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REMOTE SENSING AND DATA INTEGRATION FOR TARGETING STRATABOUND GOLD MINERALIZATION IN GLACIATED TERRAIN A CASE STUDY FROM ATIKOKAN AREA, ONTARIO, CANADA *

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ABSTRACT

The application of new techniques in mineral exploration (here remote sensing and data integration) has been done in the Atikokan area on a large property owned by Mimiska inc.

General geology consists of metavolcanics rocks structurally controlled by the Quetico fracturation system at the south and the Steeprock lake fracturation system at the east. Metasediments and metavolcanics units are respectively located south and north of the Quetico fault. A granitic batholith occupies the northern part of the area in contact with metavolcanics. Major part of the area is overlain by glacial deposits, such as lodgement till, glacio-fluviatile and glacio-lacustrine deposits.

Remote sensing has been done regionaly (1:100000) and locally (1:24000) using LANDSAT-TM-5 data. At regional scale (TM quadrant), five structural domains were delimited. At local scale, lineaments were classified by means of their geographical extent (regional and local) and their degree of importance (first and second order).
They were grouped into families of same direction and geological interpretation has been conducted considering the structural domain and the classiciation criteria for giving a clear geological signification to lineaments.

Humus geochemistry and geophysics has been done on selected part of the property e.g. The metavolcanics north of the Quetico fracturation system and part of the batholith.

Data integration has been carried on using remote sensed lineaments, geochemical and geophysical data. Multivariate statistical processing has been used to derive a good empirical and theoretical gold mineralization model and high priority drilling targets. Significant economic gold mineralization has been intersected using this technique.

Remote sensing and data integration proved to be a valuable tool for targeting gold mineralization and should be used and adopted in mineral exploration programs in similar terrains.

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1. INTRODUCTION

The McIntosh property, held by Mimiska, (member of the Ariel Mining Group with head office located in Val d'Or, Quebec) is centrally located in the Freeborn and Baker townships in the Atikokan area, North-Western Ontario (see figure 1 - TELEDETECTION - REGION COUVERTE PAR LANDSAT-TM which displays location and the area covered by satellite data). The property lies in the southern part of the Quetico volcano-sedimentary belt within the Superior structural province.

The objectives of this study are:

1. Acquisition, processing and interpretation of remote sensend lineaments
2. Definition of an empirical model of gold mineralization coming from a theoretical model
3. Interpretation of other sources of data, such as humus geochemistry, I.P. geophysics and magnetics
4. Integration of all available data for extracting maximum information
5. Suggestion of drill hole targets

2. GENERAL GEOLOGY

Regionally, the southern limit of both Freeborn and Baker townships coincides with the location of the Quetico fracturation system, which separates two geological sub-provinces: the Quetico sub-province at the south and the Wabigoon at the North. Quetico sub-province features metasediments, mainly a monotonous sequence of wackes and mudstones while the Wabigoon sub-province is composed of metavolcanics, granitic batholiths and metasediments. Two major fracturation systems are present: the Quetico fracturation system, long of 300km along the East-West direction, passing at the southern limit of the two townships and the Steeprock Lake fracturation system, direction N035E, located east of Freeborn township, which south end is stopped by the Quetico fault system.

Locally, the Freeborn and Baker Townships (see figure 2) lie on the Wabigoon sub-province, which is characterized by metavolcanics/metasediments sequences and granite batholiths that control the position of the volcanic belt. Granitic rocks vary in composition and age and granitic phases are complex. Local structural geology is also complex: intense fracturation makes correlations between volcanic units very difficult. The area is strongly influenced by the Quetico fracturation system which consist in a serie of sub-parallel shear zones confined to metavolcanic units. Granitic intrusions, north of the Quetico fault, are believed to control metavolcanic trends.

3. THEORETICAL MODEL CONDUCTING THE REMOTE SENSING INTERPRETATION AND INTEGRATION (taken from Phillips and al., 1984)

Gold mineralization is believed to be a fundamental part of the Archean greenstone belts evolution. Within these belts, two general types of gold deposits can be recognized:

1. Vein-associated deposits mainly in metavolcanic rocks.
2. Stratiform-stratabound deposits in banded iron-formation of Fe-rich chert.

While the epigenetic model is widely accepted in the case of the vein-associated deposits, there is far less consensus on the genesis of the strata-

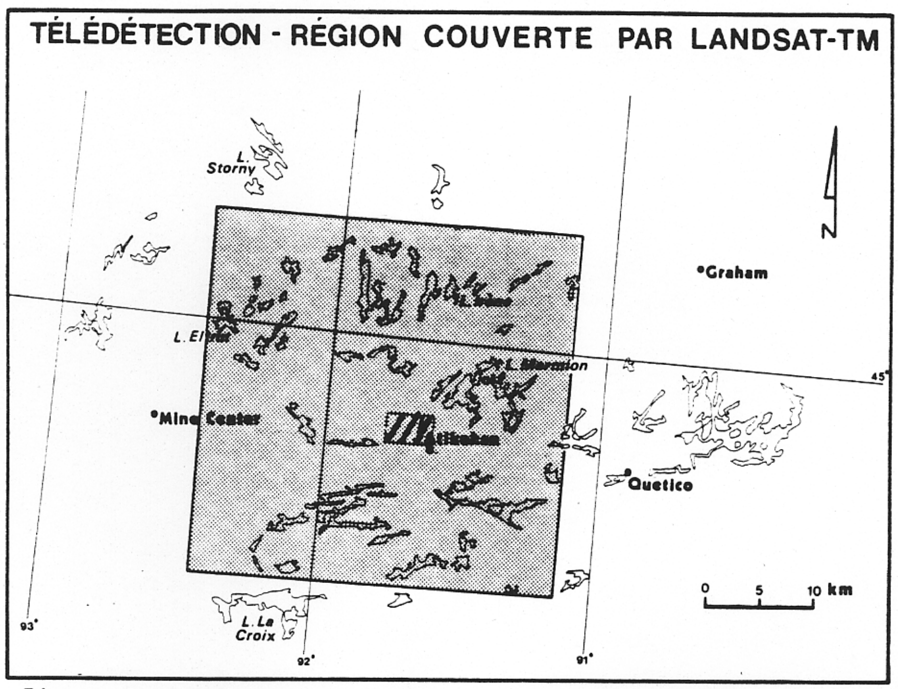

Figure I. Localisation of Freeborn-Baker townships and area covered by Landsat-TM quadrant image.

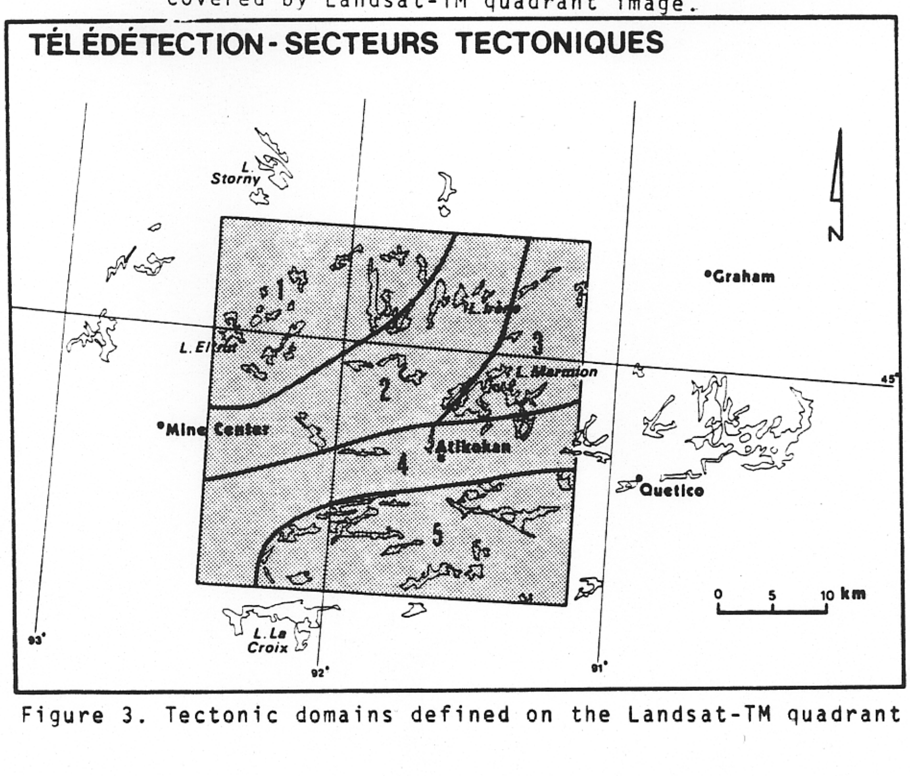

Figure 3. Tectonic domains defined on the Landsat-TM quadrant

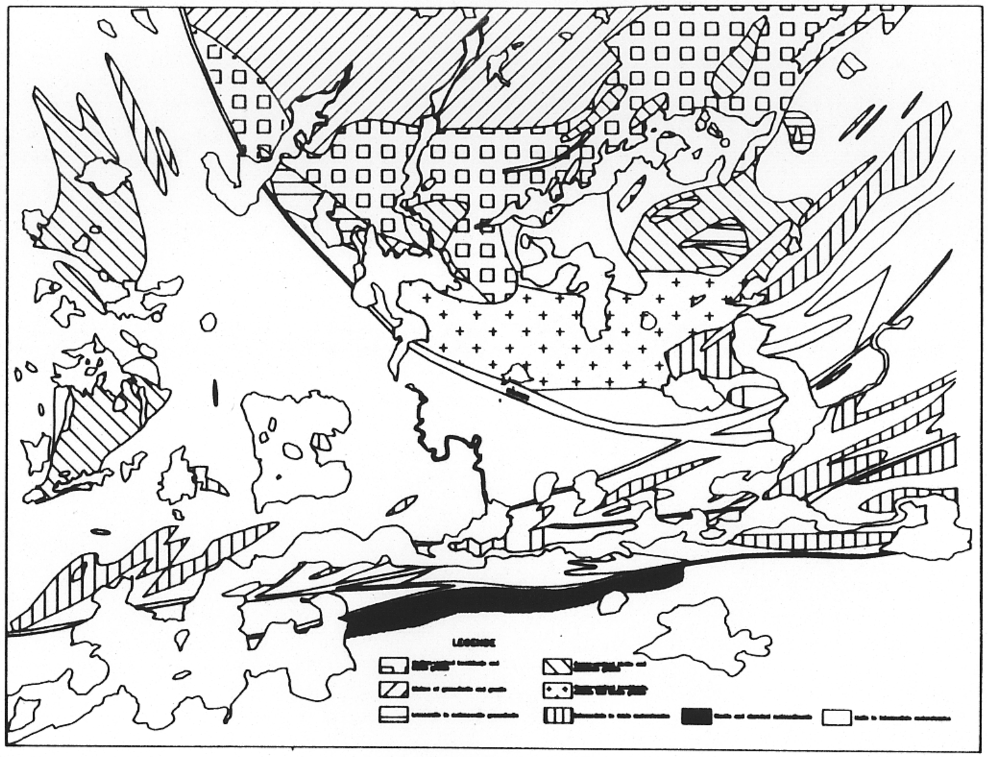

Figure 2. Regional geology map of the Freeborn-Baker townships.

bound type. The syngenetic model involves the following facts: (in a "grass-root" point of view).

1. Mineralization is stratiform and confined to particular lithologies, within specific stratigraphic units in the Archean greenstone sequence.

2. Sulfides (and gold) participated in all deformation and metamorphic events recorded in the adjacent and laterally equivalent rocks.

3. At the macroscopic scale, mineralization should not be restricted to specific folds of fault structures or zones of more intense fracturing.

4. Gold grades should not be related to transgressive features such as fractures and faults.

The epigenetic model involves the following facts:

1. Selective replacement of oxide and/or carbonate facies banded iron-formation by later S-bearing fluids. Fluids ingress via fractures and faults in the banded iron formation, and there is selective replacement of Fe-rich bands.

2. Sulfides (and gold) mineralization postdates earlier deformation or metamorphic events recorded in the oxide facies banded iron-formation.

3. At the macroscopic scale, the control of mineralization is governed by folds, faults or zones of intense fracturation.

4. Gold grades are related to transgressive features and/or sulfides are transgressive to layering.

Conclusions of Phillips and al. (1984) state that "it is premature to suggest that all Archean banded iron-formation deposits are epigenetic, although these ores (exemples from South-Africa and Western Australia) have a number of consistent features that suggest a common origin. Realization of an epigenetic origin has important exploration implications, as it points to structurally controlled mineralization rather than controlled by facies variations at the sedimentary stage".

REMOTE SENSING

1. Choice of the image

The image choosen comes from the LANDSAT satellite, specifically from the Thematic Mapper sensor, because of its ability to display the area in several infared reflective bands. An autumn scene has been selected, clearing deciduous trees from their leaves, giving the best representation possible for the detection of geological lineaments.

2. Image processing

The satellite data was processed by the EARTH PROBE V.1.2 image analysis system. Spectral bands 4, 5 and 7 (in red/green/blue order) have been selected and have undergone normal phases of image analysis e.g. contrast enhancement and filtering, and more complex processing, like Lambertian filtering.

3. Scales of interpretation - leading to lineaments classification

The first geological interpretation was performed on the LANDSAT quadrant image of which center is the Freeborn and Baker townships. The purpose of this interpretation was to define tectonic domains within the regional geological context. The second geological interpretation was performed on four 1:30700 images covering a 30km area which center again the two prior townships. Regional lineaments have been defined using these images.

The third interpretation was done on several 1:15530 scale images covering entirely the two townships. Local lineaments resulted from this interpretation.

Thus, the various scales of interpretation helped us to define three types of geological interpretation: structural domains, regional lineaments and local lineaments.

4. Processing levels - leading to another lineament classification

Some geological lineaments express themselves very cleary while others are more subtle, depending on the geological feature concerned, the depth of surficial deposits and density of vegetation.

Some image analysis processes result in a close representation of the original database (such as contrast stretching) while others are "altered" representation of the original image (such as directional filters). Surface expression of geological features can be easily correlated with image processing levels, e.g. clear lineaments will show without enhancement while subtle lineaments will need image analysis to express themselves. This statement leads to another way of classifying lineaments e.g. first-order lineament, second-order lineament, etc... The more the processing level is complex, the more subtle lineaments will appear. For this study, first-order lineaments are the ones that can be observed after contrast stretching and a light edge filtering. Second-order lineaments are the ones which appear after heavy edge filtering, directionnal filtering and Lambertian filtering (shadow image). First-order and second-order lineaments apply to either regional or local lineaments.

5. Classification of lineaments - a review

The classification of lineaments is done, in order, to put them into groups having, approximatively, the same expression (scale and processing type). For the Freeborn-Baker townships study, the lineaments have been separated in four groups:

a First-order regional lineaments: regional lineaments that can be observed on the quadrant image or on the regional images. They express as major fractures of lithological contact features.

b Second-order regional lineaments: regional lineaments visualized after image processing. They represent geological features that have undergone folding and/or faulting. The synoptic view of a satellite image allows geologists to observe that kind of features.

c First-order local lineaments: they can be seen in small scale image, but their maximum expression is achieved in large-scale images. They represent in general stratigraphic units, contacts between different lithologies and small scale structural features like fold axes or faults.

d Second-order local lineaments: these lineaments are subtle local lineaments expressing mainly lithological contacts and small scale structural features.

GEOLOGICAL INTERPRETATION OF LINEAMENTS

1. Surficial deposits

Surficial deposits must be studied in order to evaluate their influence on lineament detection. Some deposits will hide geological features while others will generate non-geological lineaments e.g. glacial features uncorrelated with sub-surface features.

In the area of the satellite quadrant, surficial deposits are sparse, thin and leaning outcrops dominate the area. But, in certain locations, glacial deposits are present:

a North-East of Atikokan area: glacio-lacustrine clayish deposits coming from Agassiz glacial Lake.

b Marmion Lake and White Otter Lake area: glacio-fluvial sand.

c South of Marmion Lake and White Otter Lake: The Eagle Lake - Finlayson Moraine on which Provincial route 17 is build.

d East of Perch Lake: glacio-lacustrine sediments probably coming from Agassiz Lake.

2. Tectonic domains

One of the major characteristic of remote sensing is its capability to provide a synoptic view of any area. In mineral exploration, the authors find important to consider an area within its regional context. For doing so, the LANDSAT-TM image was choosen in a way that the image center corresponds to the Freeborn and Baker townships. Tectonic domains are areas of distinct lithological and/or structural characteristics. Five of them were defined on the image.

Domain 1: Structural control of N-S oriented lakes and complex fracturation pattern suggesting granitic rocks.

Domain 2: Structural pattern from N-E and E-W, very proeminent in the north, decreasing toward the Western part. This domain characterizes the northern part of Freeborn and Baker townships.

Domain 3: N030E trend represents volcanic lithologies within the Steeprock Lake fracturation system.

Domain 4: N085E trend influenced by the Quetico fracturation system in metavolcanics and metasediments. It is the main domain present in the Freeborn and Baker townships.

Domain 5: Structural control of lakes and complex fracturation pattern suggesting granitic rocks.

Thus, the Freeborn and Baker townships are structurally influenced by three tectonic domains defined from two major fracture systems, the Quetico fracture system and the Steeprock Lake fault system. Tectonic domains have given here precious informations, helping to address final conclusions.

3. Regional lineaments

Regional lineaments are the surface expression of regional geological features. Detection of these lineaments is made on an area much bigger than the geographic extent of the property. Here, they represent regional trends of fracturation and folding at the scale of the greenstone belt and batholiths.

Figure 4 displays the map of regional lineaments which have been observed on the regional image. In this map the first-order regional lineaments are numeroted and the second-order ones are not. For simplification and clarity, local lineaments are not included on this map.

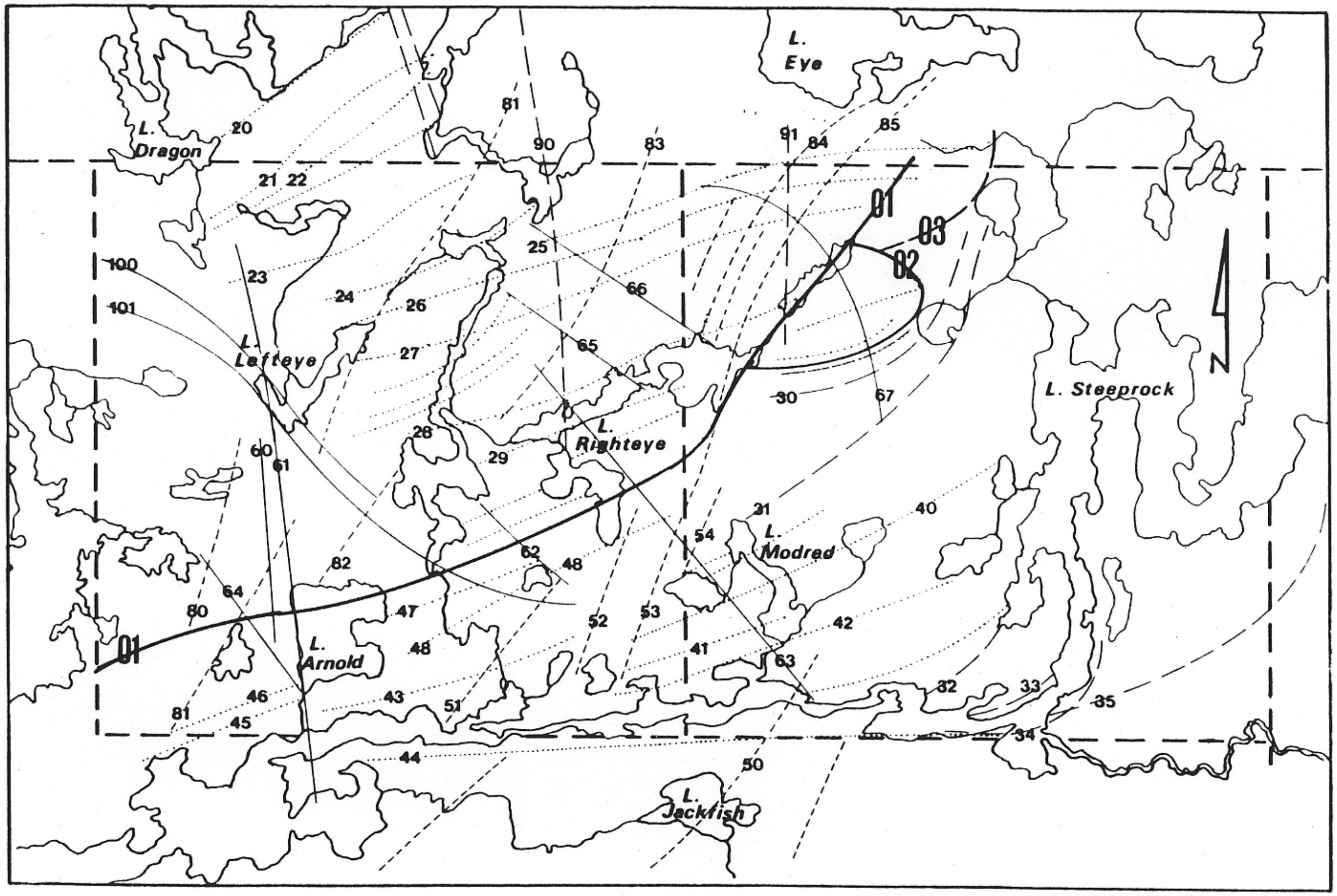

Figure 4. Map of regional geological lineamnets of the Freeborn-Baker Townships.

Another criterion of classification has been added here, in the form of families of lineaments which are groups of lineaments defining major and minor trends.

On figure 3, heavy lines represent major surface features: lineament 1 represents the frontier of three tectonic domains (explained earlier), e.g. domain 2, 3 and 4. Lineament 2 is the contact between granitic rocks (west of the lineament 1 and metavolcanics (east of the lineament). Dashed lineament 3 represents the same phenomenon but the contact is not clear.

Thin observed lineaments on the map was grouped into families, considering the tectonic domain into which they fall.

South of lineament 01, the 40-family (e.g. lineament 40 to 48) is the surface expression of metavolcanics/metasediments which is under the influence of the Quetico fracture system. The 30-family (lineaments 30 to 35) features the same rocks, but it's influenced by the Steeprock Lake fracture system. The 50-family represents late fracturation following the formation of area's major faults. North of lineament 01, families of lineaments display the complex fracturation system characterizing most of batholitic complexes. The 20-family and 80-family lineaments represent late fracturation passing through metasediments at the south, metavolcanics and granitic rocks at the north. Lineaments 100 and 101 are the surface expression of structural mylonitic phenomenum.

4. GEOCHEMISTRY

Since 80% of the McIntosh property is covered by a variable thickness of overburden, it was decided to undertake a soil survey on selected parts on the property. Sampling has been carried on a 100m x 100m density along cutted lines. Horizon "A" has been systematically sampled and at every site field informations has been codified. Then, samples have been sent to CHIMITEC (Ste-Foy, Québec) for assaying. Samples have been assayed for 20 elements (including gold) by neutron activation. 30 replicate samples have been taken for lab testing. Results indicate very good accuracy in the method and in the lab procedures.

A geochemical database has been created by combining assay results and qualitative information on surficial characteristics. The database has been processed statistically in order to determine multi-element relationships related to gold mineralization. 2 types of processing has been considered: the calculation of simple correlation matrices and factor analysis. Results from factor analysis indicate that the "factor 2" explains around 20% of the total variance of the database and that "factor 2" could be expressed as a variable that takes account of hydrothermal alteration related to gold deposition. Similar results using a threshold of 5 ppb on gold has been obtained in the calculation of the simple correlation matrix.

A geochemical interpretation of these statistical results leaded to the following relationship: Au is related and associated with Cr, U, Hf and As. This geochemical signature is associated to the altered zone related to the gold mineralization. Drilling results showed that minerals like fuschite (Cr), ferro-dolomite, quartz, carbonates, and sulphides (pyrite, chalcopyrite) are present and explain the particular geochemical signature at hands.

Instead of just plotting gold values or chromium values alone, it was decided to generate a composite map that is the gradient (second derivative) of the product of the most significant elements in the present signature. A gradient map resulting of the product of Cr, Au and U has been calculated and represented in figure 5. The general trend of contours is ENE direction (Quetico fracturation pattern). The gradient allow us to take account of variable thickness of overburden.

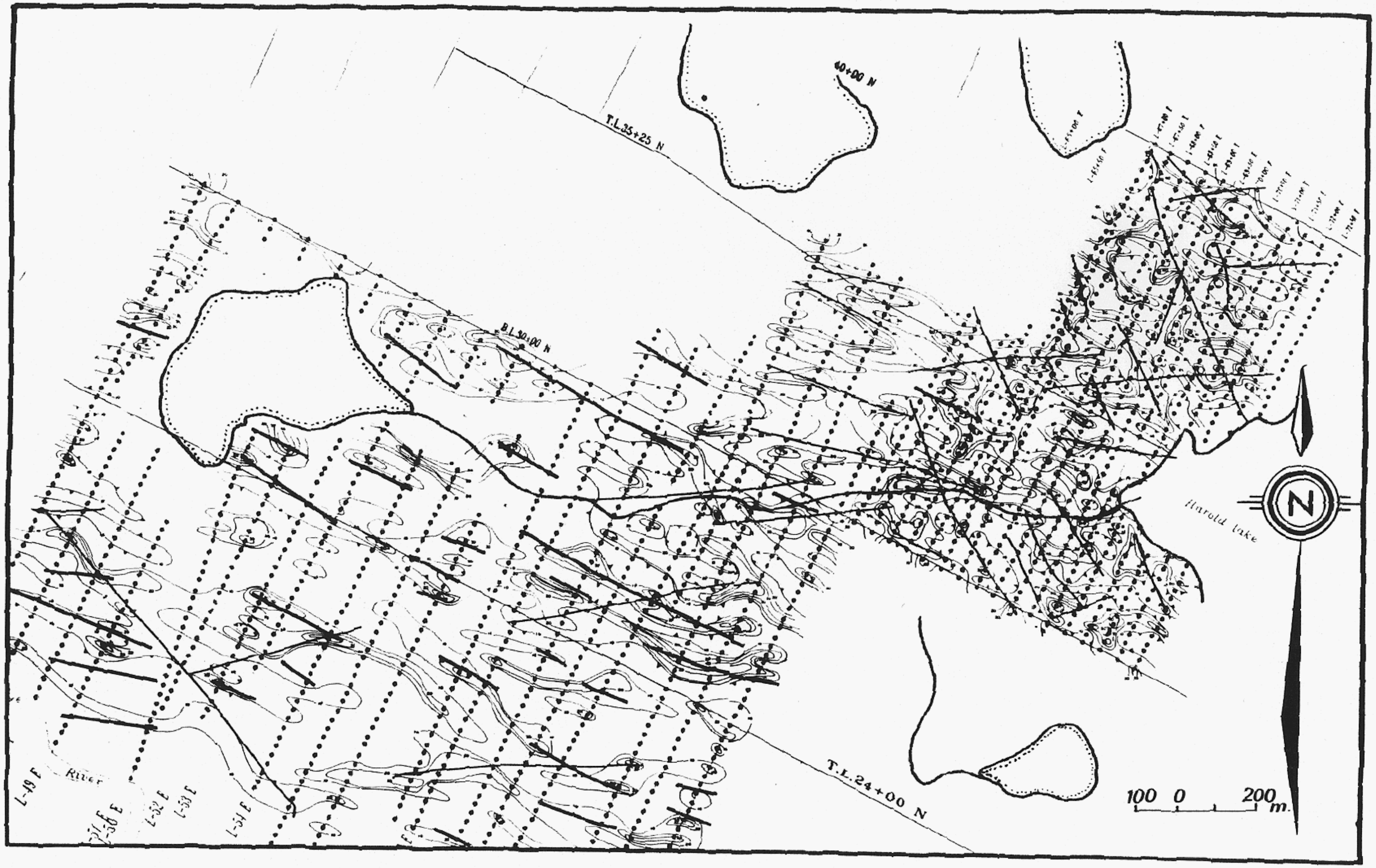

Figure 5. Geochemical gradient anomaly map

GEOPHYSICS:
This geophysical survey features magnetics (total field) anomalies and axes and has been done in the most promising part of the area

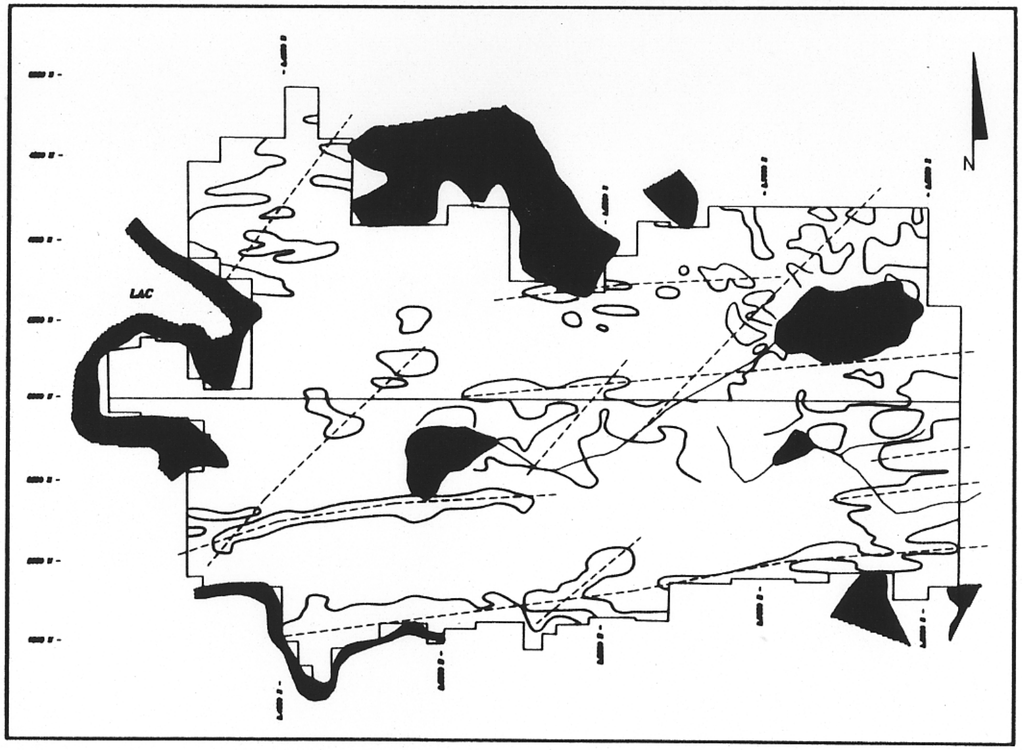

Figure 6. Magnetic axes map,

INTEGRATION MAP:
Geophysics ,lineaments, and gradient geochemistry

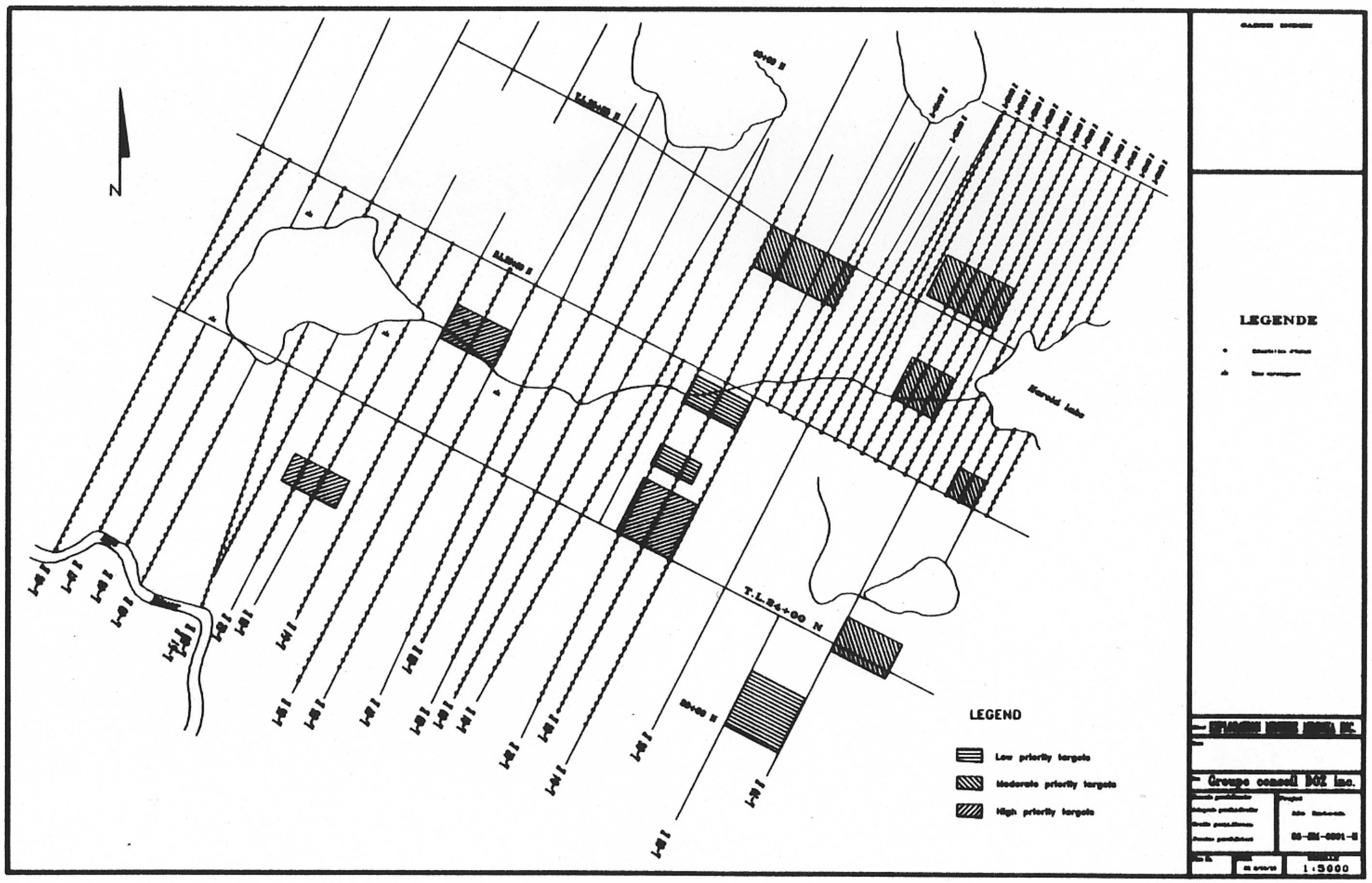

Figure 7. Integration map.

5. INTEGRATION

Integration has been performed by processing statistically different levels of information that were available: lineaments, geochemical gradient of (Au, Cr, U), I.P. geophysics and magnetics (figure 6). The property has been divided in cells having a size of 100m x 100m. Every information has been binary coded (presence or absence of a particular feature in the cell) according to a particular direction. A simple correlation matrix showed that the geochemical gradient variable was strongly associated to the late fracturation system (direction 020-030) and weakly associated with ENE (070-090) I.P. Axes and the Quetico fracturation lineaments with direction (070-090). A "priority target" map has been created by investigating all cells having the same characteristics described above. Figure 7 shows the map resulting from integration.

Drilling of the first order priority target localized between line 62 and 64 and 24+00W and 26+00N leaded to a discovery of a new gold mineralization (6.14 g/t over 10.35 meters). Subsequent drilling has confirmed the gold potential of the area.

CONCLUSION

Interpretation of each different type of survey (I.P., Magnetics, Geochemistry and Remote sensing) taken individually gives generally a very complex view of an area. This leads to this general statement: that too much information gives too much targets to verify. Moreover, it might be difficult to relate each type of survey to a theoretical and an empirical geological model of gold mineralization

The purpose of integration is to simplify the process of "decision targeting" in exploration by combining different levels of information in such a way that a synthetic view of the information is created. However, integration must not be done blindly by combining different surveys as numbers without interpreting the geological meaning of such surveys.

In the particular case of the McIntosh property, each method has been interpreted individually. Remote sensing has precized the structural picture compare to geophysics alone. Geochemistry was critical to select structures that are mineralized from barren ones and integration was succesfull for target selection. Finally, integration of different levels of information has proven to be a valuable tool for targeting a gold mineralization in the McIntosh property and should be used and adopted in mineral exploration programs in similar terrains.

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