data to a sensitivity of 0.2 ppm at 900 Hz and 0.4 ppm at 7200 Hz, and the magnetic field to one nT (i.e., one gamma). In addition, four channels of VLF were also recorded.

Appendix A provides details on the data channels, their respective sensitivities, and the flight path recovery procedure. Noise levels of less than 2 ppm are generally maintained 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.

EM anomalies shown on the electromagnetic anomaly map are based on a near-vertical, half plane model. This model best reflects "discrete" bedrock conductors. Wide bedrock conductors or flat-lying conductive units, whether from surficial or bedrock sources, may give rise to very broad anomalous responses on the EM profiles. These may not appear on the electromagnetic anomaly map if they have a regional character rather than a locally anomalous character. These broad conductors, which more closely approximate a half space model, will be maximum coupled to the horizontal (coplanar) coil-pair and are clearly evident on the resistivity map. The resistivity map, therefore, may be more valuable than the electromagnetic anomaly map, in areas where broad or flat-lying conductors are considered to be of importance.

Anomalies which occur beyond the first and last fiducials of a line, (i.e., outside the survey area) should be viewed with caution. Although the flight line extensions appear on the maps as straight dashed lines projected from the last two fiducials, they may not reflect the true flight path, which actually consists of a fairly tight loop between consecutive flight lines. The location of anomalies which are situated beyond the end fiducials may, therefore, be uncertain, although an accurate location may be determined by comparing the 35 mm flight path film with the photomosaic base. (The anomaly fiducial will correspond to the flight path frame with the same number.) Furthermore, some of the weaker anomalies could be due to aerodynamic noise, i.e., bird bending, created by abnormal stresses to which the bird is subjected during the climb and turn of the aircraft between lines. Such aerodynamic noise is usually manifested by an anomaly on the coaxial inphase channel only, although severe stresses can affect the coplanar inphase channels as well.

In areas where EM responses are evident only on the quadrature components, zones of poor conductivity are indicated. Where these responses are coincident with strong magnetic anomalies, it is possible that the inphase component amplitudes have been suppressed by the effects of magnetite. Most of these poorly-conductive magnetic features give rise to resistivity anomalies which are only slightly below background. These weak features are evident on the resistivity map but may not be shown on the electromagnetic anomaly map. If it is expected that poorly-conductive sulphides may be associated with magnetite-rich units, some of these weakly anomalous features may be of interest. In areas where magnetite causes the inphase components to become negative, the apparent conductance and depth of EM anomalies may be unreliable.

SECTION I: SURVEY RESULTS

CONDUCTORS IN THE SURVEY AREA

The survey covered a single grid with 454 km of flying, the results of which are shown on a single map sheet for each parameter. Table I-1 summarizes the EM responses on the single sheet with respect to conductance grade and interpretation.

The electromagnetic anomaly map shows the anomaly locations with the interpreted conductor type, dip, conductance and depth being indicated by symbols. Direct magnetic correlation is also shown if it exists. The strike direction and length of the conductors are indicated when anomalies can be correlated from line to line. When studying the map sheets for follow-up planning, consult the anomaly listings appended to this report to ensure that none of the conductors are overlooked.

The resistivity map shows the conductive properties of the survey area. Some of the resistivity lows (i.e., conductive areas) coincide with discrete bedrock conductors and others indicate conductive overburden or broad

TABLE I-1

EM ANOMALY STATISTICS OF THE WAWA AREA

CONDUCTOR GRADE	CONDUCTANCE RANGE	NUMBER OF RESPONSES
6	> 99 MHOS	1
5	50-99 MHOS	1
4	20-49 MHOS	4
3	10-19 MHOS	4
2	5- 9 MHOS	12
1	< 5 MHOS	111
X	INDETERMINATE	58
TOTAL		191

CONDUCTOR MODEL	MOST LIKELY SOURCE	NUMBER OF RESPONSES
D	DISCRETE BEDROCK CONDUCTOR	7
B	DISCRETE BEDROCK CONDUCTOR	41
S	CONDUCTIVE COVER	136
L	CULTURE	5
?	QUESTIONABLE	1
(BLANK)		1
TOTAL		191

(SEE EM MAP LEGEND FOR EXPLANATIONS)

conductive rock units. The resistivity patterns may aid geologic mapping and in extending the length of known zones.

Numerous cultural sources, such as powerlines, metal fences and buildings, occur within the survey area. These cultural sources may influence the resistivity and electromagnetic anomaly patterns but can usually be identified on the profiles due to their characteristic signatures. A separate map showing probable bedrock conductors can be produced for the survey area, if requested. The resulting map would display only those anomalies which have been attributed to discrete bedrock conductors. All other anomalies attributed to horizontal layers and cultural features would be intentionally deleted from this presentation to provide an uncluttered view of the more interesting anomalies.

This survey block is located northeast of the town of Wawa, Ontario. Numerous mineral occurences and former producers are located within the survey block. Past producers have included the Jubilee, Minto and Parkhill Mines. It is highly rcommended that the known geology of these mines be correlated with the airborne geophysical data in order to define a model upon which to base followup priorities.

Total field magnetic contours and enhanced magnetic contours appear to provide excellent geological mapping capability. VLF contours appear to provide additional mapping capability. Resistivity contours appear to map several weakly conductive features that may be due to either mineralization or conductive portions of structural features. Caution should be exercised when examining resistivity lows located within lakes as they are probably due to lake bottom sediments. Two resistivity lows should be considered of primary importance when following up this data. Both features reflect northwest trending lows that are folded to the east. These responses are discussed in more detail in the following section.

Anomalies 10150A, 10240xA-10280xA

This grade 1 anomaly and associated x-type responses indicate a discontinuous conductive horizon which is best defined by the resistivity contours. These conductors are associated with a river which appears to be structurally controlled. These anomalies may reflect conductive portions of a shear zone.

Anomalies 10181A, 10181B, 10190xB-10220B, 10211B

These grade 1 and grade 2 anomalies reflect a conductive horizon which strikes parallel to flight line 10181 and is then folded to the northeast. This magnetic conductor should be investigated.

Anomalies 10211xC-10230A

This magnetic bedrock conductor may belong to the same conductive source as the above group. This zone may be faulted from the folded horizons described above. This conductor and the possible fault zone should be given a high priority in any followup program.

Anomalies 10211xD-10230xE

This weak probable bedrock conductor is best described by the resistivity product. This zone is associated with a weak magnetic high with short strike length. These anomalies should be investigated.

Anomalies 10240A-10250A, 10290B, 10340xD-10350xI

This segmented zone may reflect a discontinuous structural feature. These anomalies are located to the side of a weak magnetic high best defined by the enhanced magnetic contours. This zone may be due to a contact or a shear zone.

Anomalies 10320C, 10320D

These broad anomalies appear to indicate a northwest striking conductor. This conductor is poorly defined because strike is parallel to the flight lines. This conductor may be of interest.

Anomalies 10410E-10450C

This weak conductor is located adjacent to the shoreline of Lake Wawa. This conductor should be examined with caution as it may be due to conductive overburden or perhaps to a cultural feature. This conductor should be examined in order to establish the source of conductivity.

Anomalies 10510D-10542C

This strong bedrock conductor is located along the edge of a magnetic dyke-like feature striking northeast. This conductor is located within a broader zone of conductivity that appears to be associated with the Firesand River fault. This strong conductor may be due to sulphides.

Anomalies 10600D-10620B

These grade 2 anomalies reflect strong bedrock conductors associated with a magnetic high. Available geology indicate that this conductor is due to pyrrhotite.

Group 1

This group of anomalies reflects a folded conductor best defined by the resistivity contours. This group may be due to sulphides. This horizon should be investigated in order to better define conductor axis where it is parallel to the flight lines.

Anomalies 10750B-10780A

These grade 1 anomalies have been interpreted as being due to a surficial source. The prominent resistivity low associated with these conductors indicates that this might be a bedrock/formational feature of exploration interest. These anomalies should be investigated.

SECTION II: BACKGROUND INFORMATION

Section II provides background information on products which are available from your survey data. Those products not obtained as part of the survey contract may be generated later from raw data which is available on your archive digital tape.

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 200 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 analyzed 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.

Geometric interpretation

The geophysical interpreter attempts to determine the geometric shape and dip of the conductor. Figure II-1 shows typical DIGHEM anomaly shapes which are used to guide the geometric interpretation.

Discrete conductor analysis

The EM anomalies appearing on the electromagnetic map are analyzed by computer to give the conductance (i.e., conductivity-thickness product) in mhos of a vertical sheet model. This is done regardless of the interpreted geometric shape of the conductor. This is not an unreasonable procedure, because the computed conductance increases as the

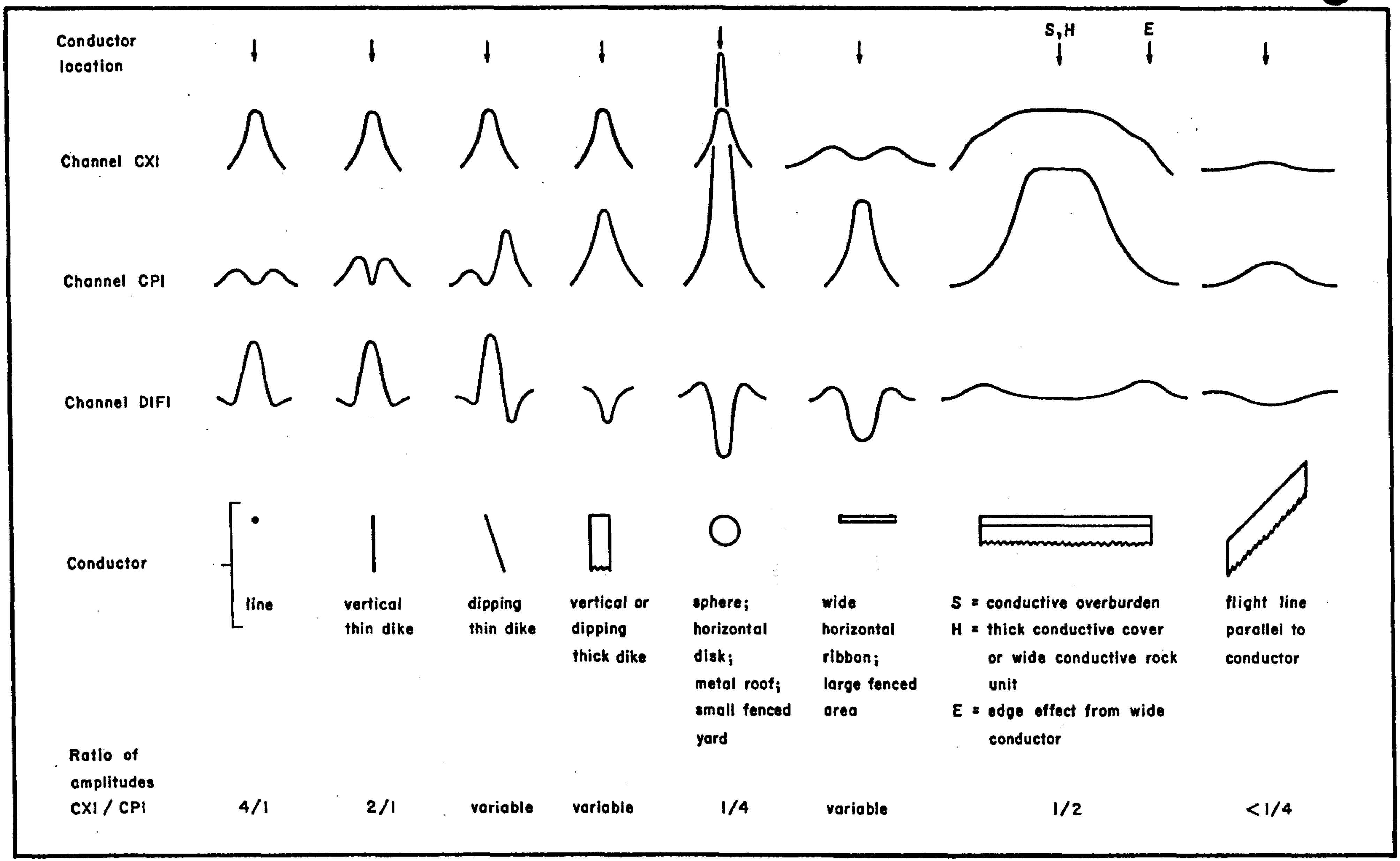

Fig. II-1 Typical DIGHEM anomaly shape

electrical quality of the conductor increases, regardless of its true shape. DIGHEM anomalies are divided into six grades of conductance, as shown in Table II-1. The conductance in mhos is the reciprocal of resistance in ohms.

Table II-1. EM Anomaly Grades

Anomaly Grade	Mho Range
6	> 99
5	50 - 99
4	20 - 49
3	10 - 19
2	5 - 9
1	< 5

The conductance value is a geological parameter because it is a characteristic of the conductor alone. It generally is independent of frequency, 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 conductance values.

Conductive overburden generally produces broad EM responses which may not be shown as anomalies on the EM maps. However, patchy conductive overburden in otherwise

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

resistive areas can yield discrete anomalies with a conductance grade (cf. Table II-1) 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 below 10 ohm-m, anomalies caused by weathering variations and similar causes can have any conductance grade. The anomaly shapes from the multiple coils often allow such conductors to be recognized, and these are indicated by the letters S, H, G and sometimes E on the map (see EM legend).

For bedrock conductors, the higher anomaly grades indicate increasingly higher conductances. Examples: DIGHEM's New Insco copper discovery (Noranda, Canada) yielded a grade 4 anomaly, as did the neighbouring copper-zinc Magusi River ore body; Mattabi (copper-zinc, Sturgeon Lake, Canada) and Whistle (nickel, Sudbury, Canada) gave grade 5; and DIGHEM's Montcalm nickel-copper discovery (Timmins, 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 graphite or sulfides of a less massive character, 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, 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., grades 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, a letter identifier and an interpretive symbol are plotted beside the EM grade symbol. The horizontal rows of dots, under the interpretive symbol, indicate the anomaly amplitude on the flight record. The vertical column of dots, under the anomaly letter, gives the estimated depth. In areas where anomalies are crowded, the letter identifiers, interpretive symbols and dots 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 tend to be accurate whereas one obtained from a small ppm anomaly (no dots) could be quite 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 conductance grade and depth estimate illustrates which of these possibilities fits the recorded data best.

Flight line deviations occasionally yield cases where two anomalies, having similar conductance 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 onto 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 conductance values are printed in the attached anomaly list 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 and dip, geometric shape, conductance, depth, and thickness (see below). The accuracy is comparable to an interpretation from a high quality ground EM survey having the same line spacing.

The attached EM anomaly list provides a tabulation of anomalies in ppm, conductance, and depth for the vertical sheet model. The EM anomaly list also shows the conductance and 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 10 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.

X-type electromagnetic responses

DIGHEM maps contain x-type EM responses in addition to EM anomalies. An x-type response is below the noise threshold of 3 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 the flight line, or aerodynamic noise. Those responses that have the appearance of valid bedrock anomalies on the flight profiles are indicated by appropriate interpretive symbols (see EM map legend). The others probably do not warrant further investigation unless their locations are of considerable geological interest.

The thickness parameter

DIGHEM can provide an indication of the thickness of a steeply dipping conductor. The amplitude of the coplanar anomaly (e.g., CPI channel on the digital profile) increases relative to the coaxial anomaly (e.g., CXI) as the apparent thickness increases, i.e., the thickness in the horizontal plane. (The 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 3 m, and thick when in excess of 10 m. Thick conductors are indicated on the EM map by crescents. For base metal exploration in steeply dipping geology, thick conductors can be high priority targets because many massive sulfide ore bodies are thick, whereas non-economic bedrock conductors are often thin. The system cannot sense the thickness 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 EM 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 correct 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. The resistivity analysis also helps the interpreter to differentiate between conductive trends in the bedrock and those patterns typical of conductive overburden. For example, discrete conductors will generally appear as narrow lows on the contour map and broad conductors (e.g., overburden) will appear as wide lows.

The resistivity profile (see table in Appendix A) and the resistivity contour map present the apparent resistivity using the so-called pseudo-layer (or buried) half space model defined by Fraser (1978)[2]. This model consists of a resistive layer overlying a conductive half space. The depth channel (see Appendix A) gives the apparent depth below surface of the conductive material. The apparent depth 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. 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

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

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 system has been flown for purposes 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 can be of significant help in distinguishing between overburden and bedrock conductors.

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. (Resistivity = 1/conductivity.)

(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 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.

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[3] The gradient analogy is only valid with regard to the identification of anomalous locations.

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 discrete bedrock conductors. The processing of DIGHEM data, however, produces six channels which contribute significantly to the recognition of bedrock conductors. These are the inphase and quadrature difference channels (DIFI and DIFQ), and the resistivity and depth channels (RES and DP) for each coplanar frequency; see table in Appendix A.

The EM difference channels (DIFI and DIFQ) 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 conductive environment therefore is based on the anomalous responses of the two difference channels (DIFI and DIFQ) and the two resistivity channels (RES). The most favourable situation is where anomalies coincide on all four channels.

The DP channels, which give the apparent depth to the conductive material, also help to determine whether a conductive response arises from surficial material or from a conductive zone in the bedrock. When these channels ride above the zero level on the digital profiles (i.e., depth is negative), it implies that the EM and resistivity profiles are responding primarily to a conductive upper layer, i.e., conductive overburden. If both DP channels are below the zero level, it indicates that a resistive upper layer exists, and this usually implies the existence of a bedrock conductor. If the low frequency DP channel is below the zero level and the high frequency DP is above, this suggests that a bedrock conductor occurs beneath conductive cover.

The conductance channel CDT identifies discrete conductors which have been selected by computer for appraisal by the geophysicist. Some of these automatically selected anomalies on channel CDT are discarded by the geophysicist. 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 arising from geologic or aerodynamic noise.

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 permeability. It was mentioned above that the EM difference channels (i.e., channel DIFI for inphase and DIFQ for quadrature) tend to eliminate the response of conductive overburden. This marked a unique development in airborne EM technology, as DIGHEM 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 permeability. 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 DIFI. This feature can be a significant aid in the recognition of conductors which occur in rocks containing accessory magnetite.

EM magnetite mapping

The information content of DIGHEM data consists of a combination of conductive eddy current response and magnetic permeability response. The secondary field resulting from conductive eddy current flow is frequency-dependent and consists of both inphase and quadrature components, which are positive in sign. On the other hand, the secondary field resulting from magnetic permeability is independent of frequency and consists of only an inphase component which is negative in sign. When magnetic permeability manifests itself by decreasing the measured amount of positive inphase, its presence may be difficult to recognize. However, when it manifests itself by yielding a negative inphase anomaly (e.g., in the absence of eddy current flow), its presence is assured. In this latter case, the negative component can be used to estimate the percent magnetite content.

A magnetite mapping technique was developed for the coplanar coil-pair of DIGHEM. The technique yields channel FEO (see Appendix A) which displays apparent weight percent magnetite according to a homogeneous half space model.[4] The method can be complementary to magnetometer mapping in certain cases. Compared to magnetometry, it is far less sensitive but is more able to resolve closely spaced magnetite zones, as well as providing an estimate of the amount of magnetite in the rock. The method is sensitive to 1/4% magnetite by weight when the EM sensor is at a height of 30 m above a magnetitic half space. It can individually resolve steeply dipping narrow magnetite-rich bands which are separated by 60 m. Unlike magnetometry, the EM magnetite method is unaffected by remanent magnetism or magnetic latitude.

The EM magnetite mapping technique provides estimates of magnetite content which are usually correct within a

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[4] Refer to Fraser, 1981, Magnetite mapping with a multi-coil airborne electromagnetic system: Geophysics, v. 46, p. 1579-1594.

factor of 2 when the magnetite is fairly uniformly distributed. EM magnetite maps can be generated when magnetic permeability is evident as indicated by anomalies in the magnetite channel FEO.

Like magnetometry, the EM magnetite method maps only bedrock features, provided that the overburden is characterized by a general lack of magnetite. This contrasts with resistivity mapping which portrays the combined effect of bedrock and overburden.

Recognition of culture

Cultural responses include all EM anomalies caused by man-made metallic objects. Such anomalies may be caused by inductive coupling or current gathering. The concern of the interpreter is to recognize when an EM response is due to culture. Points of consideration used by the interpreter, when coaxial and coplanar coil-pairs are operated at a common frequency, are as follows:

1. Channels CXS and CPS (see Appendix A) measure 50 and 60 Hz radiation. An anomaly on these channels shows that the conductor is radiating cultural power. Such an indication is normally a guarantee that the conduc-

tor is cultural. However, care must be taken to ensure that the conductor is not a geologic body which strikes across a power line, carrying leakage currents.

2. A flight which crosses a "line" (e.g., fence, telephone line, etc.) yields a center-peaked coaxial anomaly and an m-shaped coplanar anomaly.[5] When the flight crosses the cultural line at a high angle of intersection, the amplitude ratio of coaxial/coplanar (e.g., CXI/CPI) is 4. Such an EM anomaly can only be caused by a line. The geologic body which yields anomalies most closely resembling a line is the vertically dipping thin dike. Such a body, however, yields an amplitude ratio of 2 rather than 4. Consequently, an m-shaped coplanar anomaly with a CXI/CPI amplitude ratio of 4 is virtually a guarantee that the source is a cultural line.

3. A flight which crosses a sphere or horizontal disk yields center-peaked coaxial and coplanar anomalies with a CXI/CPI amplitude ratio (i.e., coaxial/coplanar) of 1/4. In the absence of geologic bodies of this geometry, the most likely conductor is a metal roof or

5 See Figure II-1 presented earlier.

small fenced yard.[6] Anomalies of this type are virtually certain to be cultural if they occur in an area of culture.

4. A flight which crosses a horizontal rectangular body or wide ribbon yields an m-shaped coaxial anomaly and a center-peaked coplanar anomaly. In the absence of geologic bodies of this geometry, the most likely conductor is a large fenced area.[6] Anomalies of this type are virtually certain to be cultural if they occur in an area of culture.

5. EM anomalies which coincide with culture, as seen on the camera film, are usually caused by culture. However, care is taken with such coincidences because a geologic conductor could occur beneath a fence, for example. In this example, the fence would be expected to yield an m-shaped coplanar anomaly as in case #2 above. If, instead, a center-peaked coplanar anomaly occurred, there would be concern that a thick geologic conductor coincided with the cultural line.

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[6] It is a characteristic of EM that geometrically identical anomalies are obtained from: (1) a planar conductor, and (2) a wire which forms a loop having dimensions identical to the perimeter of the equivalent planar conductor.

6. The above description of anomaly shapes is valid when the culture is not conductively coupled to the environment. In this case, the anomalies arise from inductive coupling to the EM transmitter. However, when the environment is quite conductive (e.g., less than 100 ohm-m at 900 Hz), the cultural conductor may be conductively coupled to the environment. In this latter case, the anomaly shapes tend to be governed by current gathering. Current gathering can completely distort the anomaly shapes, thereby complicating the identification of cultural anomalies. In such circumstances, the interpreter can only rely on the radiation channels CXS and CPS, and on the camera film.

TOTAL FIELD MAGNETICS

The existence of a magnetic correlation with an EM anomaly is indicated directly on the EM map. An EM anomaly 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, Canada) as well as magnetic (e.g., the Mattabi deposit near Sturgeon Lake, Canada).

The magnetometer data are digitally recorded in the aircraft to an accuracy of one nT (i.e., one gamma). The digital tape is processed by computer to yield a total field magnetic contour map. When warranted, the magnetic data also may be treated mathematically to enhance the magnetic response of the near-surface geology, and an enhanced magnetic contour map is then produced. The response of the enhancement operator in the frequency domain is illustrated in Figure II-2. This figure shows that the passband components of the airborne data are amplified 20 times by the enhancement operator. This means, for example, that a 100 nT anomaly on the enhanced map reflects a 5 nT anomaly for the passband components of the airborne data.

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

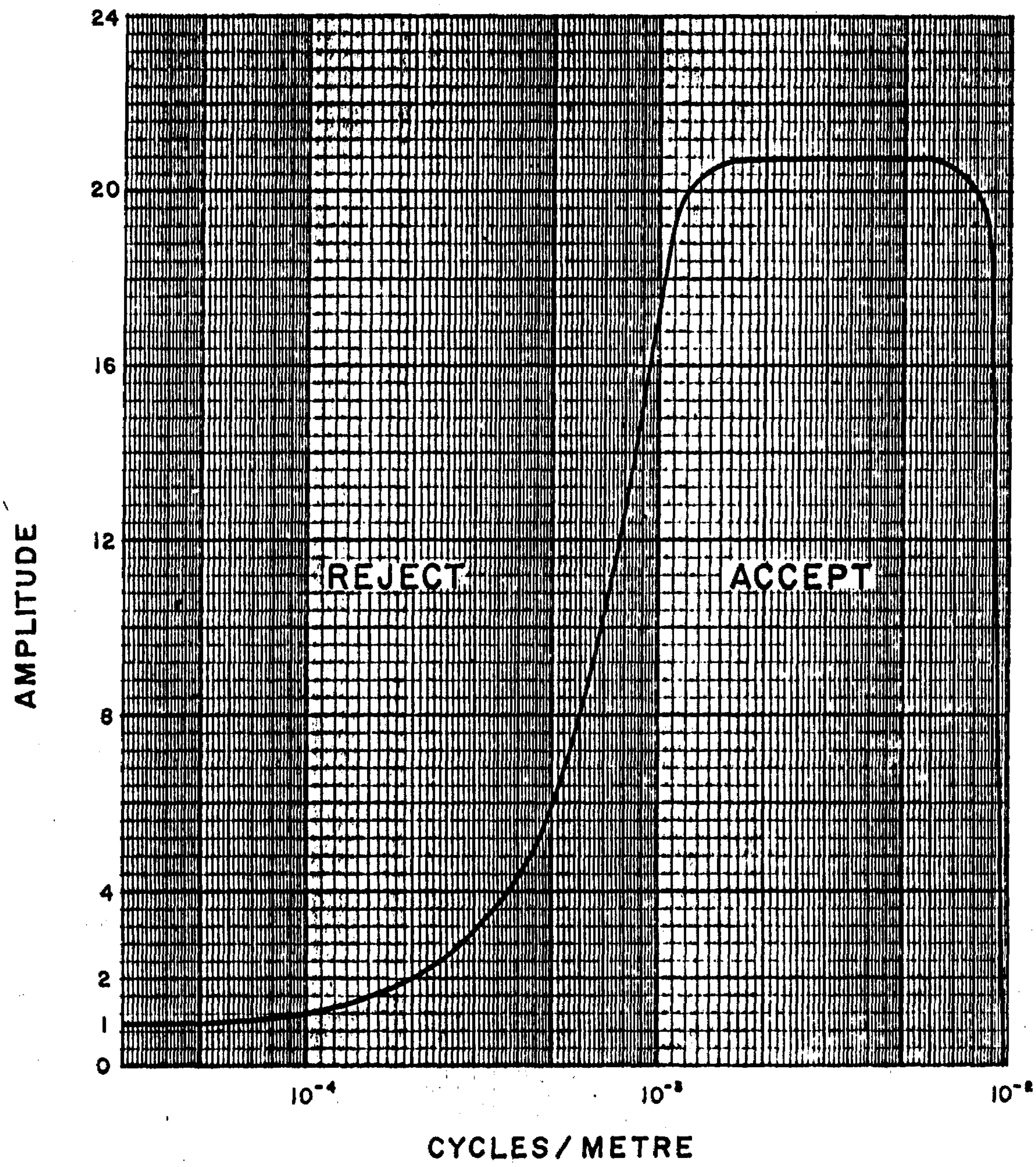

Figure 2 Frequency response of magnetic operator.

geological structure. It defines the near-surface local geology while de-emphasizing deep-seated regional features. It primarily has application when the magnetic rock units are steeply dipping and the earth's field dips in excess of 60 degrees.

VLF-EM

VLF-EM anomalies are not EM anomalies in the conventional sense. EM anomalies primarily reflect eddy currents flowing in conductors which have been energized inductively by the primary field. In contrast, VLF-EM anomalies primarily reflect current gathering, which is a non-inductive phenomenon. The primary field sets up currents which flow weakly in rock and overburden, and these tend to collect in low resistivity zones. Such zones may be due to massive sulfides, shears, river valleys and even unconformities.

The Herz Industries Ltd Totem VLF-electromagnetometer measures the total field and vertical quadrature components. Both these components are digitally recorded in the aircraft with a sensitivity of 0.1 percent. The total field yields peaks over VLF-EM current concentrations

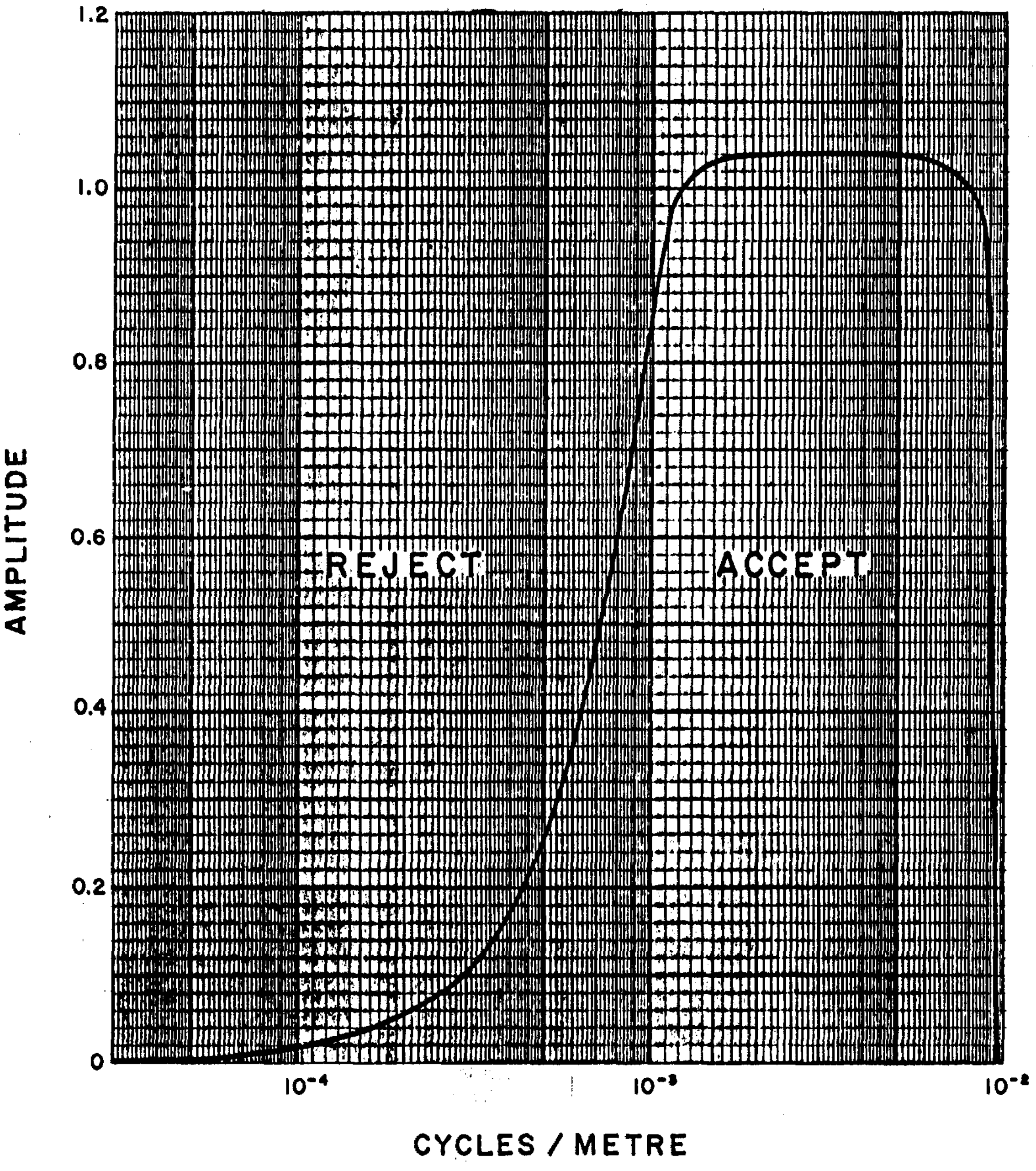

Figure 3 Frequency response of VLF-EM operator.

whereas the quadrature component tends to yield crossovers. Both appear as traces on the profile records. The total field data also are filtered digitally and displayed on a contour map, to facilitate the recognition of trends in the rock strata and the interpretation of geologic structure.

The response of the VLF-EM total field filter operator in the frequency domain (Figure II-3) is basically similar to that used to produce the enhanced magnetic map (Figure II-2). The two filters are identical along the abscissa but different along the ordinant. The VLF-EM filter removes long wavelengths such as those which reflect regional and wave transmission variations. The filter sharpens short wavelength responses such as those which reflect local geological variations. The filtered total field VLF-EM contour map is produced with a contour interval of one percent.

MAPS ACCOMPANYING THIS REPORT

Five map sheets accompany this report:

Electromagnetic Anomalies	1 map sheets
Total Field VLF Contours	1 map sheets
Resistivity	1 map sheets
Total Field Magnetics	1 map sheets
Enhanced Magnetics	1 map sheets

Respectfully submitted,
DIGHEM SURVEYS & PROCESSING INC.

S.J. Kilty
Chief Geophysicist

AD-SK-458

A P P E N D I X A

THE FLIGHT RECORDS

Both analog and digital flight records were produced. The analog profiles were recorded on chart paper in the aircraft during the survey. The digital profiles were generated later by computer and plotted on electrostatic chart paper at a scale of 1:15,000. The analog and digital profiles are listed in Tables A-1 and A-2 respectively.

In Table A-2, the log resistivity scale of 0.06 decade/mm means that the resistivity changes by an order of magnitude in 16.5 mm. The resistivities at 0, 33 and 67 mm up from the bottom of the digital flight record are respectively 1, 100 and 10,000 ohm-m.

NAVIGATION EQUIPMENT

Aircraft positioning and post-survey recovery of aircraft position was accomplished through the use of a Del Norte Flying Flagman positioning system. This electronic navigation system operates in the 8 gHz band and is therefore range limited by hills and by the curvature of the earth.

Table A-1. The Analog Profiles

Channel Number	Parameter	Sensitivity per mm	Designation on computer profile
01	coaxial inphase (900 Hz)	2.5 ppm	CXI (900 Hz)
02	coaxial quad (900 Hz)	2.5 ppm	CXQ (900 Hz)
03	coplanar inphase (900 Hz)	2.5 ppm	CPI (900 Hz)
04	coplanar quad (900 Hz)	2.5 ppm	CPQ (900 Hz)
05	coplanar inphase (7200 Hz)	5.0 ppm	CPI (7200 Hz)
06	coplanar quad (7200 Hz)	5.0 ppm	CPQ (7200 Hz)
09	altimeter	3 m	ALT
00,10	magnetics, coarse	10 nT	MAG
11	magnetics, fine	2 nT	
12	VLF-total: Annapolis	2%	
13	VLF-quad: Annapolis	2%	
14	VLF-total: Cutler	2%	
15	VLF-quad: Cutler	2%	

Table A-2. The Digital Profiles

Channel Name (Freq)	Observed parameters	Scale units/mm
MAG	magnetics	20 nT
ALT	bird height	6 m
CXI (900 Hz)	vertical coaxial coil-pair inphase	2 ppm
CXQ (900 Hz)	vertical coaxial coil-pair quadrature	2 ppm
CPI (900 Hz)	horizontal coplanar coil-pair inphase	2 ppm
CPQ (900 Hz)	horizontal coplanar coil-pair quadrature	2 ppm
CPI (7200 Hz)	horizontal coplanar coil-pair inphase	2 ppm
CPQ (7200 Hz)	horizontal coplanar coil-pair quadrature	2 ppm
	Computed Parameters	
DIFI (900 Hz)	difference function inphase from CXI and CPI	2 ppm
DIFQ (900 Hz)	difference function quadrature from CXQ and CPQ	2 ppm
SIGT	conductance	1 grade
RES (900 Hz)	log resistivity	.06 decade
RES (7200 Hz)	log resistivity	.06 decade
DP (900 Hz)	apparent depth	6 m
DP (7200 Hz)	apparent depth	6 m

AD-SK-458

The Flying Flagman uses two ground based transponder stations continuously interrogated by the helicopter mounted unit and which transmit distance information back to the helicopter. The onboard Central Processing Unit then takes the two distances and determines the helicopter position relative to the two ground stations. This is accomplished once every second. The ground stations were set up well away from the survey area and were positioned such that the signals crossed the survey blocks at an angle between 30° and 150°. After site selection, the aircraft then flew a baseline at right angles to a line drawn through the transmitter sites. The minimum distance recorded when flying this baseline established the arbitrary coordinate system used to fly the survey area. The final step was to establish the location of the first flight line on the map or photomosaic. This line was then flown while pressing a "start of line" and "end of line" switch, thereby establishing both survey boundaries and line direction. The distance from each ground transmitter site (range-range) was continuously recorded digitally.

The range-range data was transposed during data processing into an arbitrary x-y coordinate system based on the location of the two transmitter sites. This x-y grid data was then transferred to the base map by correlating a number of prominent topographical features to the navigational data points. The use of numerous visual tie-in points served two purposes: to correct for distortions in the photomosaic (if any) and to accurately relate the navigational data to the map sheet.

A P P E N D I X   B

EM ANOMALY LIST

	COAXIAL 900 HZ		COPLANAR 900 HZ		COPLANAR 7200 HZ		VERTICAL DIKE		HORIZONTAL SHEET		CONDUCTIVE EARTH	
ANOMALY/ FID/INTERP	REAL PPM	QUAD PPM	REAL PPM	QUAD PPM	REAL PPM	QUAD PPM	COND MHOS	DEPTH* M	COND MHOS	DEPTH M	RESIS OHM-M	DEPTH M
LINE 10110	(FLIGHT		5)									
A 1037 S	-1	2	0	1	-1	7	1	0	1	98	8280	0
LINE 10140	(FLIGHT		5)									
A 2285 S?	-1	4	0	9	19	68	1	0	1	54	814	0
LINE 10150	(FLIGHT		5)									
A 696 B?	0	3	0	7	14	59	1	0	1	75	913	0
LINE 10181	(FLIGHT		5)									
A 2822 B?	0	3	1	6	17	25	1	0	1	98	838	2
B 2809 B?	3	4	7	3	14	3	1	0	1	85	56	65
LINE 10190	(FLIGHT		4)									
A 3514 S	1	5	1	5	10	43	1	0	1	98	983	0
LINE 10200	(FLIGHT		5)									
A 3019 B	3	2	4	4	14	9	1	0	1	93	97	69
B 3046 S	1	5	0	8	24	16	1	0	1	64	882	0
D 3049 S	1	3	0	8	26	5	1	0	1	71	895	0
LINE 10211	(FLIGHT		4)									
A 3426 D	5	7	13	10	32	12	8	18	3	101	21	73
B 3428 D	4	7	12	9	9	12	7	20	2	93	28	64
D 3461 S?	2	4	1	9	30	70	2	0	1	43	664	0
LINE 10220	(FLIGHT		5)									
A 3159 D	3	4	6	7	20	8	5	26	2	129	61	88
B 3150 D	4	4	10	7	24	10	9	23	3	133	19	103
C 3113 S?	0	3	0	6	25	36	1	0	1	58	846	0
LINE 10230	(FLIGHT		4)									
A 3173 B	3	1	1	3	7	8	1	0	1	103	412	67
B 3123 S?	0	3	0	4	14	20	1	0	1	26	367	1
C 3121 S?	1	4	0	6	20	4	1	0	1	79	954	0
LINE 10240	(FLIGHT		5)									
A 3408 S?	0	3	0	6	16	48	1	0	1	85	985	0
B 3415 S?	0	3	0	6	20	44	1	0	1	79	960	0
LINE 10250	(FLIGHT		4)									
A 2994 S?	-1	3	-2	7	17	59	1	0	1	70	895	0

* 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.

ANOMALY/ FID/INTERP	COAXIAL 900 HZ REAL PPM	COAXIAL 900 HZ QUAD PPM	COPLANAR 900 HZ REAL PPM	COPLANAR 900 HZ QUAD PPM	COPLANAR 7200 HZ REAL PPM	COPLANAR 7200 HZ QUAD PPM	VERTICAL DIKE COND MHOS	VERTICAL DIKE DEPTH* M	HORIZONTAL SHEET COND MHOS	HORIZONTAL SHEET DEPTH M	CONDUCTIVE EARTH RESIS OHM-M	CONDUCTIVE EARTH DEPTH M
LINE 10250	(FLIGHT		4)									
B 3000 S	1	3	-2	6	16	2	1	0	1	63	867	0
LINE 10260	(FLIGHT		5)									
A 3471 S?	1	1	0	4	12	9	1	0	1	24	567	0
LINE 10270	(FLIGHT		4)									
A 2727 S	-1	3	-2	7	18	6	1	0	1	76	903	0
LINE 10280	(FLIGHT		7)									
A 2107 S	0	6	0	6	16	46	1	0	1	90	1014	0
LINE 10290	(FLIGHT		4)									
A 2555 L	54	5	176	14	191	1	616	0	71	47	1	45
B 2649 B?	-1	3	0	3	6	5	1	0	1	140	262	104
LINE 10300	(FLIGHT		7)									
A 1909 L	12	4	34	12	42	10	45	9	24	92	1	87
LINE 10310	(FLIGHT		4)									
A 2367 L	3	6	1	1	9	53	3	17	1	179	1021	25
B 2348 L	11	6	37	10	44	10	40	12	12	95	1	84
C 2236 S	-1	4	-1	6	15	44	1	0	1	101	992	2
D 2223 B	11	5	64	19	85	7	55	15	10	81	2	69
LINE 10320	(FLIGHT		7)									
B 1640 B	2	4	11	5	21	10	9	20	4	109	13	83
LINE 10330	(FLIGHT		4)									
A 2056 S	3	9	2	28	76	41	1	0	1	9	442	0
B 2189 B	3	6	7	2	14	25	1	0	1	62	207	35
C 2194 B	2	3	5	4	14	4	1	0	1	100	25	86
LINE 10350	(FLIGHT		4)									
A 2006 S	2	7	3	23	35	142	1	0	1	9	481	0
B 1902 S	0	3	-2	6	11	46	1	4	1	89	966	0
C 1871 S	0	5	-1	9	19	68	2	8	1	61	840	0
LINE 10360	(FLIGHT		7)									
A 1409 S	1	8	3	18	37	12	1	0	1	17	397	0
B 1301 S	0	3	1	6	13	24	1	0	1	80	845	0
C 1276 S	1	5	0	7	20	65	1	0	1	56	837	0

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ANOMALY/ FID/INTERP	COAXIAL 900 HZ REAL PPM	COAXIAL 900 HZ QUAD PPM	COPLANAR 900 HZ REAL PPM	COPLANAR 900 HZ QUAD PPM	COPLANAR 7200 HZ REAL PPM	COPLANAR 7200 HZ QUAD PPM	VERTICAL DIKE COND MHOS	VERTICAL DIKE DEPTH* M	HORIZONTAL SHEET COND MHOS	HORIZONTAL SHEET DEPTH M	CONDUCTIVE EARTH RESIS OHM-M	CONDUCTIVE EARTH DEPTH M
LINE 10370	(FLIGHT	4)										
A 1684 S	2	11	2	19	75	90	1	0	1	10	553	0
C 1691 S	1	3	2	6	9	10	2	18	1	16	305	0
E 1698 S	3	8	1	27	99	5	1	0	1	13	561	0
F 1764 S	-2	3	-1	9	26	64	1	0	1	62	871	0
LINE 10380	(FLIGHT	7)										
B 1099 S	5	8	5	6	124	38	4	22	1	19	250	0
D 1191 S	0	5	0	9	23	69	1	0	1	59	850	0
LINE 10390	(FLIGHT	4)										
B 1654 S	1	4	3	3	25	19	1	0	1	19	74	5
D 1641 S	0	3	-1	5	18	25	1	0	1	27	683	0
E 1571 S	-2	4	-1	6	8	51	1	0	1	95	999	0
LINE 10400	(FLIGHT	7)										
A 1073 S	4	8	5	26	114	164	2	0	1	21	243	0
B 1066 S	3	11	3	22	80	152	1	0	1	15	368	0
C 1056 S?	-1	6	0	15	39	123	1	0	1	32	721	0
LINE 10410	(FLIGHT	4)										
B 1469 S	3	5	4	14	3	74	3	11	1	16	288	0
E 1480 B?	-2	8	-1	13	29	101	1	0	1	39	749	0
LINE 10420	(FLIGHT	7)										
B 834 S	5	3	5	35	125	171	3	4	1	15	284	0
C 839 S	4	8	4	20	39	29	3	6	1	17	251	0
D 851 B?	1	6	-1	5	8	42	1	0	1	95	1035	0
LINE 10431	(FLIGHT	4)										
A 1375 S	4	11	4	26	94	123	2	0	1	13	337	0
LINE 10441	(FLIGHT	7)										
A 806 S	4	11	3	30	117	143	2	0	1	10	391	0
B 798 S	5	13	2	5	105	163	3	6	1	8	450	0
LINE 10450	(FLIGHT	4)										
A 1118 S	4	6	3	22	95	51	2	0	1	7	526	0
B 1122 S	1	5	2	10	18	52	1	3	1	11	379	0
C 1134 B?	0	2	-2	2	3	18	1	0	1	185	1035	0
LINE 10462	(FLIGHT	7)										
A 518 S	4	12	3	24	74	14	2	0	1	17	304	0

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ANOMALY/ FID/INTERP	COAXIAL 900 HZ REAL PPM	COAXIAL 900 HZ QUAD PPM	COPLANAR 900 HZ REAL PPM	COPLANAR 900 HZ QUAD PPM	COPLANAR 7200 HZ REAL PPM	COPLANAR 7200 HZ QUAD PPM	VERTICAL DIKE COND MHOS	VERTICAL DIKE DEPTH* M	HORIZONTAL SHEET COND MHOS	HORIZONTAL SHEET DEPTH M	CONDUCTIVE EARTH RESIS OHM-M	CONDUCTIVE EARTH DEPTH M
LINE 10462	(FLIGHT	7)										
B 521 S	4	13	1	24	87	138	1	0	1	10	516	0
LINE 10470	(FLIGHT	4)										
A 1102 S	4	8	1	21	85	111	2	0	1	10	567	0
B 1095 S	4	9	0	2	4	131	2	9	1	11	571	0
LINE 10480	(FLIGHT	6)										
A 3426 S	3	5	4	15	4	4	3	7	1	19	267	0
B 3419 S	6	12	2	3	121	161	1	0	1	20	75	5
LINE 10490	(FLIGHT	4)										
A 854 S	5	4	3	4	5	78	7	31	1	10	365	0
B 859 S	3	10	3	10	10	22	2	0	1	9	399	0
LINE 10500	(FLIGHT	6)										
A 3225 S	5	15	6	3	145	156	3	13	1	21	204	0
C 3233 S	5	4	6	36	136	149	3	0	1	19	279	0
LINE 10510	(FLIGHT	4)										
A 830 S	2	6	3	14	17	12	2	0	1	13	365	0
B 823 S	6	4	4	10	38	113	7	23	1	14	328	0
D 719 B	11	5	11	6	23	8	23	15	3	110	17	82
LINE 10520	(FLIGHT	6)										
B 3132 S	3	4	8	26	131	22	3	6	1	27	159	0
C 3125 S	6	3	5	29	109	127	4	8	1	24	200	0
LINE 10530	(FLIGHT	4)										
A 461 S	5	14	4	37	131	37	2	0	1	11	315	0
B 470 S	4	9	4	22	97	127	2	0	1	9	421	0
E 573 D	13	6	21	12	41	12	24	15	2	114	29	82
F 577 B	0	3	0	10	19	64	1	0	1	53	822	0
LINE 10542	(FLIGHT	7)										
A 259 S	4	1	5	40	134	188	2	0	1	10	344	0
B 266 S	3	4	6	25	3	1	3	6	1	20	219	0
C 380 B	4	6	7	9	31	22	5	16	1	89	85	48
D 387 B?	0	5	-1	7	13	56	1	0	1	64	863	0
LINE 10550	(FLIGHT	4)										
A 427 S	5	3	2	7	24	115	6	28	1	9	419	0

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ANOMALY/ FID/INTERP	COAXIAL 900 HZ REAL PPM	COAXIAL 900 HZ QUAD PPM	COPLANAR 900 HZ REAL PPM	COPLANAR 900 HZ QUAD PPM	COPLANAR 7200 HZ REAL PPM	COPLANAR 7200 HZ QUAD PPM	VERTICAL DIKE COND MHOS	VERTICAL DIKE DEPTH* M	HORIZONTAL SHEET COND MHOS	HORIZONTAL SHEET DEPTH M	CONDUCTIVE EARTH RESIS OHM-M	CONDUCTIVE EARTH DEPTH M
LINE 10550	(FLIGHT		4)									
C 327 S	1	1	0	5	14	36	1	0	1	29	509	1
LINE 10560	(FLIGHT		6)									
A 2563 S	2	5	3	11	41	69	2	15	1	24	159	0
D 2664 B?	1	4	2	3	9	4	1	0	1	72	517	37
E 2676 S	1	6	1	12	42	84	1	0	1	38	707	0
LINE 10571	(FLIGHT		4)									
A 87 S	2	4	3	2	12	11	1	0	1	22	69	7
D 197 S	2	7	-1	10	37	110	1	0	1	35	718	0
LINE 10580	(FLIGHT		6)									
A 2529 S	3	8	4	15	19	28	2	6	1	22	190	0
C 2422 S?	1	8	1	16	55	106	1	0	1	25	623	0
LINE 10590	(FLIGHT		3)									
A 655 S	4	2	4	6	26	11	7	39	1	22	226	0
C 547 S?	1	9	1	14	42	89	1	0	1	31	563	0
LINE 10600	(FLIGHT		6)									
B 2129 S	3	7	2	26	106	154	2	0	1	14	423	0
C 2230 S	1	6	0	13	51	79	1	0	1	29	706	0
D 2246 D	4	3	6	9	27	24	7	27	1	91	98	49
LINE 10610	(FLIGHT		3)									
A 388 S	0	5	1	9	26	53	1	0	1	55	585	0
B 406 B	4	5	10	13	39	25	6	14	2	85	33	54
LINE 10620	(FLIGHT		6)									
A 2012 S	2	2	1	5	16	31	1	0	1	39	345	11
B 1994 B	5	4	8	8	25	14	10	22	2	104	50	68
LINE 10630	(FLIGHT		3)									
A 160 S	1	2	0	4	8	30	1	0	1	33	660	3
LINE 10640	(FLIGHT		6)									
A 1937 S	1	3	-1	6	17	42	1	0	1	75	954	0
LINE 10662	(FLIGHT		6)									
A 1829 S	2	1	1	3	9	17	1	0	1	42	520	10
LINE 10680	(FLIGHT		6)									
A 1058 S	2	1	-1	4	19	19	1	0	1	38	324	12

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ANOMALY/ FID/INTERP	COAXIAL 900 HZ REAL PPM	COAXIAL 900 HZ QUAD PPM	COPLANAR 900 HZ REAL PPM	COPLANAR 900 HZ QUAD PPM	COPLANAR 7200 HZ REAL PPM	COPLANAR 7200 HZ QUAD PPM	VERTICAL DIKE COND MHOS	VERTICAL DIKE DEPTH* M	HORIZONTAL SHEET COND MHOS	HORIZONTAL SHEET DEPTH M	CONDUCTIVE EARTH RESIS OHM-M	CONDUCTIVE EARTH DEPTH M
LINE 10690	(FLIGHT	1)										
A 1305 S	1	3	0	6	25	1	1	3	1	81	960	0
C 1307 S	1	3	0	5	23	24	1	3	1	75	917	0
D 1318 B	1	2	2	4	11	12	1	0	1	71	300	40
LINE 10701	(FLIGHT	6)										
A 957 S	2	2	0	8	31	12	2	19	1	50	794	0
B 946 B	4	2	7	4	14	8	14	34	2	121	48	83
LINE 10711	(FLIGHT	1)										
A 1204 S	0	8	0	13	49	75	1	0	1	27	721	0
B 1195 B	5	4	9	5	14	3	13	27	2	135	28	101
D 1187 B	3	2	3	3	10	6	1	0	1	99	183	69
LINE 10721	(FLIGHT	6)										
A 745 S	1	9	1	14	58	92	1	0	1	26	613	0
B 765 B	2	2	10	5	19	6	13	37	4	129	13	103
LINE 10730	(FLIGHT	1)										
B 881 S	-1	5	1	8	33	18	1	0	1	39	647	0
LINE 10740	(FLIGHT	6)										
A 603 S	1	3	2	6	27	54	1	15	1	63	556	1
LINE 10750	(FLIGHT	1)										
B 781 S	-2	3	-4	3	8	26	1	0	1	10	884	0
C 804 S	1	3	0	8	29	10	1	0	1	56	843	0
LINE 10760	(FLIGHT	6)										
A 498 S	-2	3	-1	4	10	32	1	0	1	16	787	0
B 518 S	1	5	1	9	36	56	1	0	1	54	771	0
LINE 10770	(FLIGHT	1)										
A 735 S	0	4	-1	4	8	30	1	0	1	10	1013	0
B 719 S	1	7	0	2	45	85	1	0	1	15	234	0
LINE 10780	(FLIGHT	6)										
A 458 B?	-2	3	0	5	10	34	1	0	1	17	857	0
B 443 S	0	6	1	13	48	95	1	0	1	34	683	0
LINE 10790	(FLIGHT	1)										
A 626 S	1	6	0	15	52	96	1	0	1	26	685	0

* 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.

ANOMALY/ FID/INTERP	COAXIAL 900 HZ REAL PPM	QUAD PPM	COPLANAR 900 HZ REAL PPM	QUAD PPM	COPLANAR 7200 HZ REAL PPM	QUAD PPM	VERTICAL DIKE COND MHOS	DEPTH* M	HORIZONTAL SHEET COND MHOS	DEPTH M	CONDUCTIVE EARTH RESIS OHM-M	DEPTH M
LINE 10801 (FLIGHT 6)												
A 318 S	1	1	0	5	11	12	1	24	1	78	903	0
LINE 10810 (FLIGHT 1)												
A 481 S	2	2	1	1	17	22	1	0	1	41	333	14

* 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.

Ministry of Northern Development and Mines
Ontario

Report of Work
(Geophysical, Geological, Geochemical and Expenditures)

W.R. Mini

42C02SE0504 2.9674 MCMURRAY

900

Type of Survey(s): AIRBORNE GEOPHYSICAL	Township or Area: McMurray Twp., Wawa, Ontario
Claim Holder(s): Citadel Gold Mines Inc.	Prospector's Licence No.: T-4687
Address: 67 Yonge Street, Suite 1202, Toronto, Ontario, M5E 1J8	
Survey Company: Dighem Survey & Processing Inc.	Date of Survey (from & to): 20 10 86 (Day Mo. Yr.) – 28 10 86 (Day Mo. Yr.); Total Miles of line Cut: Ø
Name and Address of Author (of Geo-Technical report): Dighem Survey & Processing Inc., 228 Matheson Blvd., East, Mississauga, Ontario, L4Z 1X1	

Credits Requested per Each Claim in Columns at right

Special Provisions	Geophysical	Days per Claim
For first survey: Enter 40 days. (This includes line cutting)	- Electromagnetic	
	- Magnetometer	
For each additional survey: using the same grid: Enter 20 days (for each)	- Radiometric	
	- Other	
	Geological	
	Geochemical	

Man Days	Geophysical	Days per Claim
Complete reverse side and enter total(s) here	- Electromagnetic	
	- Magnetometer	
	- Radiometric	
	- Other	
	Geological	
	Geochemical	

Airborne Credits		Days per Claim
Note: Special provisions credits do not apply to Airborne Surveys.	Electromagnetic	40
	Magnetometer	40
	Radiometric	

RECEIVED
JUL 10 1987
MINING LANDS SECTION

Mining Claims Traversed (List in numerical sequence)

Prefix	Number	Expend. Days Cr.
SSM	885083	80
	885084	80
	885180	80
	885182	80
	885183	80
	885184	80
	885185	80
	885186	80
	885187	80
	885188	80
	885181	80

117/87

SAULT STE. MARIE MINING DIV.
RECEIVED
JUL 2 - 1987
A.M. P.M.
7,8,9,10,11,12,1,2,3,4,5,6

Expenditures (excludes power stripping)

Type of Work Performed: Airborne Geophysics

Performed on Claim(s):

Calculation of Expenditure Days Credits

Total Expenditures: $ ÷ 15 = Total Days Credits:

Instructions: Total Days Credits may be apportioned at the claim holder's choice. Enter number of days credits per claim selected in columns at right.

Total number of mining claims covered by this report of work: 11

For Office Use Only		
Total Days Cr. Recorded: 880	Date Recorded: July 2/87	Mining Recorder: [signature]
	Date Approved as Recorded: 1987.08.28	Branch Director: [signature]

Date	Recorded Holder or Agent (Signature)
June 29, 1987	Paul Sukman

Certification Verifying Report of Work

I hereby certify that I have a personal and intimate knowledge of the facts set forth in the Report of Work annexed hereto, having performed the work or witnessed same during and/or after its completion and the annexed report is true.

Name and Postal Address of Person Certifying: Citadel Gold Mines Inc., Paul A. Sukman - Landsman

Date Certified	Certified by (Signature)
June 29/1987	Paul A. Sukman

Ministry of Natural Resources
Ontario

Report of Work
(Geophysical, Geological, Geochemical and Expenditures)

2.9674
#172-86.

The Mining Act

Instructions: – Please type or print.
– If number of mining claims traversed exceeds space on this form, attach a list.
Note: – Only days credits calculated in the "Expenditures" section may be entered in the "Expend. Days Cr." columns.
– Do not use shaded areas below. R.P.

Type of Survey(s)	Township or Area
AIRBORNE GEOPHYSICAL	McMurray Twp., Wawa, Ontario

Claim Holder(s)	Prospector's Licence No.
Citadel Gold Mines Inc.	T-4687

Address: 67 Yonge Street, Suite 1202, Toronto, Ontario, M5E 1J8

Survey Company	Date of Survey (from & to)	Total Miles of line Cut
Dighem Surveys & Processing Inc.	20 / 10 / 86 (Day / Mo. / Yr.) – 28 / 10 / 86 (Day / Mo. / Yr.)	Ø

Name and Address of Author (of Geo-Technical report): Dighem Surveys & Processing Inc., 228 Matheson Blvd.,East, Mississauga, Ontario, L4Z 1X1

Credits Requested per Each Claim in Columns at right

Special Provisions		Days per Claim
For first survey: Enter 40 days. (This includes line cutting)	Geophysical – Electromagnetic	
	– Magnetometer	
For each additional survey: using the same grid: Enter 20 days (for each)	– Radiometric	
	– Other	
	Geological	
	Geochemical	
Man Days		**Days per Claim**
Complete reverse side and enter total(s) here	Geophysical – Electromagnetic	
	– Magnetometer	
	– Radiometric	
	– Other	
	Geological	
	Geochemical	
Airborne Credits		**Days per Claim**
Note: Special provisions credits do not apply to Airborne Surveys.	Electromagnetic	40
	Magnetometer	40
	Radiometric	

RECEIVED
MINING LANDS SECTION

SAULT STE. MARIE MINING DIV.
RECEIVED
DEC 24 1986
A.M. 7|8|9|10|11|12|1|2|3|4|5|6 P.M.

Mining Claims Traversed (List in numerical sequence)

Prefix	Number	Expend. Days Cr.	Prefix	Number	Expend. Days Cr.
SSM	469255	80	SSM	847748	80
	256	80		749	80
	257	80		750	80
	258	80		751	80
	259	80		752	80
	260	80		753	80
	261	80		754	80
	262	80		X 755	80
	X263	80		885189	80
	841062	80		885195	80
	063	80		196	80
	064	80		197	80
	065	80		198	80
	066	80		199	80
	x067	80		x200	80
	841565	80		924401	80
	847741	80		402	80
	742	80		924405	80
	743	80		406	80
	744	80		407	80
	745	80		408	80
	746	80		409	80
	747	80		410	80

See attached list

Total number of mining claims covered by this report of work: 49

Expenditures (excludes power stripping)

Type of Work Performed: Airborne Geophysics

Performed on Claim(s):

Calculation of Expenditure Days Credits

Total Expenditures: $36,900.00 ÷ 15 = Total Days Credits: 2460

Instructions: Total Days Credits may be apportioned at the claim holder's choice. Enter number of days credits per claim selected in columns at right.

For Office Use Only		
Total Days Cr. Recorded	Date Recorded	Mining Recorder
3380	Dec. 24/86	ACTING [signature]
	Date Approved as Recorded: 87.3.4	Branch Director: [signature]

Date	Recorded Holder or Agent (Signature)
Dec. 23/86	[signature]

Certification Verifying Report of Work

I hereby certify that I have a personal and intimate knowledge of the facts set forth in the Report of Work annexed hereto, having performed the work or witnessed same during and/or after its completion and the annexed report is true.

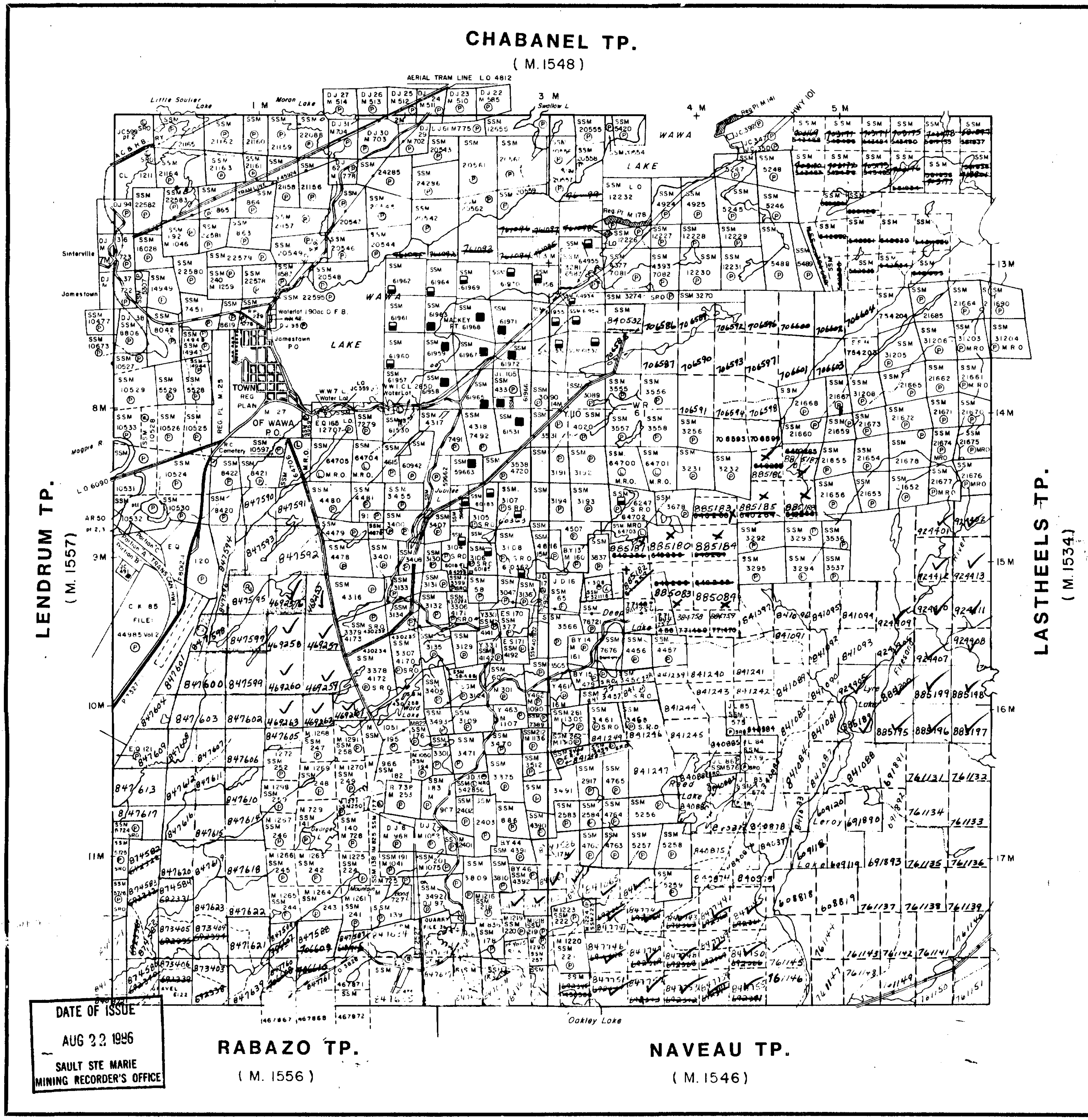
Name and Postal Address of Person Certifying: CITADEL GOLD MINES INC. , Neil O. Willoughby, Project Geologist

Date Certified	Certified by (Signature)
Dec. 23/86	[signature]

2.9674

CITADEL GOLD MINES INC.

Mining Claim	Expend. Days Cr.
SSM 924411	80
SSM 924412	80
SSM 924413	80



TOWNSHIP OF

McMURRAY

(T.P. 29 R. 23)

DISTRICT OF ALGOMA

SAULT STE. MARIE MINING DIVISION

SCALE: 1-INCH = 40 CHAINS

LEGEND

PATENTED LAND	● or Ⓟ
CROWN LAND SALE	C.S.
LEASES	■ Ⓛ
LOCATED LAND	Loc.
LICENSE OF OCCUPATION	L.O.
MINING RIGHTS ONLY	M.R.O.
SURFACE RIGHTS ONLY	S.R.O.
ROADS	
IMPROVED ROADS	
KING'S HIGHWAYS	
RAILWAYS	
POWER LINES	
MARSH OR MUSKEG	
MINES	
CANCELLED	C.
PATENTED for S.R.O.	
LEASED FOR M.R.O.	

NOTES

400' SURFACE RIGHTS RESERVATION AROUND ALL LAKES AND RIVERS.

THIS TOWNSHIP UNDER SUBDIVISION CONTROL OF THE MUNICIPALITY OF THE TOWNSHIP OF MICHIPICOTEN. Refer to Twp. By-Law 18-59 File:16756

MINING CLAIMS SSM 10524, 25, 26, 27, SSM 10528, 29, 30, 31, SSM 10532 & 33 ARE PATENTED SURFACE RIGHTS ONLY WITHDRAWN FROM STAKING

L.O 3826 COVERS TELEPHONE LINE FROM WAWA STA FOLLOWING THE MINES ROAD

AREAS WITHDRAWN FROM DISPOSITION

S.R. – SURFACE RIGHTS M.R. – MINING RIGHTS

Description	Order No.	Date	Disposition
	W 1/80	7/2/80	
	W 7/84		

QUARRY PERMIT

PLAN NO. M 1547

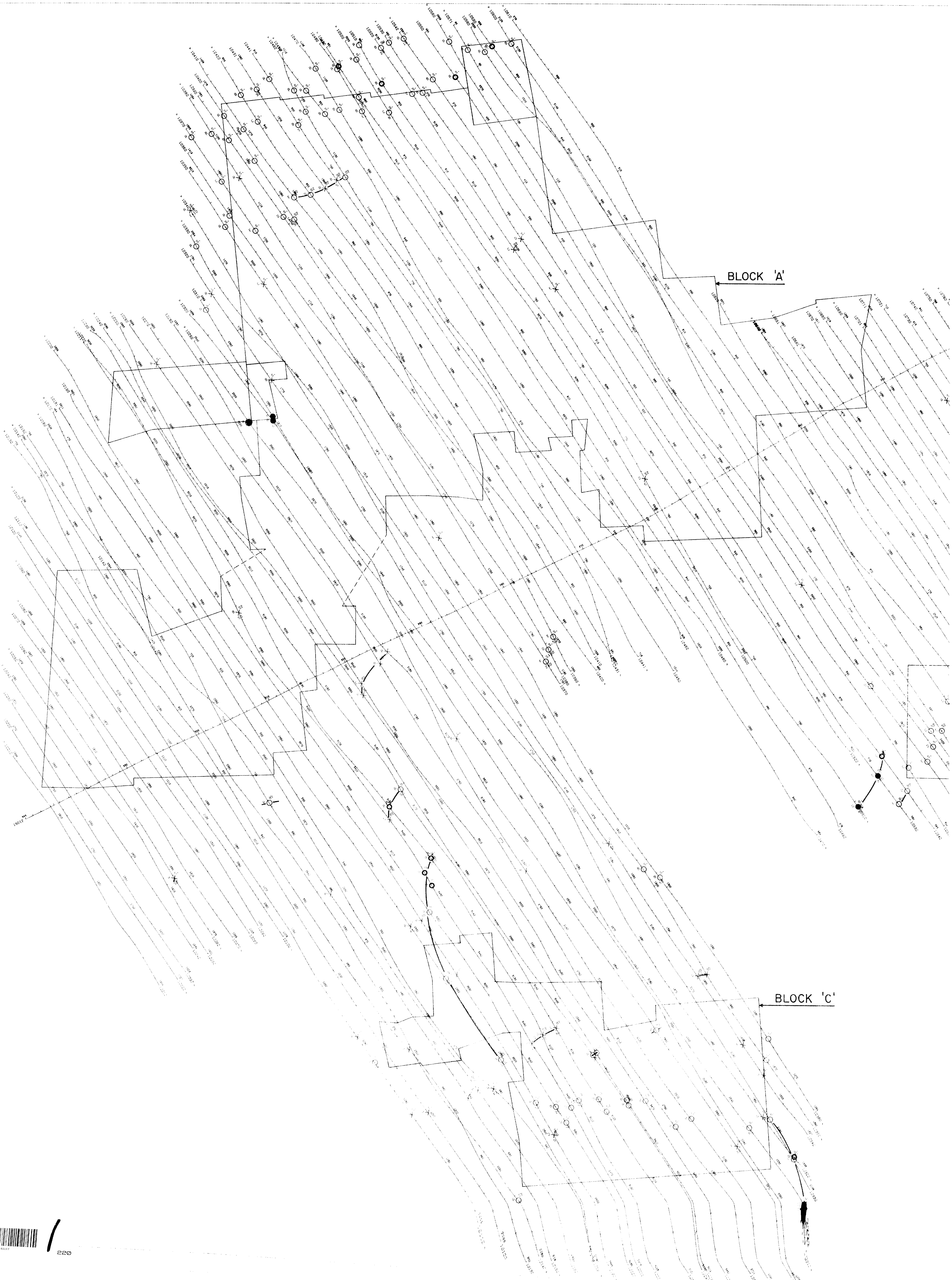
Ministry of Natural Resources

Ontario

200

42C02SE0504 2.9674 MCMURRAY

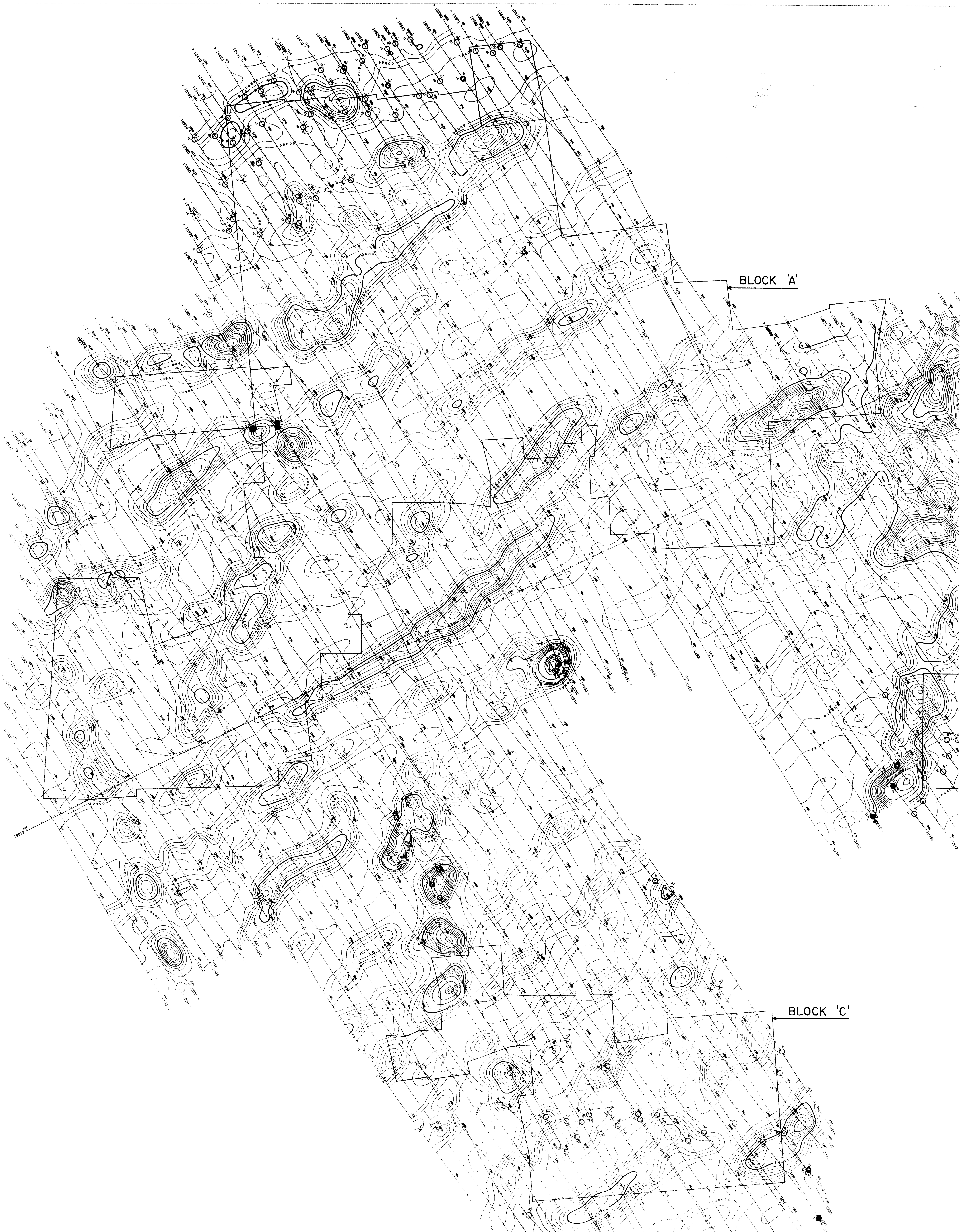
210

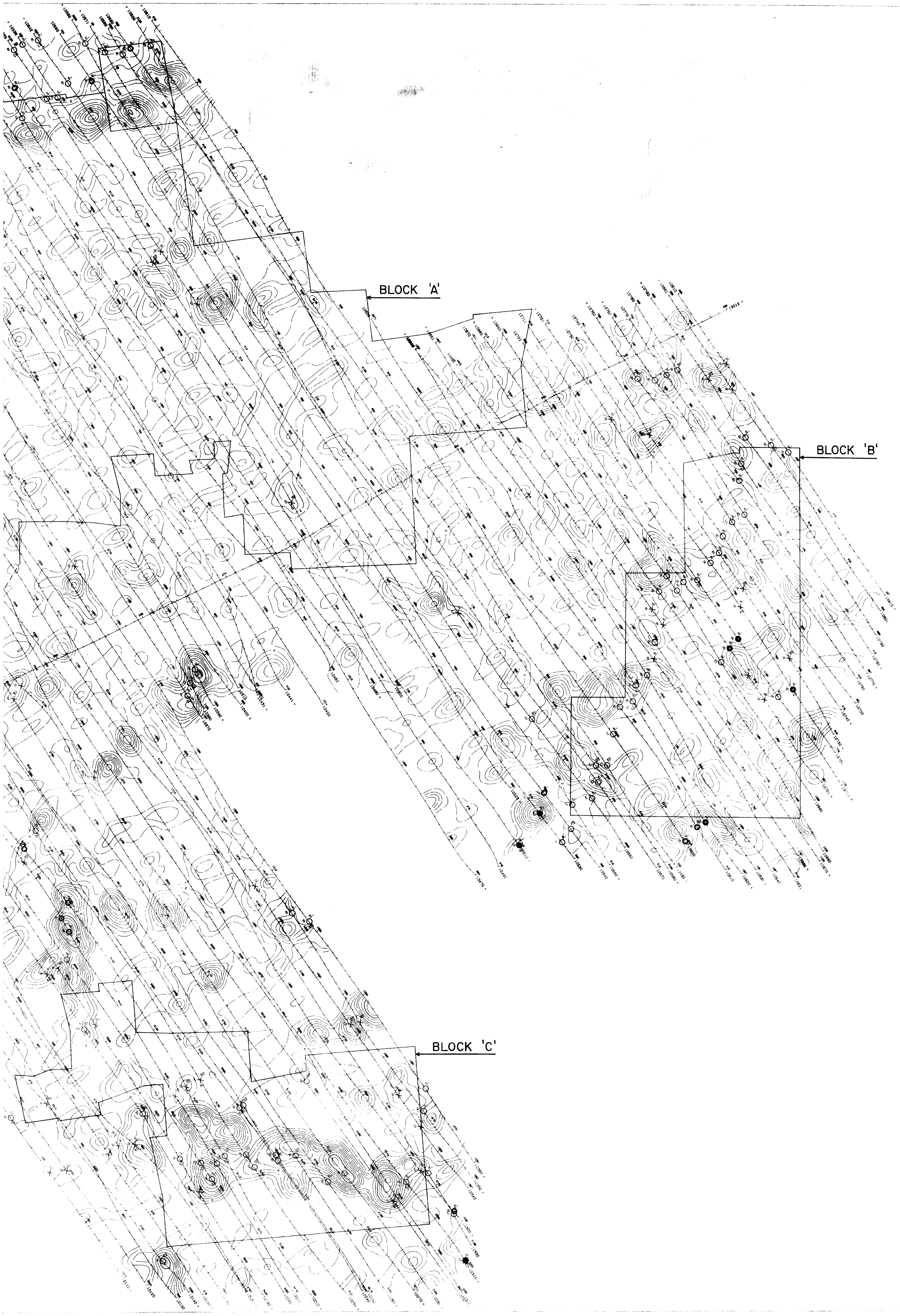


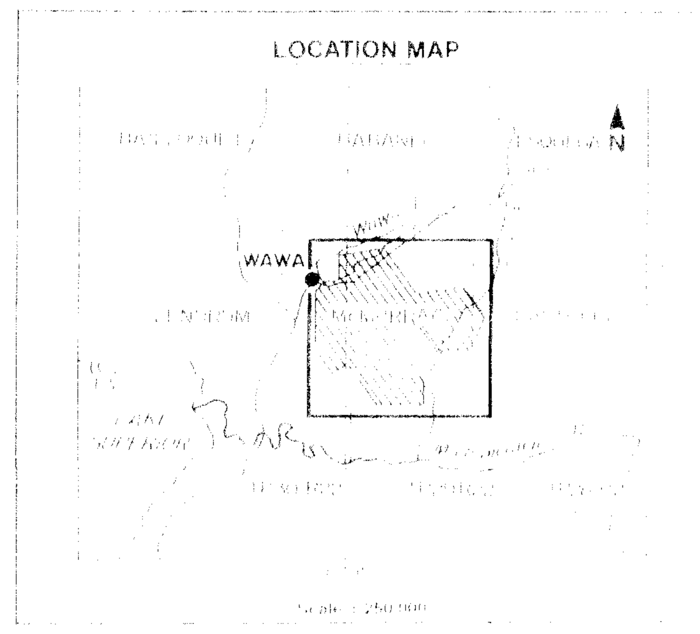
220

230


BLOCK 'A'
BLOCK 'C'


BLOCK 'A'
BLOCK 'C'



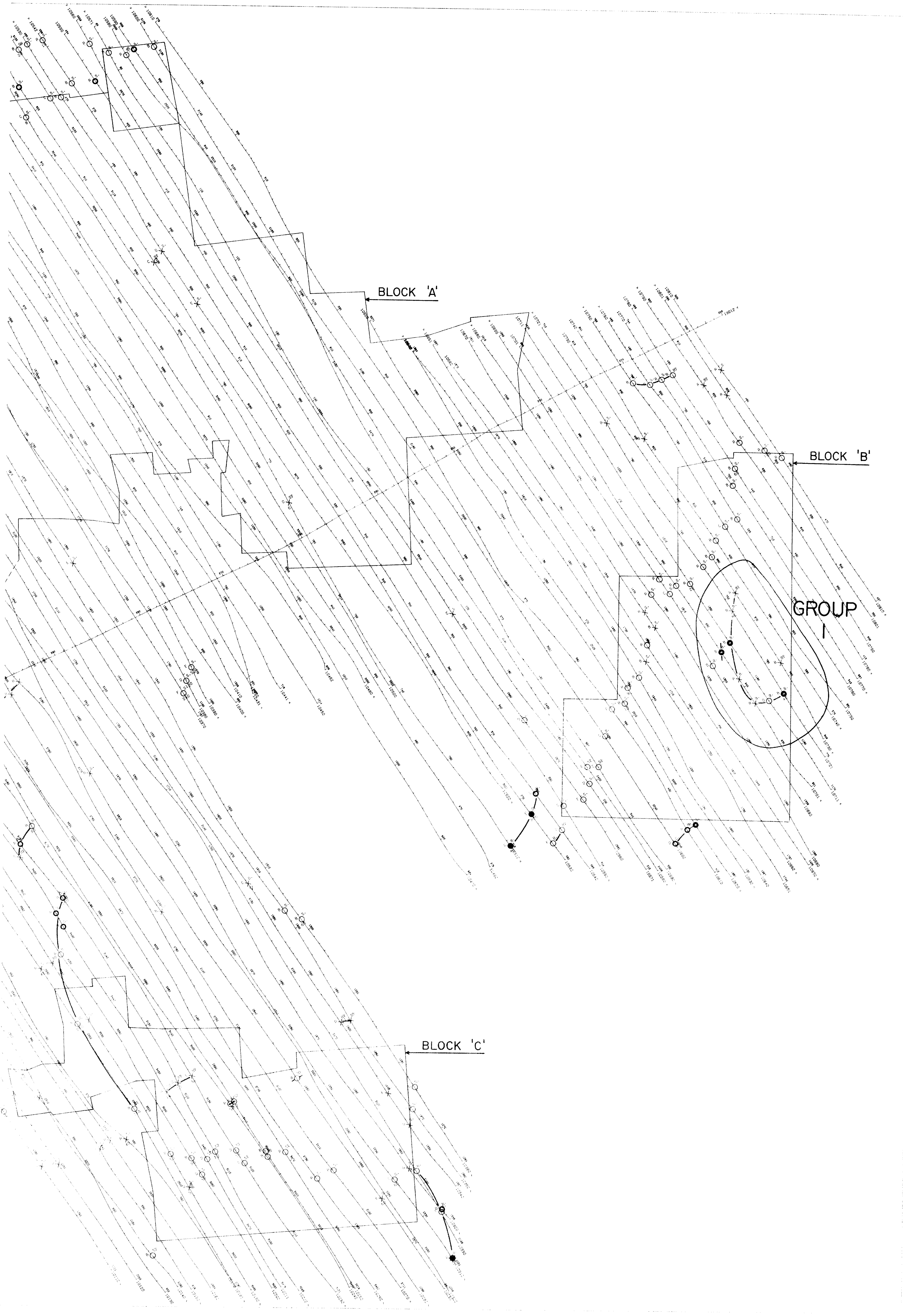


FLIGHT LINES WITH EM ANOMALIES

LEGEND

CITADEL GOLD MINES, INC.
McMURRAY TWP., ONTARIO

FILTERED VLF (ANNAPOLIS)
BY DIGHEM SURVEYS & PROCESSING INC



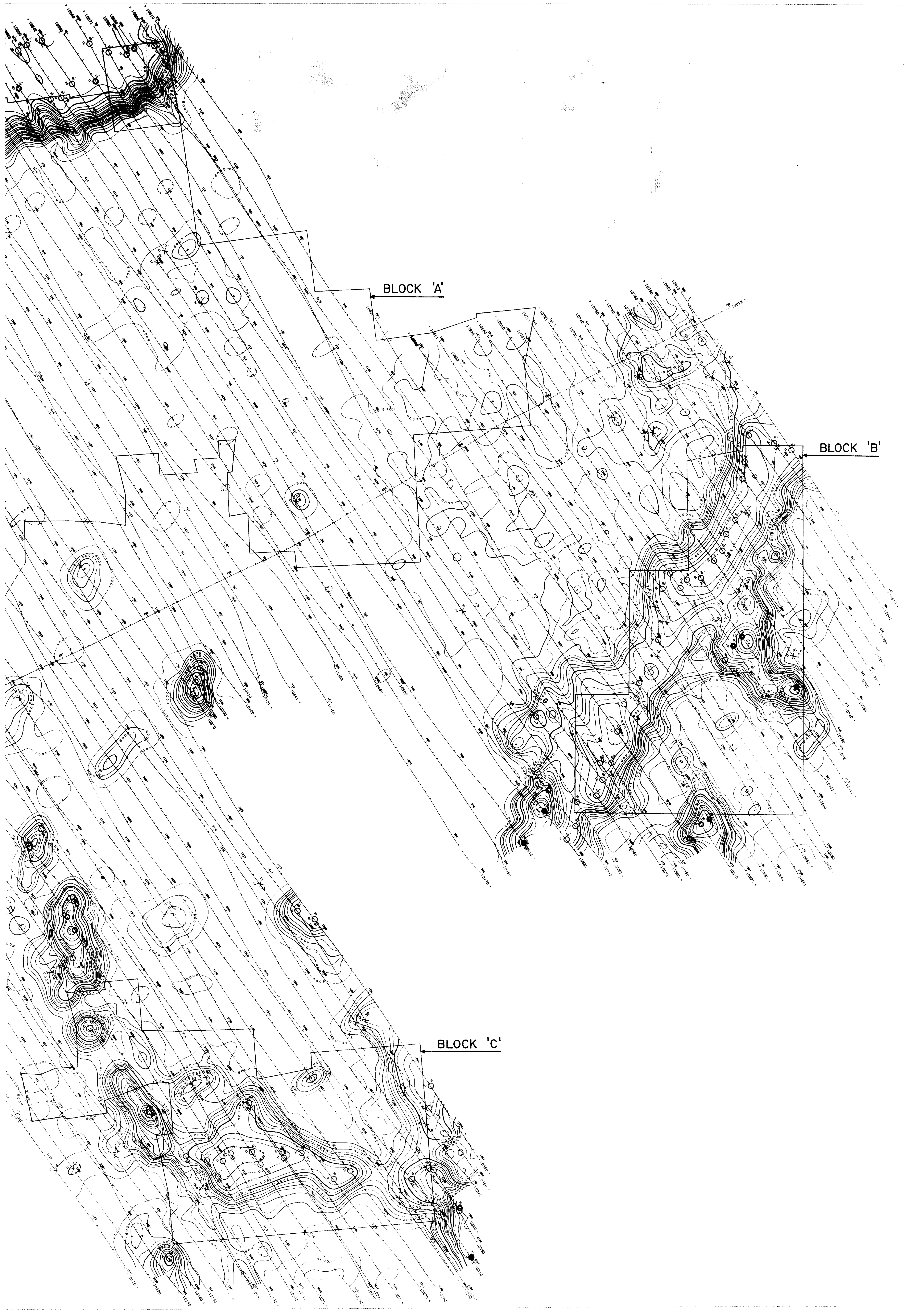
LOCATION MAP

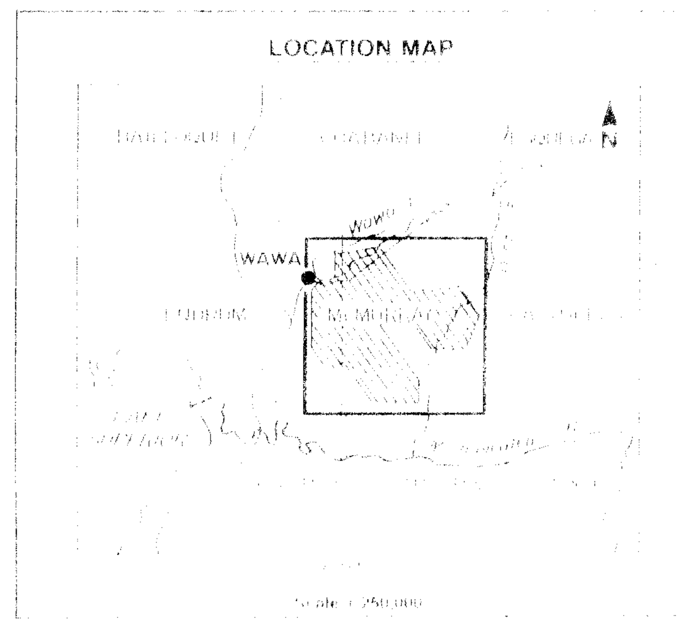
WAWA

FLIGHT LINES WITH EM ANOMALIES

CITADEL GOLD MINES INC.
McMURRAY TWP. ONTARIO

ELECTROMAGNETIC ANOMALIES
BY DIGHEM SURVEYS & PROCESSING INC.





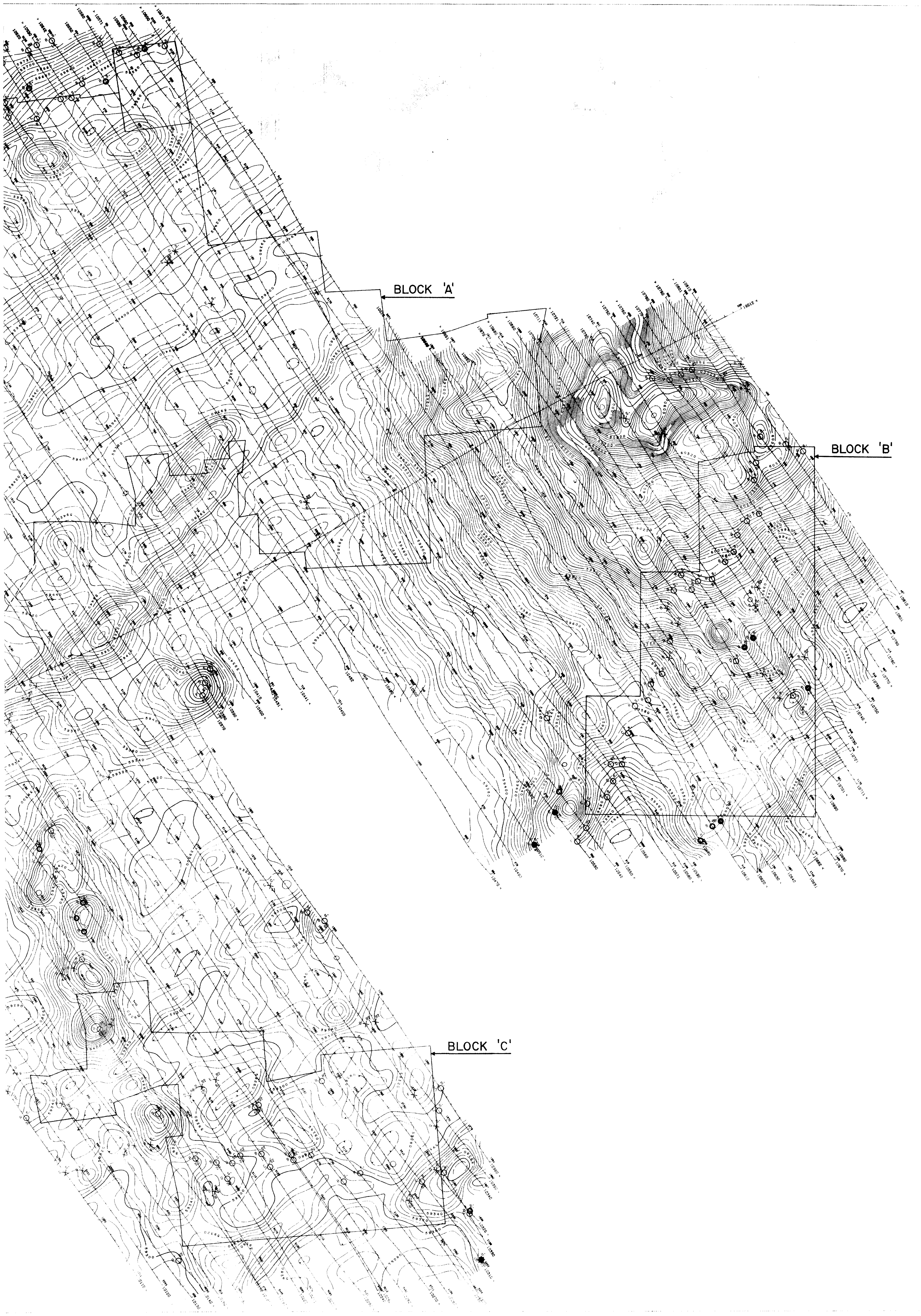
LEGEND

CITADEL GOLD MINES, INC.

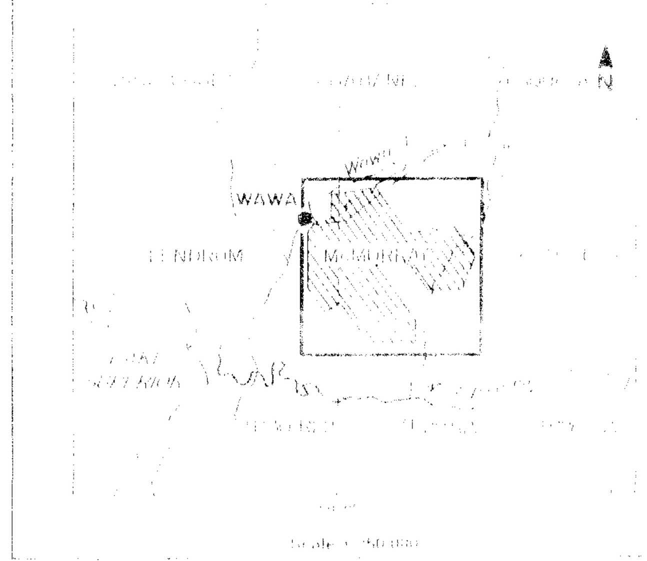
McMURRAY TWP. ONTARIO

RESISTIVITY (7200 Hz)

BY DIGHEM SURVEYS & PROCESSING INC.



LOCATION MAP



FLIGHT LINES WITH EM ANOMALIES

LEGEND

CITADEL GOLD MINES, INC.
McMURRAY TWP., ONTARIO

TOTAL FIELD MAGNETICS
BY DIGHEM SURVEYS & PROCESSING INC.

DIGHEM SURVEY
DATE: DEC. 1986


BLOCK 'A'
BLOCK 'C'