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PRELIMINARY ANALYSIS OF MINERAL POTENTIAL MODELLING OF THE VICTORIA LAKE SUPERGROUP VOLCANIC ROCKS: A WEIGHTS OF EVIDENCE APPROACH

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ABSTRACT

The Victoria Lake Supergroup, in central Newfoundland, is highly prospective for gold and base-metal mineralization, but covers a large area. The volcanic and volcaniclastic rock types alone cover an area over 1300 km^2. Modelling the mineral potential of this area will provide a focus for mineral exploration. A model for the mineral potential of VMS occurrences in the Victoria Lake Supergroup volcanic rocks was prepared using the weights-of-evidence method as provided in the program Arc Spatial Data Modeller (ArcSDM). This technique is best applied to areas that have been moderately to highly prospected resulting in a large number of mineral occurrences. The final model can then be applied to other areas having similar geological characteristics.

Fifteen evidence maps (e.g., geology, proximity to faults, Cu in till etc.) were compared with 47 surface VMS mineral occurrences (training sites) to determine which evidence proves to be associated with the mineral occurrences. Nine of the fifteen evidence maps were favourably associated with the mineral occurrences. These are, in decreasing order of favourability, the regional geology, detailed geology, Cu in lake sediments, magnetic vertical gradient, residual Zn in lake sediment, gamma ray K, Cu in till, regional fault proximity and Pb in lake sediments. Combining these nine evidence maps, using Bayesian probability theory, produced a mineral potential map of the study area.

Four areas were delineated as having high mineral potential for VMS occurrences, defined here as being 18 to 50 times higher than the probability of finding an occurrence due to chance. These areas coincide with, or are in close proximity to, known prospects and deposits, including those not used in the analysis process, verifying that the weights-of-evidence modelling can define promising areas for mineral deposit exploration.

The existing weights tables, derived from an area that is well explored, can be applied to evaluate new areas of interest with few existing mineral occurrences. The model produced in this study can be further improved by completing the coverage of those surveys with missing data in parts of the Victoria Lake Supergroup.

INTRODUCTION

In recent years geological, geochemical, geophysical and mineral occurrence datasets have been compiled in digital form by provincial and federal geological surveys. It is now possible to undertake digital and statistical modelling of the mineral potential of areas of the Province for which this data is available.

Many software programs are available to help organize and analyze earth science data to assess the mineral potential of an area. These consist of traditional statistical programs that use logistic regression, multiple regression or decision tree methods, among others, to analyze point data derived from digital or other sources (Bonham-Carter and Chung, 1983; Bonham-Carter *et al.*, 1988; Bonham-Carter, 1994; Harris *et al*., 2001; Wright *et al.*, 1988). Newer methods such as weights-of-evidence analysis, fuzzy logic and neural networks, use a geographic information system (GIS) directly to assess the spatial association between mineral occurrences and various 'evidence' layers of information, and then combine them to provide an interpretation of the

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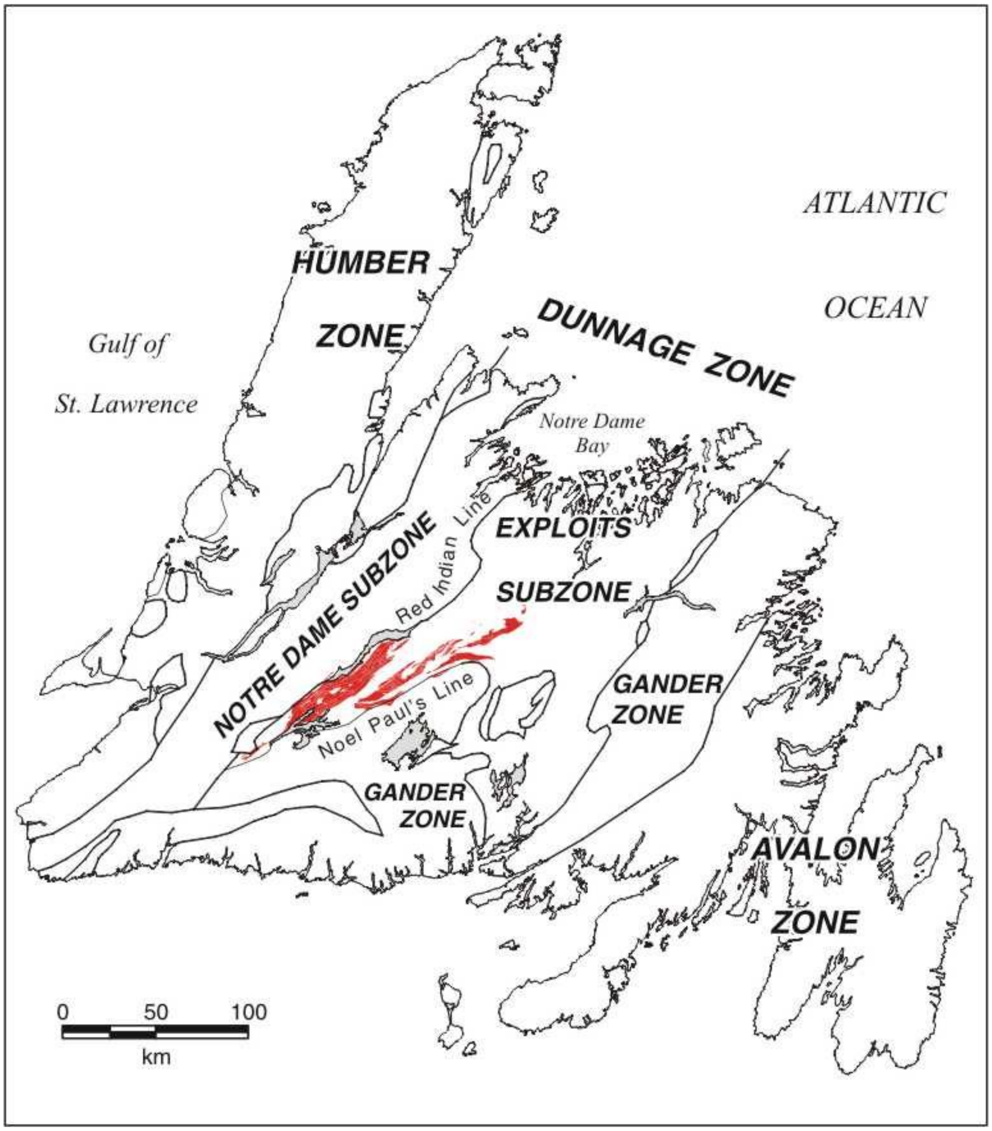

Figure 1. *Location of the study area in central Newfoundland with the Victoria Lake Supergroup volcanic rocks highlighted in red (based on Rogers and van Staal, 2002).*

mineral potential (Agterberg, 1992; Agterberg *et al.*, 1993; Bonham-Carter, 1994; Cheng and Agterberg, 1999).

This study will use the weights-of-evidence (WofE) method, which is an objective data treatment method that utilizes empirical data as the driving force of the analysis (Bonham-Carter, 1994). Alternatively, subjective, knowledge-based methods, such as fuzzy logic methods, require information from 'experts' to provide reliable quantitative weighting values for each layer of information such as proximity to faults or magnetics. The WofE method, on the other hand, derives these weights from probability calculations involving the area of the favourable patterns (e.g., anomalous copper values in till) and the number of mineral occurrences inside and outside the pattern. The weights from various evidence maps are then combined using Bayesian probability theory to produce a mineral potential map of the area (Bonham-Carter, 1994).

The WofE technique will be used to analyze the mineral potential of the volcanic rocks of the Victoria Lake Supergroup in central Newfoundland (Figure 1). The Victoria Lake Supergroup has been widely studied and contains numerous mineral occurrences (Evans and Kean, 1987, 2002; Moore, 2003; Squires and Moore, 2004). It is still considered to be one of the most favourable areas for the exploration of volcanogenic massive sulphide (VMS) deposits in the Province. It also has a large amount of digital data already compiled by the provincial and federal geological surveys, as well as the exploration industry.

Due to time constraints, only compiled digital data readily available as of January 2004, from the Geological Survey Branch and the Geological Survey of Canada were used in this study. Some minor changes were made to the detailed Tally Pond geology and to update the mineral occurrences where new information was available. These will be discussed below.

GEOLOGY AND MINERAL OCCURRENCES

REGIONAL GEOLOGY

The study area consists of the Victoria Lake Supergroup (VLSG) volcanic rocks. The VLSG is part of the Exploits Subzone of the central Newfoundland Dunnage Zone (Figure 1). It occurs to the south of the Red Indian Line fault sytem (Figure 1; Williams *et al.*, 1988). The VLSG includes all Cambrian and pre-Caradocian Ordovician arc-volcanic,

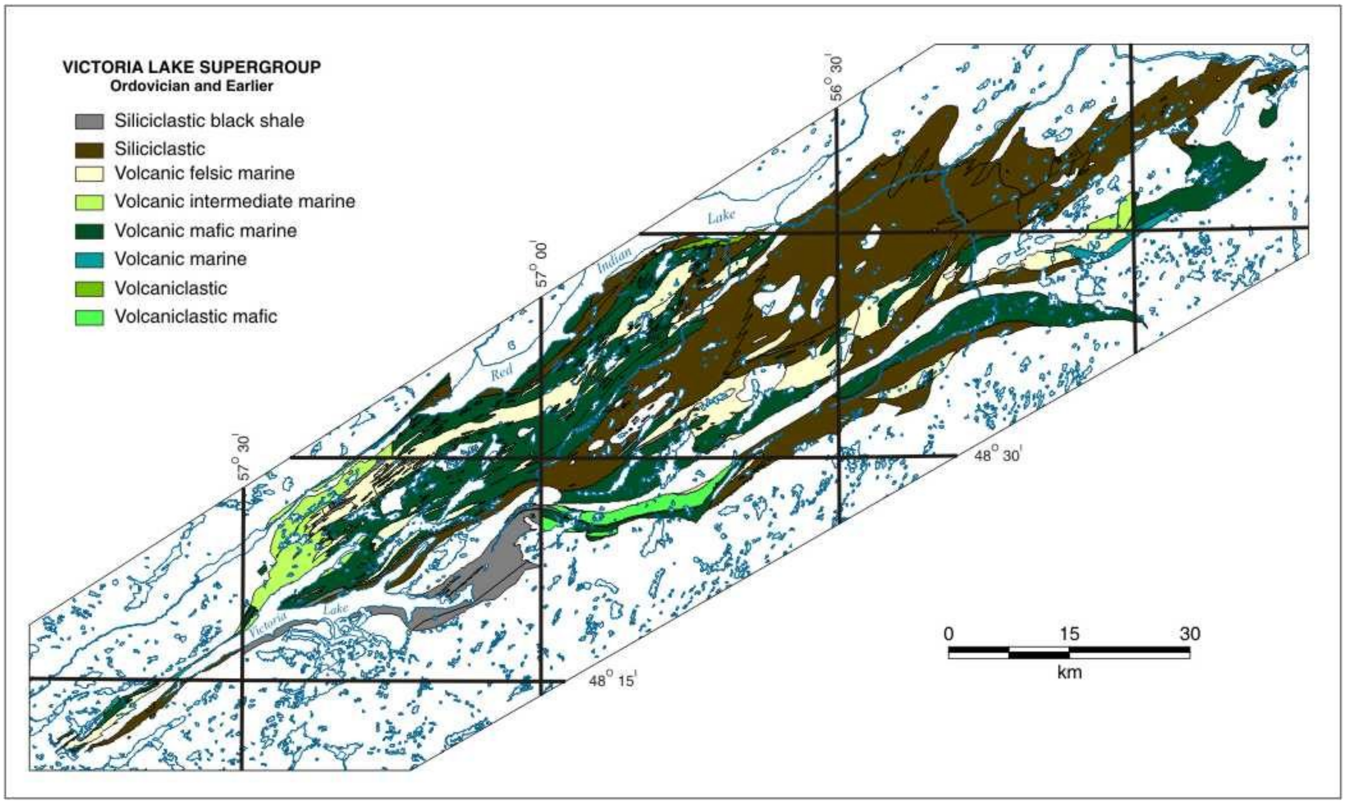

Figure 2. *Regional geology of the Victoria Lake Supergroup.*

volcaniclastic and sedimentary rocks between the Red Indian Line fault system (Williams *et al*., 1988) to the northwest, Noel Paul's Line to the southeast and the Caradocian black shales to the northeast and southwest (Evans and Kean, 2002; Figures 1 and 2).

The following description is based mainly on Evans *et al*. (1990). There are two belts of volcanic rocks in the VLSG; the Tulks belt volcanic rocks (e.g. 498 +6/-4 Ma) to the northwest and the Tally Pond belt volcanic rocks (e.g. 513 ± 2 Ma) to the southeast. Both volcanic suites consist of felsic flow, autoclastic and pyroclastic units and reworked equivalents, intercalated with mafic pillow lava, tuff, agglomerate and breccia as well as sedimentary units. The Tally Pond volcanic rocks tend to be dominated more by mafic compositions. The Tulks belt volcanic rocks are characterized by more intense deformation, with chlorite and sericite defining a regional foliation.

The sedimentary rocks of the VLSG include greywacke and interbedded siltstone, shale, argillite, conglomerate, and rare limestone and chert. Intrusive rocks in the VLSG consist of quartz porphyry, quartz monzonite, granite, granodiorite and gabbro. For more recent information on the VLSG refer to the Newfoundland Department of Natural Resources Current Research volumes from 2002 to 2004.

A section of the Tally Pond belt has been mapped in detail, starting with industry mapping by Noranda Inc. and continued by Thundermin Resources Inc. and Altius Minerals Corporation. The mapping has been modified by G. Squires and the digital compilation (Figure 3) for this study was provided with permission from Altius Minerals Corp. (R. Churchill, personal communication, 2004) and Aur Resources (T. Brace, personal communication, 2003). This map contains significant detailed lithologic information related to the location of VMS mineralization within the Tally Pond belt. The quartz-phyric tuffaceous rocks and altered felsic volcanic rocks respectively indicate the proximity to shallow magma chambers and hydrothermal systems interpreted to be conducive to the formation of massive sulphide deposits, and are both empirically associated with sulphide mineralization in this area. It should be noted that many occurrences in the Tulks belt are also associated with quartz-phyric felsic volcanics and alteration zones, but available maps did not sufficiently resolve these characteristics.

MINERAL OCCURRENCES

Evans and Kean (1987) report two main types of mineralization occur within the VLSG; VMS and epigenetic gold. Volcanogenic massive-sulphide mineralization occurs

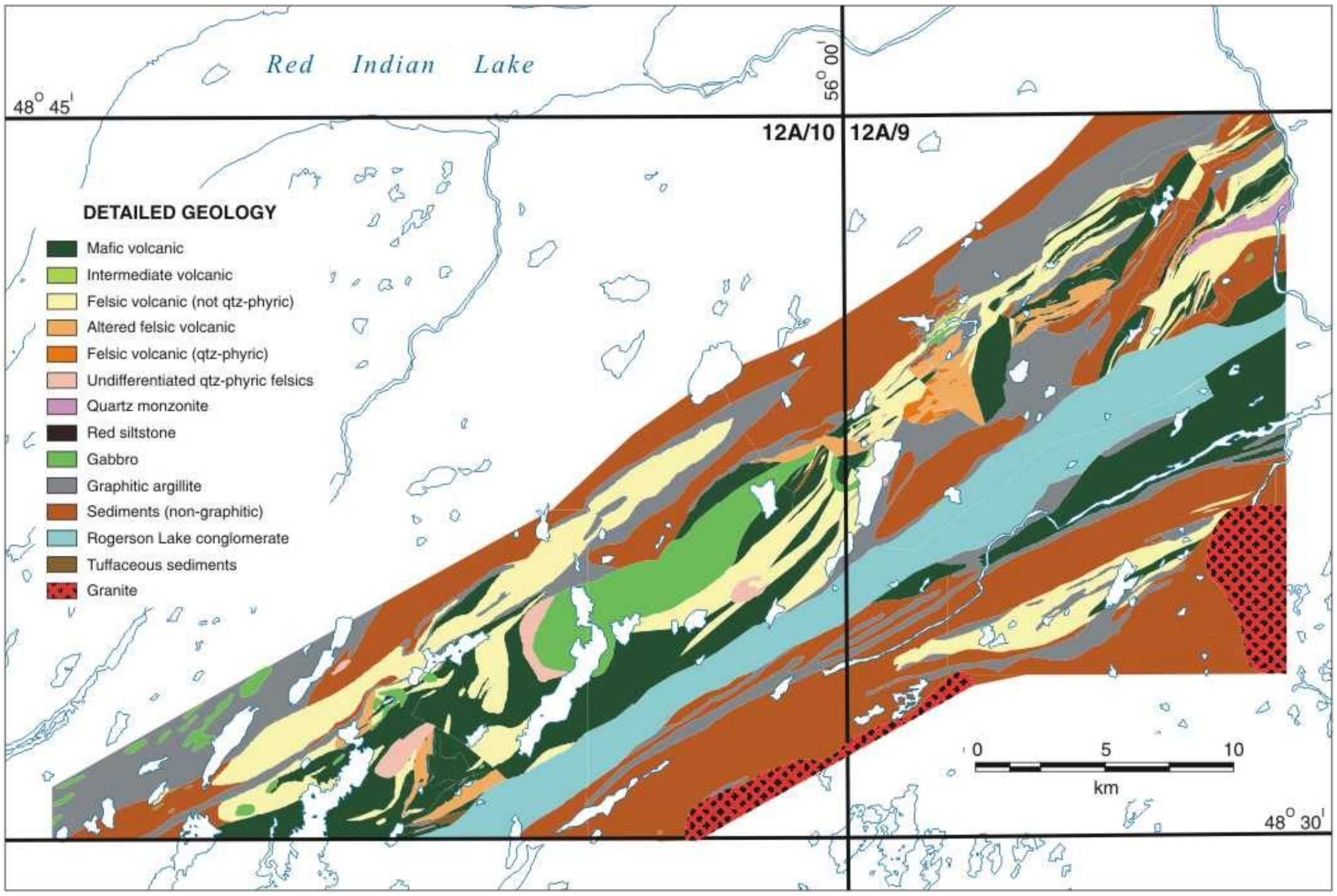

Figure 3. *Detailed geology map of the Tally Pond map area, NTS 12A/9 and 10. Compiled from industry sources (Noranda, Thundermin and Altius) and modified by Squires (2004).*

predominantly within the Tally Pond and Tulks volcanic belts and consists of copper, zinc and lead mineralization with minor (but significant) local silver and gold (Swinden *et al.*, 1989). Gold mineralization in the VLSG appears to be spatially related to major fault zones, lineaments and alteration zones (Evans *et al*., 1990).

There are about 170 mineral occurrences recorded from the VLSG area (Stapleton *et al*., 2000). These are located within the volcanic and sedimentary rocks and occur mainly in syngenetic volcanogenic massive sulphide and epigenetic Au environments. They range in size from indications to deposits. These mineralized areas will henceforth be collectively referred to as “mineral occurrences”. They have been extracted from the provincial Mineral Occurrence Data System compilation (MODS; Stapleton *et al*., 2000). The WofE modelling program provides a more targeted mineral potential when just one deposit type is chosen. Since the vast majority of the mineral occurrences in the study area are of the VMS deposit type, they have been chosen as the focus of this study.

Volcanogenic massive-sulphide deposits consist of syngenetic accumulations of pyritic to base-metal and precious metal-rich sulphides that are precipitated from rapidly cooling hydrothermal fluids escaping through fracture and fault zones below sea floor vents (Franklin, 1993). As well, copper-rich sulphide mineralization can occur within a stockwork zone immediately below a massive sulphide zone. Alteration of the host and footwall rocks (commonly submarine volcanic and/or sedimentary rocks), including silicification, sericitization, chloritization and carbonitization, occurs along the faults and fracture zones.

One of the largest deposits in the VLSG area is the Duck Pond deposit. This deposit is not directly included in the analysis in this study, as the deposit occurs more than 200 m below the surface (i.e., only surface deposits are included in this study; *see* Methods section). But this deposit has significant features or associations that provide insight into what other data layers to incorporate as evidence maps. This deposit is, in part, hosted by altered quartz-phyric tuffs, which exhibit primary and replacement sulphide lamination, debris-flow textures, and ‘chaotic carbonate’ alteration (Squires *et al*., 2001).

METHODS

The method of data preparation is based on the requirements of the weights-of-evidence (WofE) module in the ArcView™ Spatial Data Modeller extension (ArcSDM). Therefore, a brief overview of the WofE method will be presented, followed by a description of the data preparation for the study area, the training sites and the evidence maps.

WEIGHTS-OF-EVIDENCE METHOD

The WofE method is based on the spatial association between an evidential theme (e.g., Cu concentration in till) and a set of mineral occurrences (training points). The evidential themes are binary layers of information such as geology, geochemistry, or geophysical maps where the binary pattern consists of those areas favourably associated with the mineral occurrences and those areas less favourably associated. Positive and negative weights are calculated for each binary map, which are then combined, using Bayesian statistical techniques to produce a mineral potential map (Bonham-Carter, 1994).

The WofE method is based on the analysis of prior and posterior probabilities using measures of the number of unit cells in the study area, the binary evidence maps and the mineral occurrences. In the calculations each mineral occurrence is assumed to occupy a small area or unit cell allowing the probability of a point location to be defined as the probability per unit area (*see* equation 1). The choice of the unit cell size affects the prior and posterior probability values but the weights are relatively insensitive to unit cell size and approach an asymptotic value as the unit cell becomes very small (Bonham-Carter, 1994).

The prior probability, P{D}, is calculated first. It is the expected outcome of an event in the absence of evidence (i.e., the outcome due to chance). This is calculated as the density of the mineral occurrences (i.e., number of mineral occurrences per unit area):

$$P\{D\} = N\{D\} / N\{T\} \qquad (1)$$

where,

N{D} = count of unit cells containing a deposit or mineral occurrence

N{T} = count of unit cells in the study area.

For the example shown in Figure 4, the study area is 4 km^2. The unit cell is defined as having dimensions of 0.1 by 0.1 km, which results in 400 unit cells in the study area. There are 10 unit cells containing a mineral occurrence. The prior probability is P{D} = N{D} / N{T}, where N{D}=10 and N{T}=400, resulting in P{D}=0.025. Therefore, the probability of finding another mineral occurrence in this area, based on no other evidence (i.e., due to chance), is 2.5%.

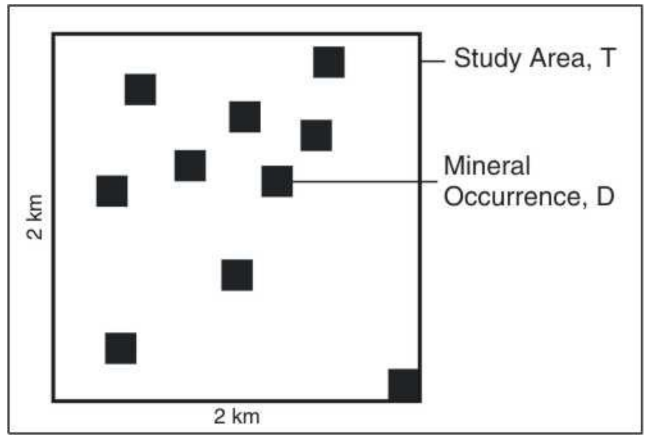

Figure 4. *Calculating the prior probability of finding a mineral occurrence, given no other information, is based on the size of the study area and the number of mineral occurrences (Bonham-Carter, 1994).*

Given some new evidence, such as the copper concentration in till, the prior probability can be updated to define the posterior probability as:

*Posterior probability = prior probability * factor for each evidential theme* (2)

where the posterior probability of D (the probability of finding a new occurrence) given new evidence B is denoted by P{D|B}, the prior probability = P{D}, and the factor = P{B|D} / P{B}. This is represented graphically in Figure 5, where the binary map and associated Venn diagram indicate the spatial association (intersection) between the mineral occurrences and the presence or absence of a theme (e.g., anomalous Cu in till). P{D} was calculated above as 0.025. The positive binary pattern B covers 100 unit cells of the total study area of 400 unit cells. There are 7 mineral occurrences intersecting the positive binary pattern (e.g., anomalous Cu in till) and 3 mineral occurrences in the negative binary pattern (e.g., background Cu in till). Therefore, the numerator of the factor P{B|D} is equivalent to $N\{B \cap D\}/N\{D\}$ = 7/10 = 0.7 and the denominator P{B} is equivalent to N{B}/N{T} = 100/400=0.25. This results in a factor of 0.7/0.25 = 2.8. Therefore, the posterior probability is the prior probability, 0.025, times the factor for that theme, 2.8, which results in 0.07. This indicates that with the presence of the binary pattern B, the probability of finding a mineral occurrence in this area has been increased from 2.5% to 7%.

To calculate the posterior probability given more than one evidential theme, the factor for the evidential themes can be converted to weights of evidence and combined by using the log-linear form of equation 2:

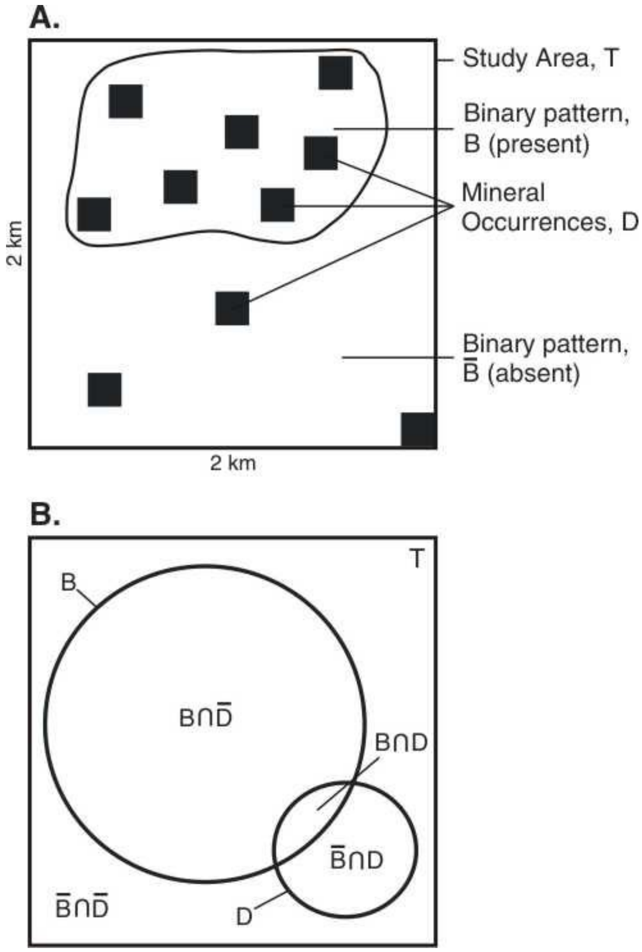

Figure 5. *These diagrams (after Bonham-Carter, 1994) indicate the relationship between a binary pattern (e.g., anomalous versus background Cu in till) and the mineral occurrences.* ***A.*** *Binary map containing 10 VMS mineral occurrences; 7 occurrences intersect the pattern B (anomalous Cu) and 3 occurrences intersect the pattern $\overline{B}$ (background Cu).* ***B.*** *Venn diagram (not to scale) illustrating the intersections between the presence and absence of the binary pattern and the mineral occurrences.*

$$\text{Posterior logit} = \text{prior logit} + \text{weight for each evidential theme} \qquad (3)$$

To determine the probability (i.e., the mineral potential) the logit is converted to odds:

$$logit = log_e\ Odds$$
$$Odds = P/(1-P) \qquad (4)$$
$$\text{so } logit = log_e\ [P/(1-P)]$$

where P is the probability of an event.

Using these concepts of the intersections between the presence and absence of binary themes and the mineral occurrences, the positive and negative weights can be calculated as follows:

$$W^+ = log_e \frac{P\{B|D\}}{P\{B|\overline{D}\}} \qquad (5)$$

where the probability P of the presence of a theme class B, given an occurrence is present, is

$$P\{B|D\} = \frac{P\{B \cap D\}}{P\{D\}}$$

and the probability P of the presence of a theme class B, given an occurrence is absent, is

$$P\{B|\overline{D}\} = \frac{P\{B \cap \overline{D}\}}{P\{\overline{D}\}}$$

$$\text{and } W^- = log_e \frac{P\{\overline{B}|D\}}{P\{\overline{B}|\overline{D}\}} \qquad (6)$$

where the probability P of the absence of a theme class $\overline{B}$, given an occurrence is present, is

$$P\{\overline{B}|D\} = \frac{P\{\overline{B} \cap D\}}{P\{D\}}$$

and the probability P of the absence of a theme class $\overline{B}$, given an occurrence is absent, is

$$P\{\overline{B}|\overline{D}\} = \frac{P\{\overline{B} \cap \overline{D}\}}{P\{\overline{D}\}}$$

Each of these probabilities is calculated similar to equation 1, where unit cells are counted and divided by the total unit cells in the study area. To generate a mineral potential map, the appropriate weights (W^+ for the presence of a theme class, and W^- for the absence of a theme class) for each layer are added to the prior logit to find the posterior logit (equation 3). The posterior logit is then converted to odds (equation 4) and subsequently converted to the posterior probability. Therefore, the posterior probability is simply a constant, which is equal to the prior probability if no evidence is known. However, given one or more evidential themes (e.g., Cu in till) the posterior probability can increase or decrease depending on the values of the weights. Missing data is assigned a weight of zero and does not affect the posterior probability.

The contrast (C) value is a measure of association between an evidential theme (e.g., Cu in till) and the training points (i.e., mineral occurrences). For a binary evidence map the contrast is defined as:

$$C = W^{+} - W^{-} \quad (7)$$

If there is no spatial association between the points and evidential theme then $W^{+} - W^{-} = 0$. Positive W^{+} values indicate that more mineral occurrences occur on the evidential theme than the number expected due to chance (e.g., more mineral occurrences are coincident with high Cu values in till than low Cu values), and negative W^{-} values indicate that fewer mineral occurrences occur on the absence of the evidential theme than the number expected due to chance (e.g., few mineral occurrences are coincident with background Cu values in till). A relatively large C value indicates a strong association and suggests that the evidential theme is a good predictor of the known mineral occurrences. The C value can also be used to help determine the threshold value with which to divide a theme (e.g., proximity to faults) into a binary map: those areas favourable for mineral occurrences (usually close to the faults) and those areas not favourable for mineral occurrences (far from faults). This will be discussed below.

The Studentized value of the contrast indicates the certainty of the contrast value C and is defined as:

$$\textit{Studentized } C = C / (\sigma), \quad (8)$$

where σ is the standard deviation of the contrast C. Since the standard deviation is dependent on the measurement units, only large values of the Studentized C (i.e., greater than 1.5) indicate that the C value is significant.

The WofE method assumes that the evidential themes have no influence on one another with respect to the locations of known occurrences (Bonham-Carter, 1994). This is often not the case in data used for mineral exploration. For example, Cu and Zn concentrations in till are often related and show the same pattern of anomalies. Including both of these conditionally dependent evidence themes would result in a mineral potential map that overestimates the posterior probability values. Thus, maps that severely violate the conditional independence assumption should be either disregarded or combined into a single map using Boolean operators (e.g., AND, OR) or principal components analysis before their use in the WofE modelling procedure. In this study, maps that show conditional dependence were reviewed and the map with the higher contrast was retained.

The digital data were organized using ArcGIS™ (8.3), ArcView™ (3.2) and MapInfo™ (5.0). Geostatistical analysis (variogram analysis and kriging) of the geochemical data was undertaken using Geostatistical Analyst™ , an add-on application to ArcGIS™. The final maps were all compiled as integer grids using ArcView™ (3.2) Spatial Analyst. The WofE analysis was conducted using Spatial Data Modeller™ (SDM; Kemp *et al*., 2001), an Avenue extension for ArcView 3.2. (available free-of-charge from *http://cgpd.cgkn.net/sdm/default_e.htm*).

STUDY AREA AND TRAINING POINTS

From the weights of evidence calculations above it can be seen that the mineral potential modelling technique is based on a study area (*see* probability calculation in equation 1), a set of mineral occurrences used as training points, and a set of binary evidential theme maps. The study area should be as small as possible to define the area of interest; terrains which may not host the chosen mineral deposit type should not be included. In this study, a preliminary assessment of the mineral occurrences indicated that the weights calculations were being diluted by the large area of sedimentary rocks between the Tally Pond and Tulks belt volcanic rocks. Only a few of the mineral occurrences occur on the edges of these sedimentary units, and therefore all major siliciclastic units were removed from the study area. The study focuses on the mineral potential of the volcanic and volcaniclastic rock types (Figures 2 and 3) which comprise an area of 1321.4 km^2.

As stated previously, the WofE method works best when focused on a specific mineral deposit type. Also, since so many evidence maps contain information from the surface (e.g., geology, till, lake sediments) rather than information at depth (e.g., drill-core information was not included) only mineral occurrences with a surface expression are included in the study. There are a total of 64 surface VMS mineral occurrences in the VLSG; 62 of which occur in volcanic rocks. To validate the final mineral potential map, a set of randomly chosen mineral occurrences were set aside as a validation dataset. From a total set of 62 mineral occurrences, approximately 25% (n=15) were set aside and the modelling was performed on the remaining 47 mineral occurrences (Table 1, Figure 6).

The analyses are best performed on gridded data rather than ArcView shape files. Therefore, a grid cell size was chosen based on the predominant locational uncertainty of the mineral occurrence sites. The locational uncertainty is available in the MODS database. Most of the uncertainties are on the order of 100 m or less, therefore, the grid cell size was chosen to be 100 by 100 m or 10 000 m^2 (0.01 km^2). This results in 132 143 unit cells in the study area. Therefore, with 47 mineral occurrences in the study area, the prior probability (the probability of finding an occurrence due to chance alone) is 47/132143 = 0.000356 (*see* equation 1).

Table 1. Surface mineral occurrences (Stapleton et al., 2000) in the Victoria Lake Supergroup volcanic rocks and within the study area

Deposit	UTM East(m)	UTM North (m)	Mineral Inventory Number	Primary Commodity	Secondary Commodity	Status*
Victoria Lake Northwest	458820	5347000	012A/05/Pyr005	Pyrite		I
Curve Pond (Green Zone)	475060	5362060	012A/06/Cu 004	Copper	Zinc	S
Dragon Pond	479900	5370570	012A/06/Cu 005	Copper		S
Henry Waters North (Vic. Lk NW)	479070	5362160	012A/06/Pyr002	Pyrite		I
Long Lake Deposit	493700	5368300	012A/06/Zn 004	Zinc	Copper, Gold, Silver, Lead	DP
Baxter Pond Zone	472670	5361670	012A/06/Zn 007	Zinc		S
Lake Douglas North	524670	5371000	012A/07/Pyr001	Pyrite		I
Tally Pond Northeast #3	540290	5388560	012A/09/Ag 003	Silver	Copper	I
East Pond Prospect	540549	5391723	012A/09/Cu 006	Copper	Zinc, Copper, Gold?	S
Burnt Pond Southwest	544991	5392966	012A/09/Cu 008	Copper		I
Trout Pond South #2	537430	5387450	012A/09/Cu 011	Copper	Zinc	I
Trout Pond South #4	537260	5387730	012A/09/Cu 013	Copper		I
Tally Pond Northeast #1	541460	5389210	012A/09/Pyr025	Pyrite		I
Tally Pond Northeast #4	539680	5389090	012A/09/Pyr027	Pyrite		I
Old Sandy Road	562750	5397350	012A/09/Pyr034	Pyrite	Copper	S
Burnt Pond Prospect	550059	5394899	012A/09/Zn 001	Zinc	Copper, Gold, Lead, Silver	DP
Tally Pond Northeast #2 (Loop Rd)	540977	5388346	012A/09/Zn 004	Zinc	Lead, Copper	S
Tally Pond Camp Showing	539860	5387740	012A/09/Zn 005	Zinc	Copper	S
South Moose Pond	544440	5392330	012A/09/Zn 009	Zinc	Copper, Lead	S
Boundary Deposit	540885	5389294	012A/09/Zn 011	Zinc	Copper, Lead, Silver, Gold	DP
Spencers Pond	520860	5372550	012A/10/Au 003	Gold		S
Rogerson Lake	518599	5376468	012A/10/Cu 005	Copper		I
Rogerson Lake East #2	522590	5374300	012A/10/Pyr002	Pyrite	Copper	I
Lake Ambrose	525300	5376450	012A/10/Pyr003	Pyrite	Copper	I
Beaver Lake South #1	522090	5377425	012A/10/Pyr005	Pyrite		I
Lake Ambrose West	523550	5376950	012A/10/Pyr006	Pyrite		I
Beaver Lake East #1	523450	5378475	012A/10/Pyr007	Pyrite		I
Beaver Lake East #2	523650	5379050	012A/10/Pyr008	Pyrite		I
Chickadee Lake West	533290	5381065	012A/10/Pyr009	Pyrite		I
Gill's Pond South Pyrite	533150	5383500	012A/10/Pyr010	Pyrite	Copper	I
Victoria River East #1	527900	5398250	012A/10/Pyr015	Pyrite		I
Red Indian Lake Southeast #2	521450	5398890	012A/10/Pyr018	Pyrite		I
Victoria River #1	523700	5395925	012A/10/Pyr019	Pyrite	Copper	I
Victoria River East #2	524725	5395550	012A/10/Pyr020	Pyrite	Copper	I
Victoria River #2	520325	5389900	012A/10/Pyr021	Pyrite		I
Bobbys Pond West Pyrite	510625	5387350	012A/10/Pyr022	Pyrite		I
Beaton's Pond	509450	5383100	012A/10/Pyr023	Pyrite	Copper	I
Harbour Round Pond	504700	5383500	012A/10/Pyr024	Pyrite		I
Cathys Pond	501290	5379960	012A/10/Pyr026	Pyrite	Gold, Copper	S
Havens Steady (Road Zone)	529700	5372000	012A/10/Pyr027	Pyrite	Zinc	I
Hoffs Pond Deposit (Bobbys Pn)	514630	5389860	012A/10/Zn 001	Zinc	Copper, Lead, Silver, Gold	DP
Bobbys Pond West Zinc #1	510850	5387000	012A/10/Zn 006	Zinc	Lead	S
Daniels Pond	507550	5385600	012A/10/Zn 009	Zinc	Silver, Lead, Copper, Gold	DP
Tulks Hill Deposit	485075	5373300	012A/11/Zn 001	Zinc	Lead, Copper, Silver, Gold	DP
Tulks East Deposit	490290	5375840	012A/11/Zn 002	Zinc	Lead, Copper, Silver, Gold	DP
Rogerson Lake East #1	518725	5374210	012A/10/Pyr001	Pyrite		I
Higher Levels Prospect	523016	5377398	012A/10/Pyr	Pyrite	Zinc	P

* I = indication, S = showing, P = prospect, DP = developed prospect

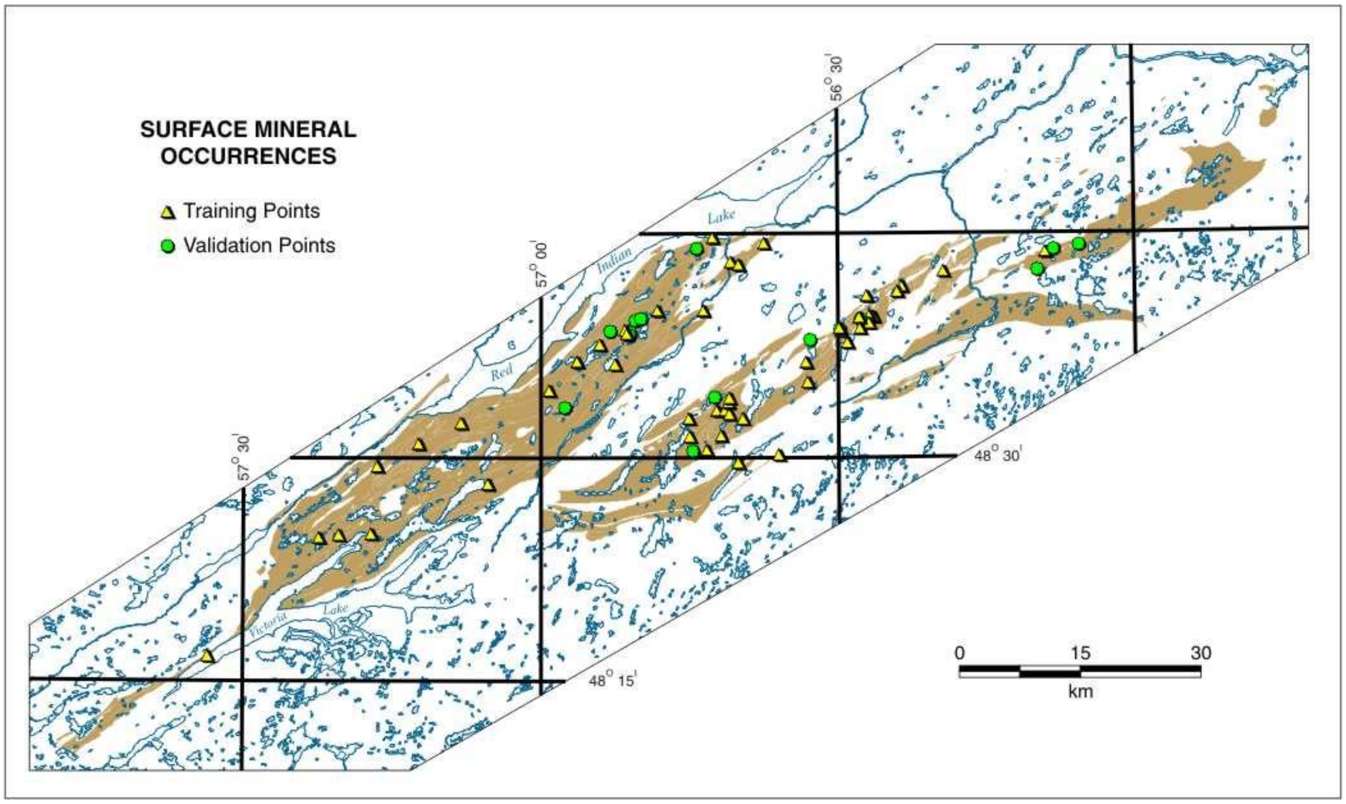

Figure 6. Location of 62 VMS surface mineral occurrences (47 training points and 15 validation points). The shaded area is the extent of the VLSG volcanic rocks.

EVIDENCE MAPS

A large number of possible evidence maps are available to include in the WofE calculation (e.g., the regional till and lake-sediment samples were analyzed for a full suite of elements, all of which could be tested). Knowledge of the VMS mineral deposit model is used to reduce the number of evidence layers to those which may have some relationship to the favourable geology, processes of mineral formation and related ore-deposit alteration. The VMS occurrences in this area were reviewed in the MODS database; specifically the sections "Nature of Mineralization and Genesis", "Geophysical Expressions" and "Geochemical Expressions". For example, the MODS database indicates that VMS mineral occurrences often occur in proximity to contacts between volcanic and sedimentary units. Therefore, these contacts were extracted and buffered to provide a proximity layer.

Prior to becoming a binary evidence map, each layer of raw data (e.g., lithological units, Cu concentrations in till, etc.) was compiled and tested in a multi-stage procedure. The first step is to compare the raw data with the mineral occurrences (training sites) to determine if there is a spatial association between the data values at the site of the mineral occurrences. The data values may be categorical (as in the case of geological units, such as felsic volcanic or mafic volcanic) or they may be continuous (as in the case of geochemical or geophysical values). If the weights indicate a spatial association exists between some of the data values (e.g., anomalous values of Cu) and the mineral occurrences, then the data is generalized to a binary map (e.g., coded 1 for the more favourable pattern area, which in this case is anomalous Cu, and coded 2 for the less favourable pattern area, which in this case is the background Cu) and the final weights for each binary code are determined. If the contrast and Studentized C values are large enough (i.e., >0.5 and >1.5, respectively as suggested in Bonham-Carter, 1994) this data can now be considered as an 'evidence' map. Once all the evidence maps have been prepared they are compared with other evidence maps, using ArcSDM, to determine if they are conditionally independent. If so, then they are combined to determine the final response theme; the mineral potential map.

Generalizing continuous data to produce a binary evidence map is accomplished by analyzing the weights for each individual class (i.e., each Cu value) and then analyzing the weights for cumulative Cu values. Groups of higher positive weights usually occur for high Cu values and indicate their positive association with the mineral occurrences.

These preliminary analyses will help to determine the optimal threshold Cu value used to convert the data to binary form (i.e., Cu values above the threshold define areas positively associated with areas containing many mineral occurrences, and values below the threshold define areas containing few mineral occurrences; Figure 5A). A similar procedure can be used to convert categorical data (e.g., geological units) into two groups to make a binary map. For example, geological units can be grouped into favourable and unfavourable units based on their individual weights indicating association with the mineral occurrences or not.

Geology Evidence Maps

The digital geology for the VLSG has been regionally compiled at the 1:50 000 scale (Colman-Sadd and Crisby-Whittle, 2002). As mentioned above, more detailed geological data is available from industry sources for most of the Tally Pond belt and environs (Figure 3). In this detailed geology, the quartz-phyric tuffaceous rocks and altered felsic volcanic rocks indicate the contemporanity with magma chambers and proximity to hydrothermal systems, respectively (Squires and Moore, 2004). This makes it essential to include the detailed geology as a separate data layer in this study.

Due to the small number of VMS mineral occurrences in the VLSG siliciclastic sedimentary rocks, these rocks were removed from the regional and detailed geology maps prior to combining the two maps to define the extent of the study area.

Both the regional and detailed geology layers were edited slightly to make sure that the geology stipulated in the MODS database at the site of the occurrence was actually present in the geology files. This problem occurred due to the small scale of the geology maps but also occurred due to generalizing the maps to 100 m grid cells, which resulted in the geology listed in the mineral occurrence dataset not matching the geology layer information. Therefore, in a few cases, the geological boundaries were moved slightly (using the outcrop locations on the original geology maps as guides) or, in the extreme case, a small lens of a geological unit was inserted in the geology maps at the location of the mineral occurrence.

In summary, the geology of the study area is represented by two separate maps; the detailed information in the Tally Pond Belt area (Figure 3) and the more regional 1:50 000 scale mapping in the rest of the study area (Figure 2). These two layers were tested separately by the WofE technique. For the regional geology, the categorical felsic volcanic and volcaniclastic units correlate favourably with the mineral occurrences (Figure 7a). For the detailed geology layer the quartz-phyric units as well as the altered felsic volcanics correlate favourably with the mineral occurrences (Figure 7b). The two geology maps were converted to binary maps and the final weights were tested. The contrast and Studentized C values are favourable (Table 2) so these two maps were included as evidence maps in the final mineral potential analysis.

Detailed information available in the MODS database (Stapleton *et al*., 2000) indicate that many VMS occurrences are in close proximity to felsic or mafic volcanic rocks in contact with sedimentary rocks. Therefore, the contacts between the volcanic and the VLSG sedimentary rocks were extracted and buffered (using 100 m incremental buffer distances) to determine the best distance threshold value to use to convert the buffered map into a binary proximity map that represents areas favourable and less favourable for mineralization. The area within 500 m of the contacts is most favourable for mineralization. However, this contact layer is conditionally dependent on many other layers including the detailed geology and the residual zinc in lake sediments. Since the binary contact map has a very low contrast (Table 2; contrast=0.69) compared to the other layers, it was removed as an evidence map. The low contrast (indicating a low positive association between the mineral occurrences and the binary contact map) may indicate problems with the small scale of mapping, the style of contact (faulted versus stratigraphic) or whether the contacts represent late, faulted juxtapositions of units with no VMS-related potential. As well, many VMS zones are associated with “sediment” horizons too small to be portrayed on the current scale maps.

The regional and detailed geology datasets also provided two scales of fault structures. The VMS deposit model presumes that proximity to some faults is considered to be significant because faults can act as syn-mineralization conduits for mineralizing fluids, or as post-mineralization structures that nucleate in the vicinity of VMS-altered rocks (Thurlow and Swanson, 1987). Therefore, the faults were buffered to determine the optimal threshold to convert the buffered map to a binary map. This optimal threshold was determined to be 900 m. A preliminary analysis of the binary fault map (where areas within 900 m of a fault are considered favourable) with the other evidence maps indicate a conditional dependence with the detailed geology map around the Tally Pond belt. Since this geology map is of major importance to this study, only the regional faults were included and the buffering was not extended into the area of detailed geology. The regional fault buffers were re-analyzed by WofE. The contrast and Studentized C values for the cumulative buffer distance away from the faults are presented in Figure 8. Even though higher contrast values occur at 3200 and 4300 m away from the faults, these thresholds had lower Studentized C values (2.20 and 1.94, respective-

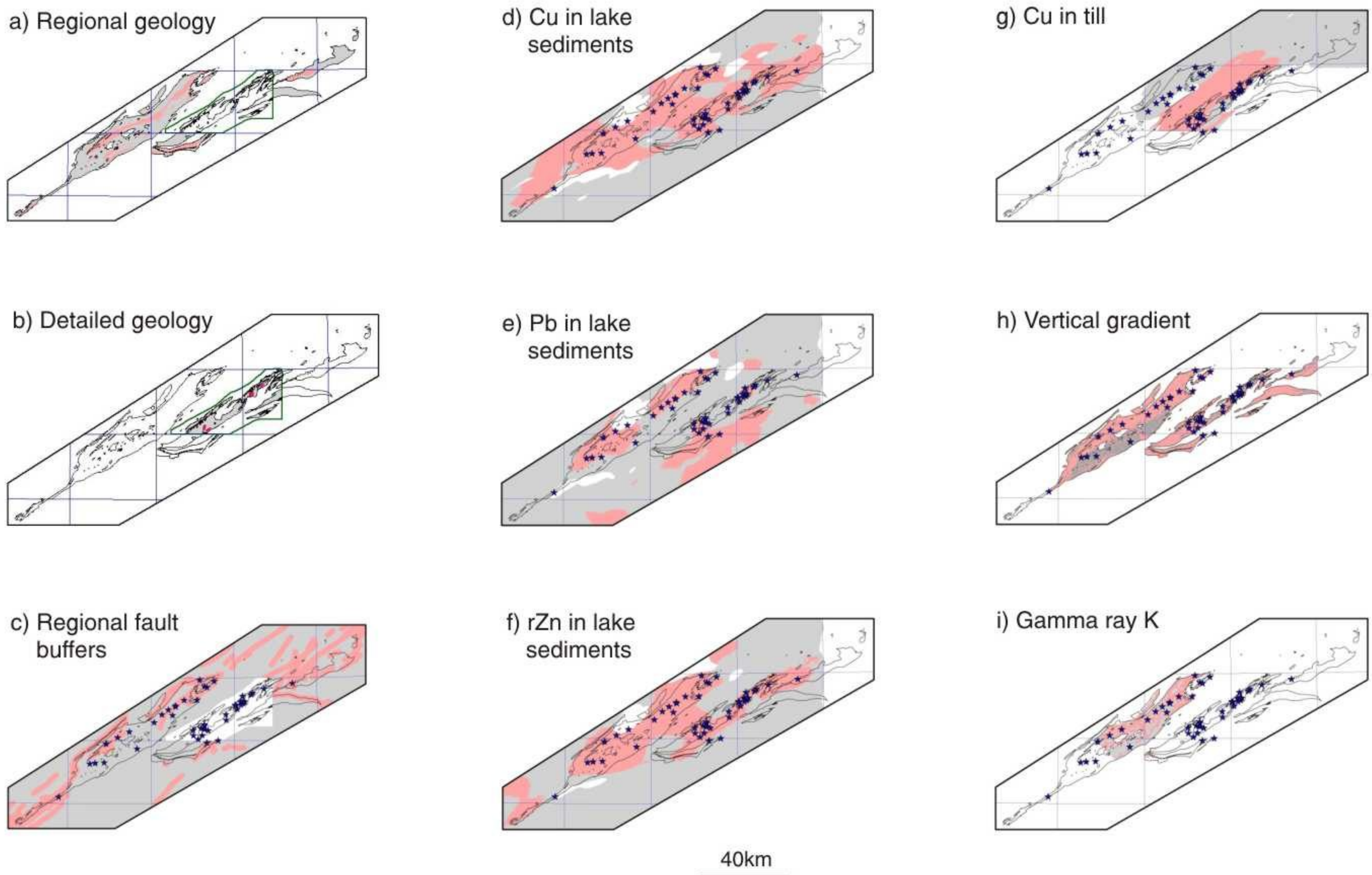

Figure 7. *Binary evidence maps indicating favourable (pink) and less favourable (grey) areas and extent of information (white represents missing data). Note that only information within the study area (outlined by the VLSG volcanic rocks) are included in the WofE calculations. Blue stars represent the mineral occurrence location.*

Table 2. Possible evidence maps analysed by WofE method to determine if they are favourably associated with mineral occurrences. The rank reflects the contrast value; the measure of association between the evidence theme and the mineral occurrences

Description	Positive Pattern	Area (sqkm)	# Points	W+	W-	C	Stud C	Rank	Comments
Geology:									
volc/sed contact buffers	<= 500 m	382.1	21	0.43	-0.25	0.69	2.34		conditional dependence with other layers
regional geology	volc fels & volcaniclastic	259.7	18	1.24	-1.43	2.67	4.83	1	total of 22 points in regional geol, area=834
detailed geology	volc fels (alt and qtz-phyric)	15.0	9	1.70	-0.38	2.08	4.98	2	total of 25 points in detailed geol, area=227.4
detailed geology	all volc fels	109.9	16	0.28	-0.36	0.64	1.54		to be consistent with regional geology
all fault buffers	<=900 m	397.5	28	0.68	-0.55	1.23	4.14		chose 900 rather than 300 to include more regional flts
regional fault buffers	<=1200 m	367.7	14	0.64	-0.60	1.24	2.80	8	regional flts, total 22 points
Geochem: Till									
till Zn	>=100 ppm	301.9	25	0.28	-0.57	0.85	2.10		includes set around Higher Levels prospect
till Pb	<=16 ppm	237.5	19	0.28	-0.30	0.58	1.61		low Pb levels related to Tally Pond, higher=Tulks
till Cu	>=75 ppm	156.1	21	0.69	-0.56	1.25	3.63	7	Tally Pond higher, Tulks lower (12 pt.missing)
Geochem: Lakeseds									
lakeseds rZn	>=48	906.1	42	0.26	-1.08	1.35	2.85	5	large area but does exclude Point of the Woods etc
lakeseds Pb	>=6 ppm	485.3	29	0.44	-0.50	0.95	3.04	9	>=4 has best C, good Sc, but area too large
lakeseds Cu	>=18 ppm	959.8	43	0.15	-1.40	1.56	2.15	3	
Geophys:									
mag vertical gradient	>=-2, <1	873.7	42	0.30	-1.16	1.46	3.09	4	
total field mag	<=-3 nT	1087.3	44	0.13	-1.02	1.15	1.93		conditional dependence with vert. gradient
Tulks gamma - K	>=4 %	262.9	12	0.43	-0.87	1.30	2.01	6	total area=504, total pnts=15 pnts=15
gravity									too regional
em									graphitic units, not levelled

ly) than the threshold at 1200 m (Studentized C value of 2.80). The 1200 m threshold also provides a more targeted favourable pattern area, than the larger areas represented by the 3200 and 4300 m buffers, and the 1200 m buffer may preferentially incorporate the small scale offsetting structures, which may be economically more important than the

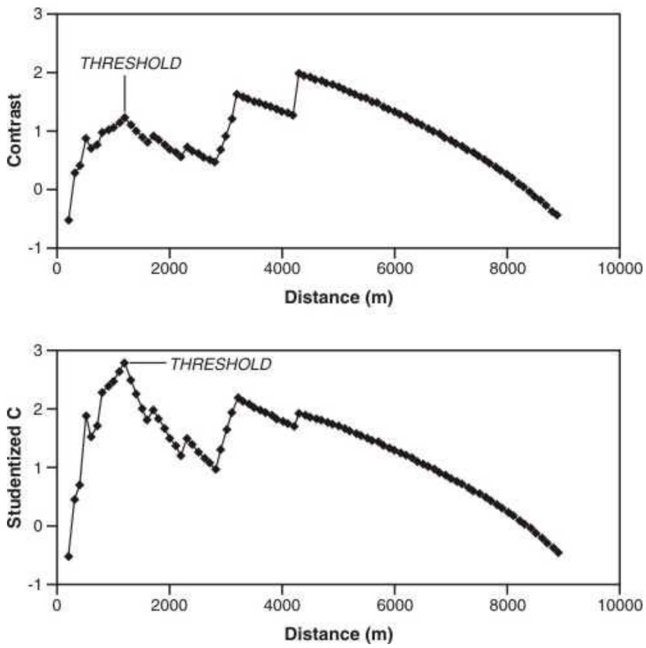

Figure 8. *Contrast (upper plot) and Studentized C (lower plot) values for the cumulative buffer distance from regional faults. The optimal threshold value is 1200 m.*

regional faults. The fault buffer map was recoded to a binary map such that a value of 1 represents favourable areas within 1200 m of a fault and a value of 2 represents less favourable areas which are more than 1200 m from a fault (Figure 7c).

Geochemistry Evidence Maps

Regional till sampling data is available for a portion of the area (Figure 7g; Liverman *et al*., 1996). Due to time constraints, only the Cu, Pb and Zn till data were processed.

A continuous gridded surface is the best type of data layer for the WofE analysis. To assess whether the till values are point representations on a continuous surface their semivariograms were analyzed (using ArcGIS Geospatial Analyst) to determine if the point values are autocorrelated (i.e., the spatial correlation of a value with itself indicating whether values close together are more similar than values further apart). The Cu, Pb and Zn till values are autocorrelated and their semivariograms were used to determine the kriging parameters to produce a continuous grid for each element. All three till elements have an anisotropic northeast trend, reflecting the main northeast–southwest glaciation and bedrock trends. An error map was used to determine the extent of the gridded extrapolation around the sample points and areas with larger errors were masked out. The weights for the three gridded maps (Cu, Pb and Zn) were determined in the WofE program with the result that only Zn and Cu in till have favourable areas associated with the mineral occurrences. The cumulative values were checked and the optimal thresholds were determined. The continuous gridded maps were generalized to produce a binary map for each element. On testing for conditional independence with all other evidence maps, the Zn and Cu binary maps did show some dependence with each other, therefore, only the 'Cu in till' binary map (Figure 7g) was accepted as an evidence map as it has the higher contrast value (1.25 versus 0.85; Table 2).

Regional lake-sediment samples for the map area NTS 12A were extracted from the Geoscience Atlas of Newfoundland (Davenport *et al*., 2002). Again, due to time constraints only the Cu, Pb and Zn lake-sediment data were processed. The possible problem of lake effects on the metal values (e.g., due to adsorption on organics or hydroxides of Fe and Mn) was tested using the procedure described in Davenport *et al.* (1974). High correlations (r>0.7) between the logged values of Cu, Pb and Zn with Fe, Mn and loss-on-ignition (a measure of organic content) would indicate adsorption problems. Only logZn was highly correlated with logFe and logMn so residual Zn values (rZn) were calculated and, along with Cu and Pb, interpolated using the method described below.

Ordinarily, the drainage basins of the sampled lakes would be used to represent the area of influence of each element value, but the drainage basin boundaries were not available in digital form, so the lake sediment Cu, Pb and rZn values were gridded by first analyzing their variograms (using ArcGIS Geostatistical Analyst™) to determine if the data are autocorrelated. All three lake-sediment elements are positively autocorrelated and interpolated grids were produced. The variogram analysis, to determine the kriging parameters, indicated that the data has an anisotropic northeast trend, again reflecting the northeast trend in the bedrock and possibly the northeast trend in the glacial dispersion. An error map, produced as part of the gridding procedure, was used to determine the extent of the gridded extrapolation around the sample points and areas with larger errors were masked out (Figures 7d, e and f). The weights for the three gridded maps were determined using the WofE program. The results indicate that all three elements, Cu, Pb and rZn in lake sediments, have favourable patterns (anomalous areas) associated with the mineral occurrences (Table 2). On testing for conditional independence, the three elements showed no dependence with other evidence maps, so all three were accepted as evidence maps.

Geophysics Evidence Maps

A review of the 'Geophysical Expression' section in the MODS database indicated that total field magnetic data was relatively 'flat' in areas of VMS mineral occurrences, whereas gravity data indicated positive mineral occurrence associations with gravity values greater than 0.3 mGal. A

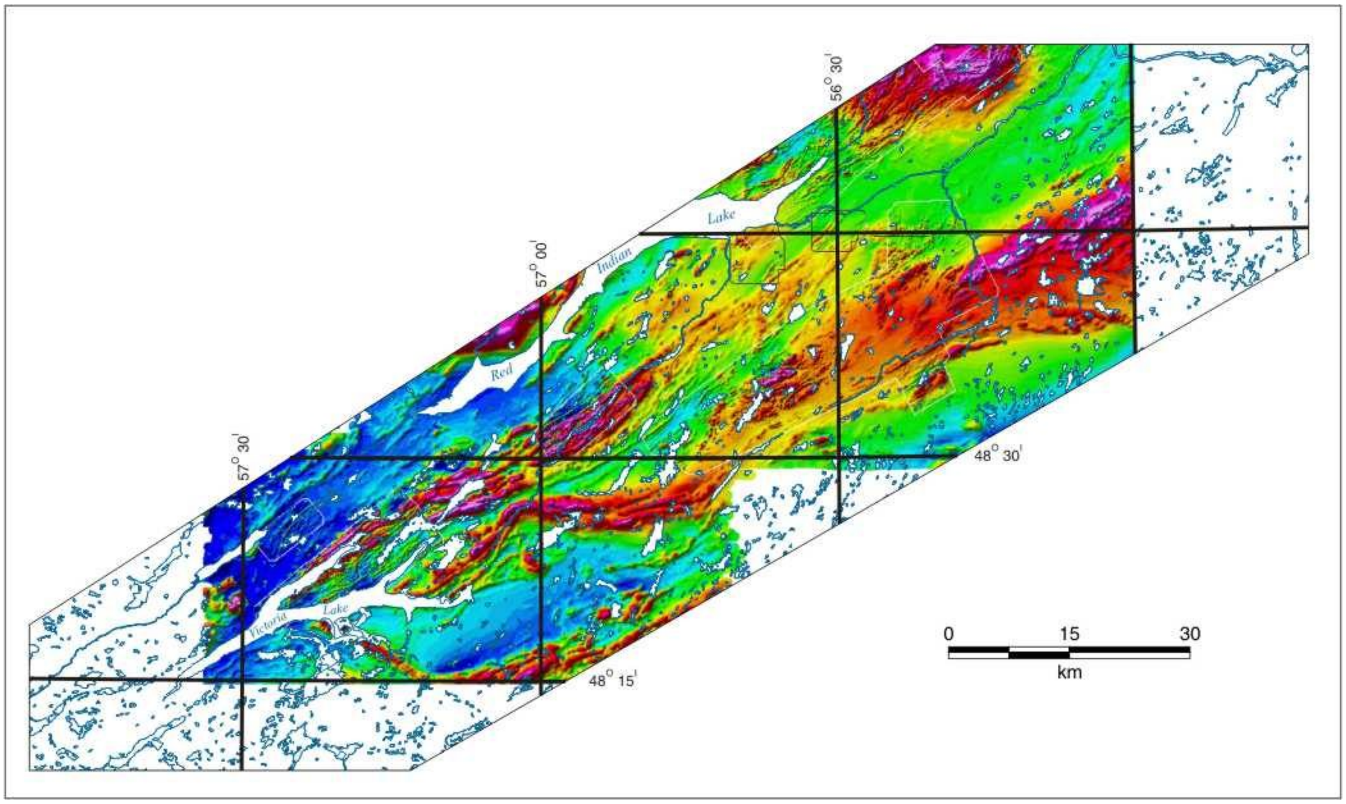

Figure 9. *Red Indian Line airborne magnetics compilation (Oneschuck* et al., *2002). Grid outlines indicate where the detailed industry surveys were merged into the regional GSC data. Data range is approximately -465 nT for dark blue to 540 nT for purple.*

review of the geophysical data in other VMS districts (e.g., Bathurst New Brunswick, *see* Keating *et al.*, 1998) indicated some association with the magnetic vertical gradient data.

Regional aeromagnetic and gravity data is available in digital form for the study area. However, the GSC, along with the NL Geological Survey, compiled and levelled some detailed industry-sponsored aeromagnetic data with the regional GSC data for the Red Indian Line compilation in the map area NTS 12A (Oneschuk *et al*., 2002). This data covers most of the study area (Figure 9). The gridded data was converted to integer values because the SDM program can only handle integer data. The total field magnetic data was analyzed by WofE and values less than -3 nT indicated some favourability with mineral occurrences (Table 2).

The magnetic vertical gradient data was calculated from the aeromagnetic data (Newfoundland Department of Natural Resources). This data was multiplied by 10 to convert to integer values. The WofE analysis indicated the vertical gradient theme has favourable weights for values around 0 nT/m. Since the vertical gradient is highly correlated with the aeromagnetic data, only one layer could be included as an evidence map; the magnetic vertical gradient (Figure 7h) was chosen as this has the higher contrast value (1.46 versus 1.15 for the total field magnetics).

Noranda Inc. completed detailed airborne surveys over the Tally Pond belt in 1988 (Oneschuk *et al.*, 2001). The contacts of the graphitic argillite units were mapped from the locations of the EM conductors obtained from these airborne surveys. An original error in the positioning of this survey with respect to the drainage resulted in an error in the location of the contacts between the graphitic argillites and other units. These contacts (or faults) are locally in error by up to several hundred metres (determined by G. Squires using ground survey data). This locational error may affect the weights and final mineral potential depending on the relative location of the mineral occurrences and other evidence maps. The compiled airborne total field magnetic data (Oneschuk *et al.*, 2002) for the same area have been corrected for this displacement.

EM anomalies, as point data, were also compiled as part of the Red Indian Line project (Oneschuk *et al.*, 2001). This information was not levelled with respect to the various industry grids and could not be used as such in this study.

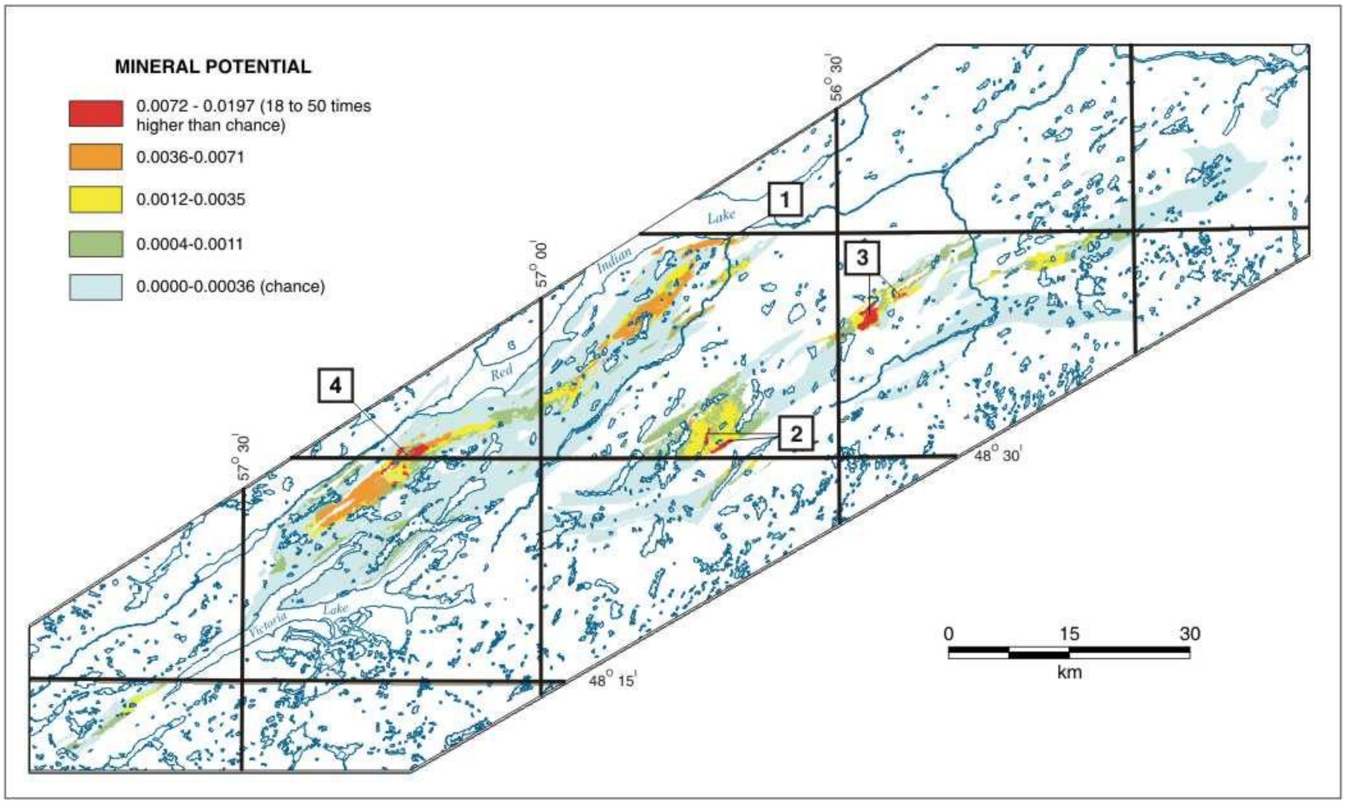

Figure 10. *Final mineral potential map for VMS mineral occurrences in the Victoria Lake Supergroup volcanic rocks, based on nine evidence maps consisting of geology, geophysics, lake and till sediments. Areas labelled 1 to 4 have the highest mineral potential and are discussed in the text.*

Information from VMS deposits at Bathurst, NB, indicate that sulphides occurring at surface in felsic volcanic units can be mapped using gravity surveys (Thomas, 1998). But mafic volcanic and gabbroic rocks can also produce positive gravity anomalies that can be mistaken for sulphide occurrences (Keating *et al*., 1998). In the VLSG area, the regional gravity data available from the GSC was tested. This data did not show any relationship with the mineral occurrences, probably because the gravity data points are too widely spaced and only show regional trends in gravity. This data was not used as an evidence map in this study.

Another survey conducted by the GSC was the Tulks Belt gamma ray survey flown in 1991 (Ford, 1991). The average altitude was 125 m and the flight line direction was northwest–southeast at a spacing of 500 m. The gamma ray information represents data from the top 30 cm of the Earth's surface and represents an average radioactivity from outcrop, overburden, vegetation and moisture content (Carson *et al.*, 2003). Potassium values were measured directly but the uranium and thorium values were calculated equivalents measured from their daughter products (Ford, 1991). Ground gamma ray surveys by Ford (1993) indicated that variations in the radioactivity do represent a lithologic component. As well, potassic alteration can be identified as low values on eTh/K ratio maps (Ford, 1993). Due to time constraints, only the gamma ray K data was used in this study. The range of values are from about 0 to 2%. The WofE analysis indicated gamma ray K values greater than 0.4% showed some positive correlations with the mineral occurrences in this area (Figure 7i; Table 2).

RESULTS

Fifteen data layers were tested by the WofE method to determine if they are positively spatially associated with the VMS surface mineral occurrences. Of the fifteen data layers tested, nine layers are significantly associated with the mineral occurrences and so were considered as evidence maps to be combined by Bayesian probability methods into a final mineral potential map (Figure 10). These evidence maps consist of (in decreasing order of their Contrast values) regional geology, detailed geology, Cu in lake sediments, magnetic vertical gradient, residual Zn in lake sediments, gamma ray K, Cu in till, regional faults and Pb in lake sediments. None of the evidence maps cover the entire study area (Figure 7). The test for conditional independence indicated that the final nine evidence maps are independent.

The final mineral potential map has four areas with relatively high potential for VMS mineral occurrences; defined here as ranging from 18 to 50 times higher than chance (Figure 10).

Area 1 is about 1 km southwest of the Red Indian Lake Southeast #2 occurrence (in the vicinity of the Victoria Mine west occurrences and within 1 km of the Victoria Mine prospect). It is a very small area, but out of the nine evidence maps used, only one is missing in this area (detailed geology) and all others have favourable weights. This area has a mineral potential about 50 times higher than chance and the immediate surrounding area has a potential about 10 to 20 times higher than chance.

Area 2 is in the region of the Spencers Pond, Rogerson Lake and Lemarchant occurrences in the Tally Pond belt. The Lemarchant occurrence was not included in the training points as it is defined by drill results at depth. This area consists of six evidence maps that overlap (Cu, Pb and rZn in lake sediments, Cu in till, detailed geology and vertical gradient) and all six maps have favourable weights for this area, combining to form a high mineral potential. The other three evidence maps are missing in this area. This area has a mineral potential about 30 times higher than chance.

Area 3 is in the region of the Tally Pond/Boundary deposits. The same six evidence maps present in Area 2 also overlap in Area 3 with all six having favourable weights. This area is bounded to the north and south by graphitic argillites. The contacts of these graphitic units were mapped using EM conductors and may be in error by up to several hundred metres (see section on Geophysics Evidence Maps). However, Area 3 is approximately 2 km wide so most of the anomalous area is located accurately. This area has a mineral potential about 27 times higher than chance.

Area 4 is in the vicinity of the Tulks Hill Deposit and has a mineral potential 25 times higher than chance. There are seven overlapping evidence maps present in this area (Cu, Pb and rZn in lake sediments, proximity to regional faults, regional geology, vertical gradient and gamma ray K) and all seven have favourable weights. The other two evidence maps are missing in this area.

As an independent check on the measure of credibility of the WofE results presented above, the posterior probability was extracted at the site of the 15 validation mineral occurrences (i.e., those not included in the WofE analysis) and compared with the posterior probability of 16 randomly selected sites not associated with any known mineralization. One would expect that the randomly selected sites would have a wide range of posterior probabilities (mineral potential) and the mineral occurrence sites would have a smaller

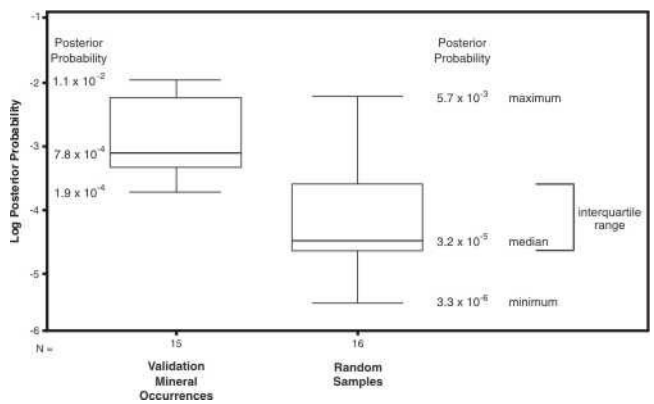

Figure 11. *Box-and-whisker plot comparison of the posterior probability at the 15 validation mineral occurrence sites with 16 randomly selected sites not associated with mineralization.*

range with higher posterior probabilities. This is borne out by the results shown in the box-and-whisker plots (Figure 11) where the validation mineral occurrences have a distinctively higher posterior probability than most of the random samples.

Fifteen layers of information were analyzed by WofE and nine were determined to be of use in producing a mineral potential map. The data preparation and analysis took time and effort. A further WofE analysis was conducted using only four evidence themes from the readily available digital lake-sediment and till datasets (Davenport *et al*., 2002) to determine if the results provide similar favourable target areas as the results from the nine evidence maps. Since the previous analysis of Pb in till did not indicate any positive weights and the Zn in till correlated highly with the Cu in till, only the Cu in till and Cu, Pb and rZn lake sediments were used. The resulting 'till/lake sediment' (T/LS) mineral potential map (Figure 12) indicates higher potential in two areas of the Tally Pond belt and a broad area in the Tulks belt. These higher potential areas on the T/LS map are only two to four times more than expected due to chance but still roughly correspond with the high mineral potential Areas 2, 3 and 4 on Figure 10.

DISCUSSION AND CONCLUSIONS

The final mineral potential map is a combination of nine binary evidence maps that show favourable association patterns with the VMS surface mineral occurrences. The favourable evidence maps are, in order of decreasing favourability, regional geology, detailed geology, Cu in lake sediments, magnetic vertical gradient, residual Zn in lake sediment, gamma ray K, Cu in till, regional fault proximity and Pb in lake sediments. This indicates that a variety of

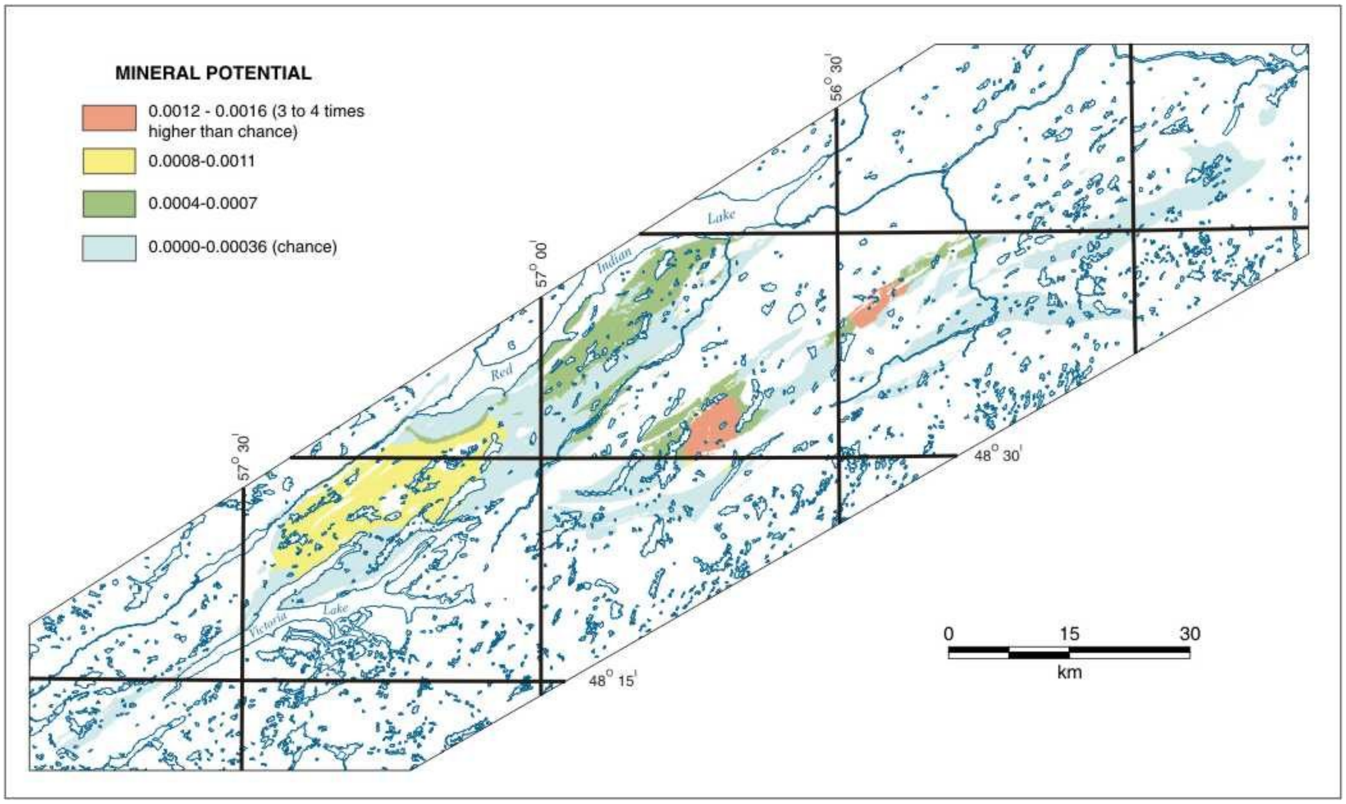

Figure 12. *Mineral potential map based on four evidence maps: Cu, Pb and rZn in lake sediments and Cu in till.*

exploration techniques are helpful in delineating favourable mineral potential areas but that a favourable geological environment is probably the most important component.

There are four areas of high mineral potential (arbitrarily defined as greater than 20 times the probability due to chance). All four areas (Figure 10) have a previous history of being highly prospective. Area 1 coincides with the Jig Zone (a prospect) and is within 200 m east of the Victoria Mine (a developed prospect). Neither of these two occurrences were used as training points in the WofE analysis as they did not have surface expressions. Area 2 is within 300 m of the Lemarchant Prospect, which was also not part of the WofE training set. Area 3 coincides with the Boundary desposit and various Tally Pond northeast occurrences (all included as WofE training points). The Duck Pond Deposit is to the southwest of Area 3. It is in an area with a mineral potential of only about 10 times higher than chance, but this lower mineral potential is a surface expression that may reflect the location of the deposit more than 200 m below the surface. Area 4 coincides with the Tulks Deposit and the Tulks West Prospect. The Tulks Deposit was included as a WofE training point but the Tulks West Prospect was not. In general, the fact that the WofE model identified several prospects that were not part of the training set as being associated with high mineral potential can be viewed as a success for the WofE approach.

The areas with moderate mineral potential (orange and yellow areas on Figure 10; 3 to 20 times higher than chance) along the Tulks belt, between areas 1 and 4, have proven occurrences such as the Tulks East Deposit, Jack's Pond Deposit, Daniels Pond Prospect and Hoffs Pond Deposit. Only the Jack's Pond Deposit was not included as a WofE training point. This suggests that even those areas that have a mineral potential as low as three times higher than chance still define a more focused area for targeting exploration.

The lake-sediment (Cu, Pb and rZn) and till (Cu) evidence maps combined to provide a mineral potential map with many of the same regional areas of high mineral potential as those identified by the analysis using all nine evidence maps. The lake-sediment and till data are readily available for many areas of the Province and they can serve as an excellent source of data for an initial, less intensive style of WofE analysis (i.e., a reasonable preview of mineral potential is possible without having to prepare all nine of the evidence maps). This approach would benefit from more complete coverage of regional till sampling, especially along the southwest Tulks belt, which would reduce areas with missing data (i.e., increasing the weights calculated from the evidence maps and, therefore, increasing mineral potential where anomalies occur).

In this study, the gamma ray K data (Ford, 1993) proved to be a good evidence map. Analysis of other data acquired during the same survey, such as the eTh/K ratio, which reflects K alteration (Ford, 1993), may provide an even better evidence map to be used in the WofE model. Extending the gamma ray survey over the rest of the Victoria Lake Supergroup would remove the areas with missing data and potentially increase the mineral potential where anomalies occur.

Overall, the mineral potential modelling results do provide a focus for continued or further exploration in the vicinity of the areas of high mineral potential. Incomplete coverage of the existing till survey, the gamma ray survey and the detailed geological mapping have the effect of neither upweighting nor downweighting the mineral potential in the areas where these surveys are missing. Completing the coverage of these surveys over the whole of the Victoria Lake Supergroup would provide a more balanced analysis with no areas of missing data. Also, due to time constraints, all of the voluminous data available for the area (e.g. in assessment report on file at the Department of Natural Resources) could not be included in this study. Given a new, poorly explored study area which has the potential for a VMS deposit in a similar geological environment, and given the same nine evidence maps, the mineral potential model developed in this study can be applied through the ArcSDM program, using the existing weights tables, to provide a mineral potential map of this new area of interest. In this regard, the WofE model can be readily generalized to evaluate new areas of interest.

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