Controls on volcanogenic massive sulphide mineralization in the Kamiskotia area, Ontario, Canada: insights from lithogeochemical analysis and mineral prospectivity modelling

Samuel E. K. Tetteh[1*], Stefanie M. Brueckner[1,2], Lionel Bonhomme[3], John Ayer[2], Jeff Harris[2], Ross Sherlock[2]

[1] University of Manitoba, Department of Earth Sciences, Winnipeg, Canada; [2] Laurentian University, Harquail School of Earth Sciences, Mineral Exploration Research Centre, Sudbury, Canada; [3] International Explorers & Prospectors Inc., Timmins, Ontario, Canada

*Corresponding author: tettesek@myumanitoba.ca

1. Geological context

The Kamiskotia area, Ontario, Canada, is dominated by the Blake River (2704 – 2696 Ma) and Kidd Munro (2719 – 2711 Ma), bimodal assemblages of tholeiitic basalts intercalated with abundant high-silica FIII rhyolites (Fig. 1). Other Neo-Archean assemblages in the area include the Deloro, Tisdale, and Porcupine. The area is one of Abitibi's VMS hosting districts.

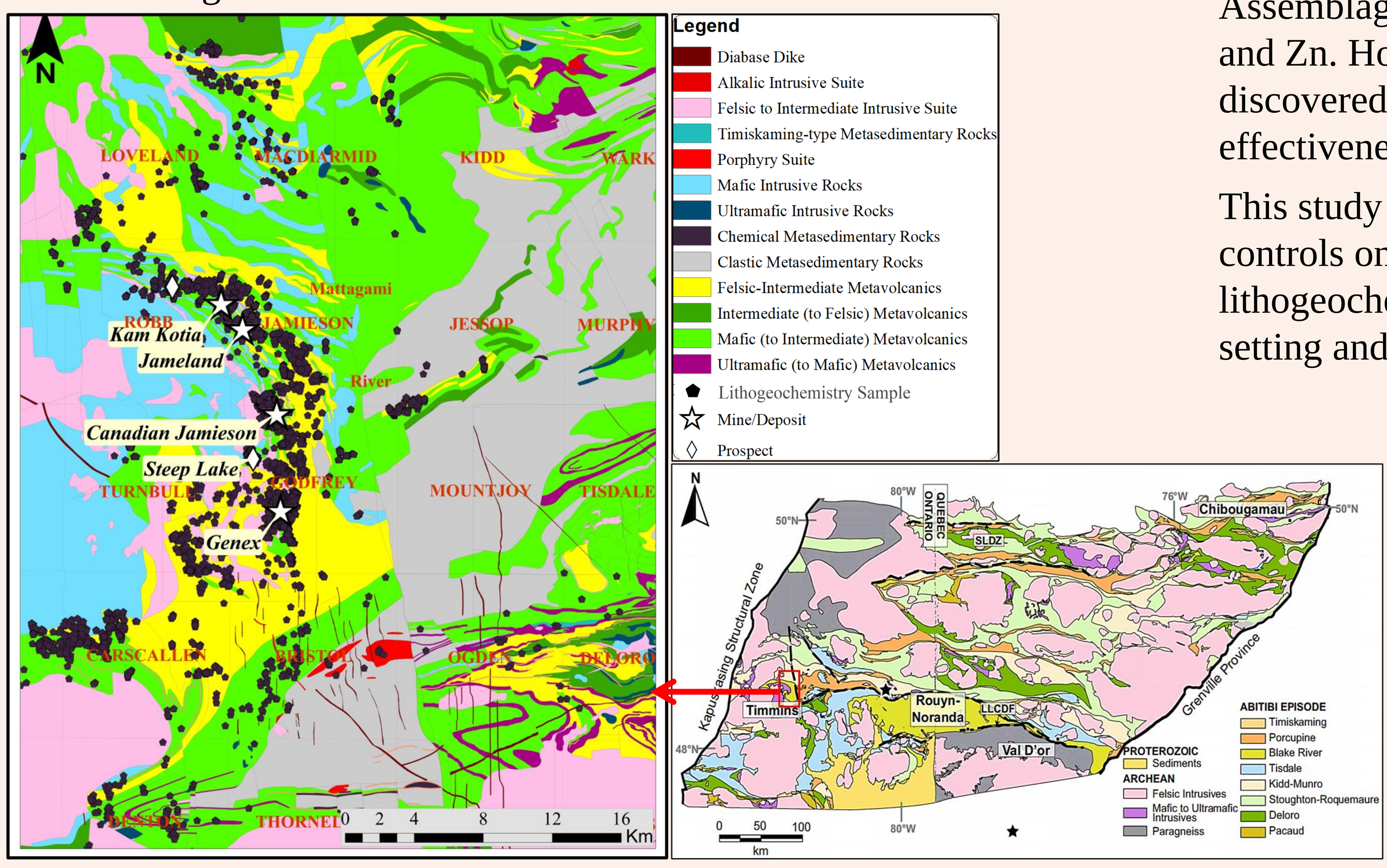

Fig. 1. Rock types in the Kamiskotia area.

2. Background

Bimodal mafic Cu-Zn ± Au ± Ag VMS deposits in the area share similarities regarding (i) their host lithologies (i.e., bimodal assemblage), (ii) alteration (i.e., proximal chloritic - distal sericitic alteration), (iii) morphology (numerous small dipping lenses), (iv) stratigraphy (i.e., restricted < 150 m stratigraphic interval), and (v) ore assemblage (i.e., pyrite, pyrrhotite, chalcopyrite, sphalerite) (Barrie, 2000; Hathway *et al*., 2008).

Based on these observations, it is likely that the Kamiskotia Volcanic Complex (correlated to the Blake River Assemblage) hosts yet unidentified VMS deposits that would contribute to the increasing metal demand of Cu and Zn. However, given the extensive overburden cover and the fact that most near-surface deposits have been discovered and exploited, new approaches such as mineral prospectivity modelling are required to increase the effectiveness of exploration.

This study seeks to address this need using a large geochemical dataset with other geoscience data to outline controls on VMS mineralization in the Kamiskotia area. Also, the project will constrain ore assemblage, lithogeochemistry, and potentially geochronology on the Genex deposit to contribute to age, lithology, tectonic setting and mineralogy of the Kamiskotia Volcanic Complex

3. Approach

- Identify **key geochemical features** (e.g., magmatic affinity, rhyolite type) through analysis of a lithogeochemical database with 10357 samples
- Identify **alteration trends** (e.g., boxplot, molar K/Al vs Na/Al plot), especially in units that are geochemically and stratigraphically similar to known VMS host units
- Produce 3D models (metal grades, alteration and geology)
- Produce **mineral prospectivity maps** through machine learning techniques to delineate potential exploration targets

4. Results

The units are tholeiitic to transitional basalts, basaltic andesites, and rhyodacites. The mafic units have contaminated (i.e., Th/Nb ratio) MORB-like magma affinities (Fig. 2) and Fe-Ti signatures (i.e., P_2O_5 > 0.3 wt %, TiO_2 > 2.2 wt %; Fig. 3). Rhyolites are of high-silica and high-Zr FIII-FII type (Fig. 4). These geochemical signatures are similar for all sampled assemblages. Cu, Zn, alteration indices, and the key geochemical signatures have strikingly similar spatial distributions (Fig. 5).

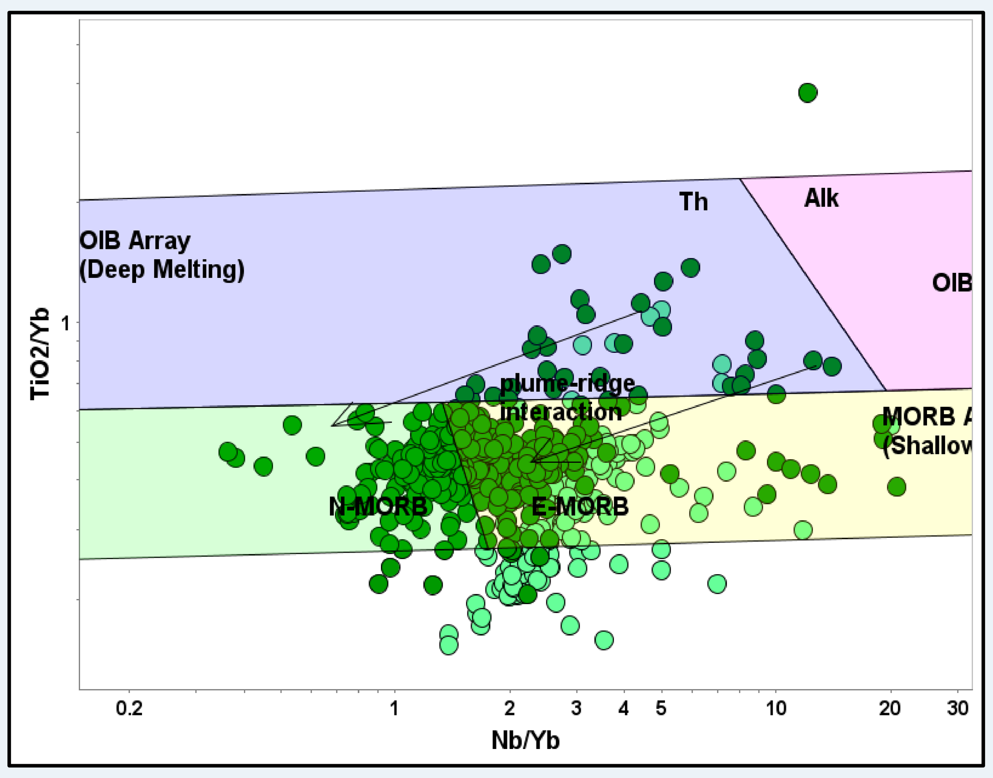

Fig. 2. TiO_2 /Yb vs. Nb/Yb plot (*after* Pearce, 2008) for mafic-intermediate rocks showing a dominant MORB signature.

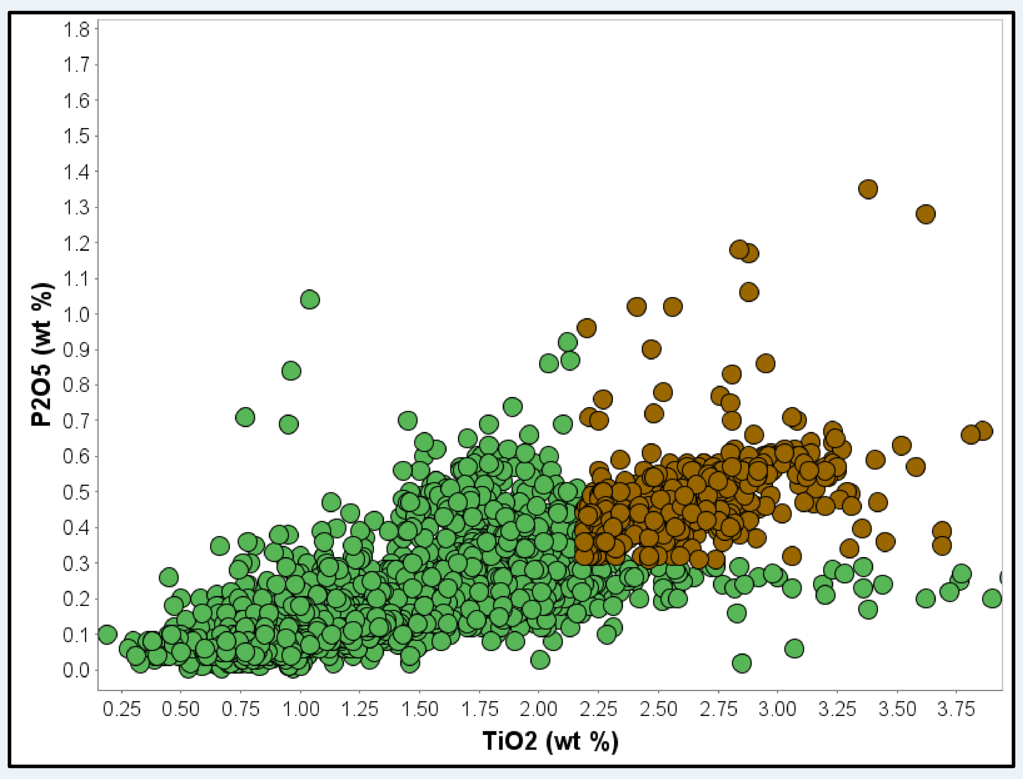

Fig. 3. P_2O_5 Vs. TiO_2 plot showing Fe-Ti (evolved) mafic units with P_2O_5 > 0.3 wt %, TiO_2 > 2.2 wt %, and higher Fe_2O_3 and Zr than primitive units.

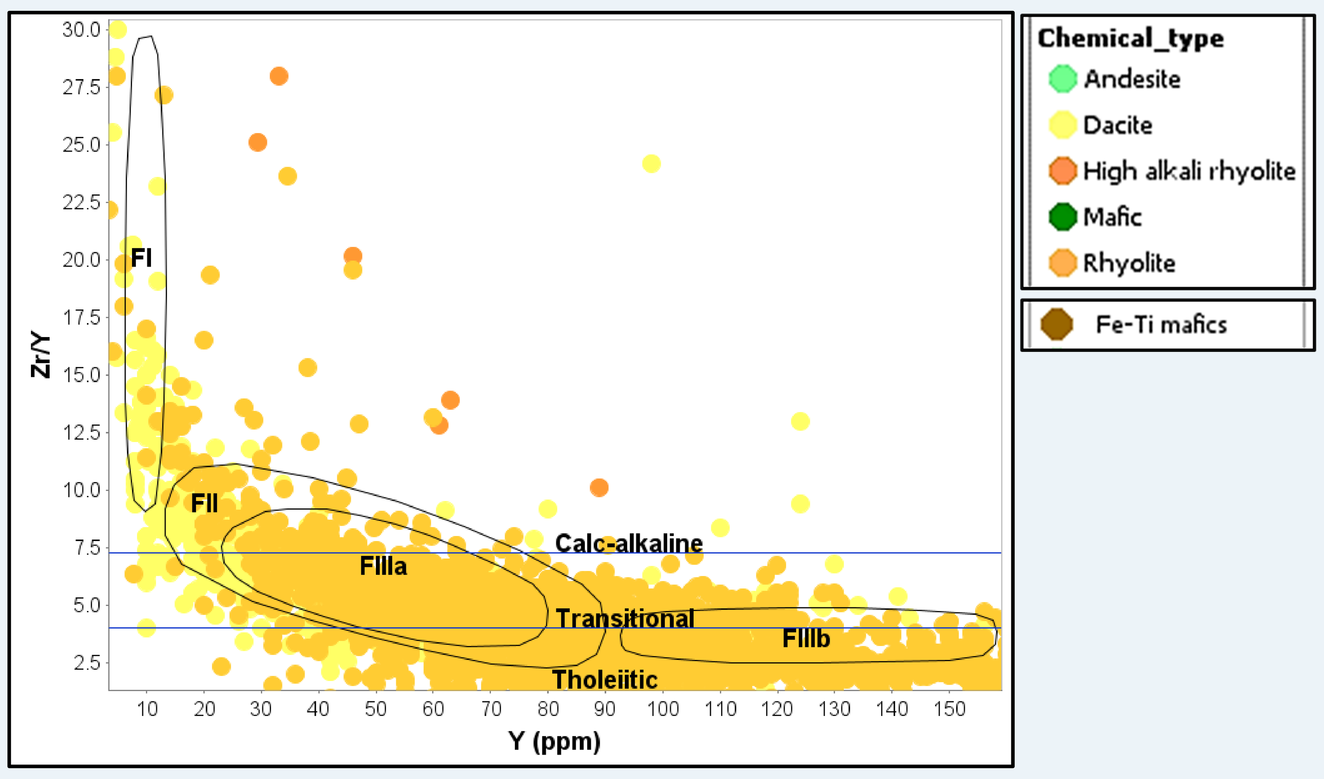

Fig. 4. Zr/Y vs Y plot (after Lesher *et al*., 1986) displaying different rhyolite types. FIII and FII rhyolites host the most VMS mineralization in the Abitibi greenstone belt.

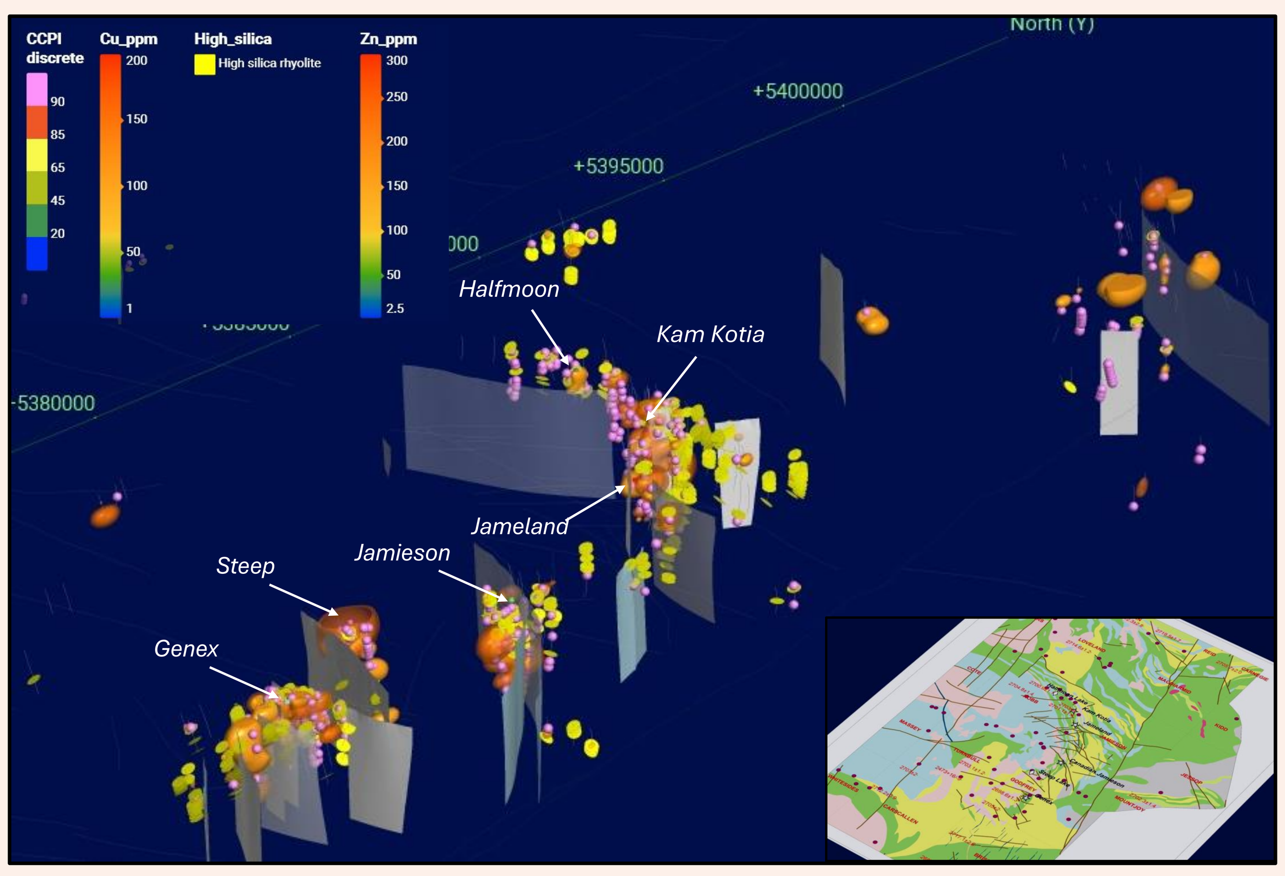

Fig. 5. A 3D LeapFrog numerical model of Cu and Zn showing potentially anomalous areas in orange. These areas coincide with zones with strong hydrothermal alteration signatures (i.e., CCPI), favourable geochemical signatures (i.e., high silica rhyolites) and synvolcanic faults (i.e., light grey planar surfaces).

40 evidence layers (i.e., predictors maps) were generated from available geoscience data, in binary and continuous forms (Fig. 6). A Random Forest (RF) algorithm was employed to integrate these layers using 44 known mineralization locations. The resulting probability maps are used as prospectivity maps (Fig. 7).

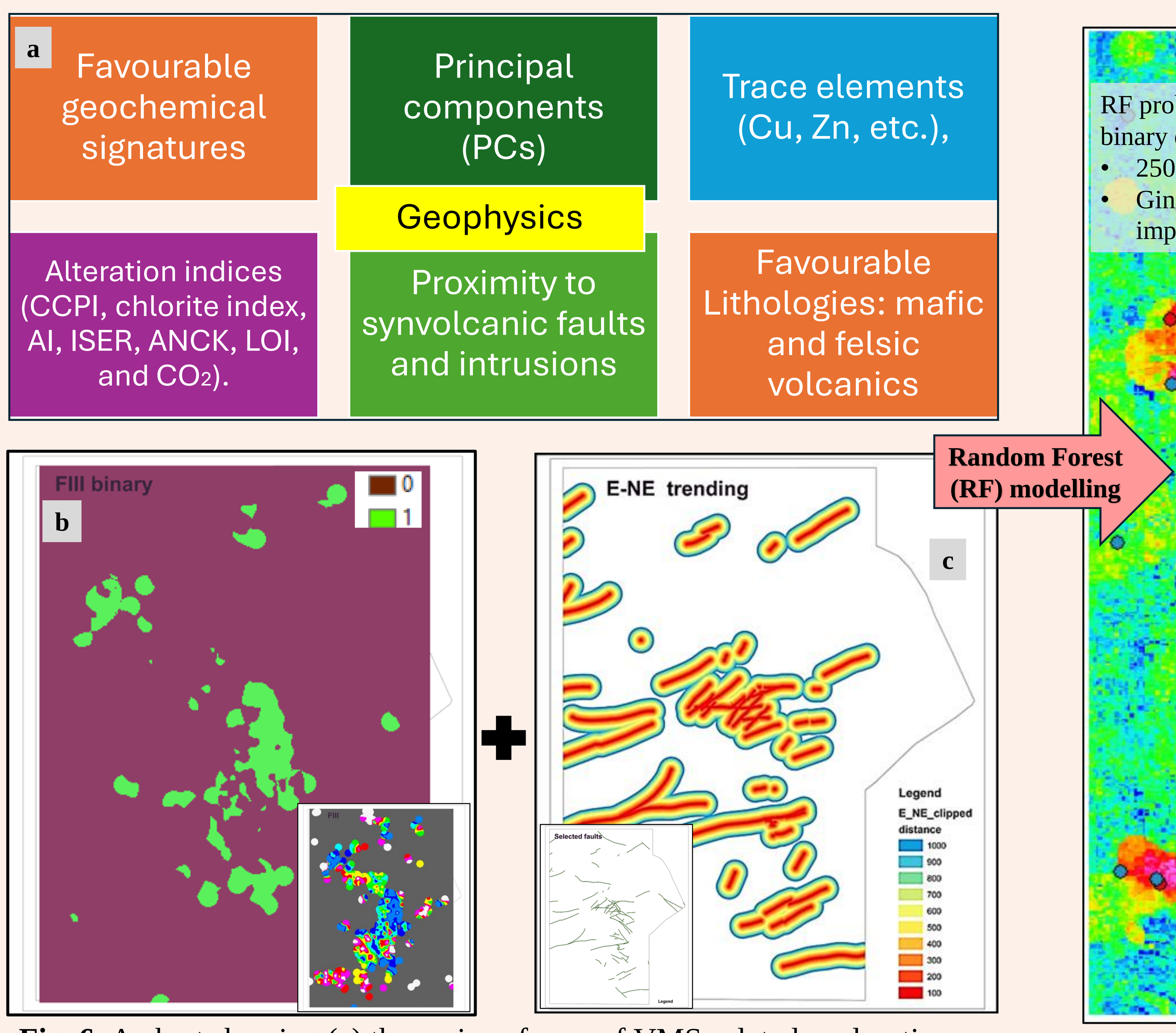

Fig. 6. A chart showing (a) the various forms of VMS-related exploration data selected and processed into predictors for RF modelling, with examples for (b) binary (FIII rhyolites where 0 = non-anomalous and 1 = anomalous) and (c) continuous (east-northeast trending faults) forms of evidence maps.

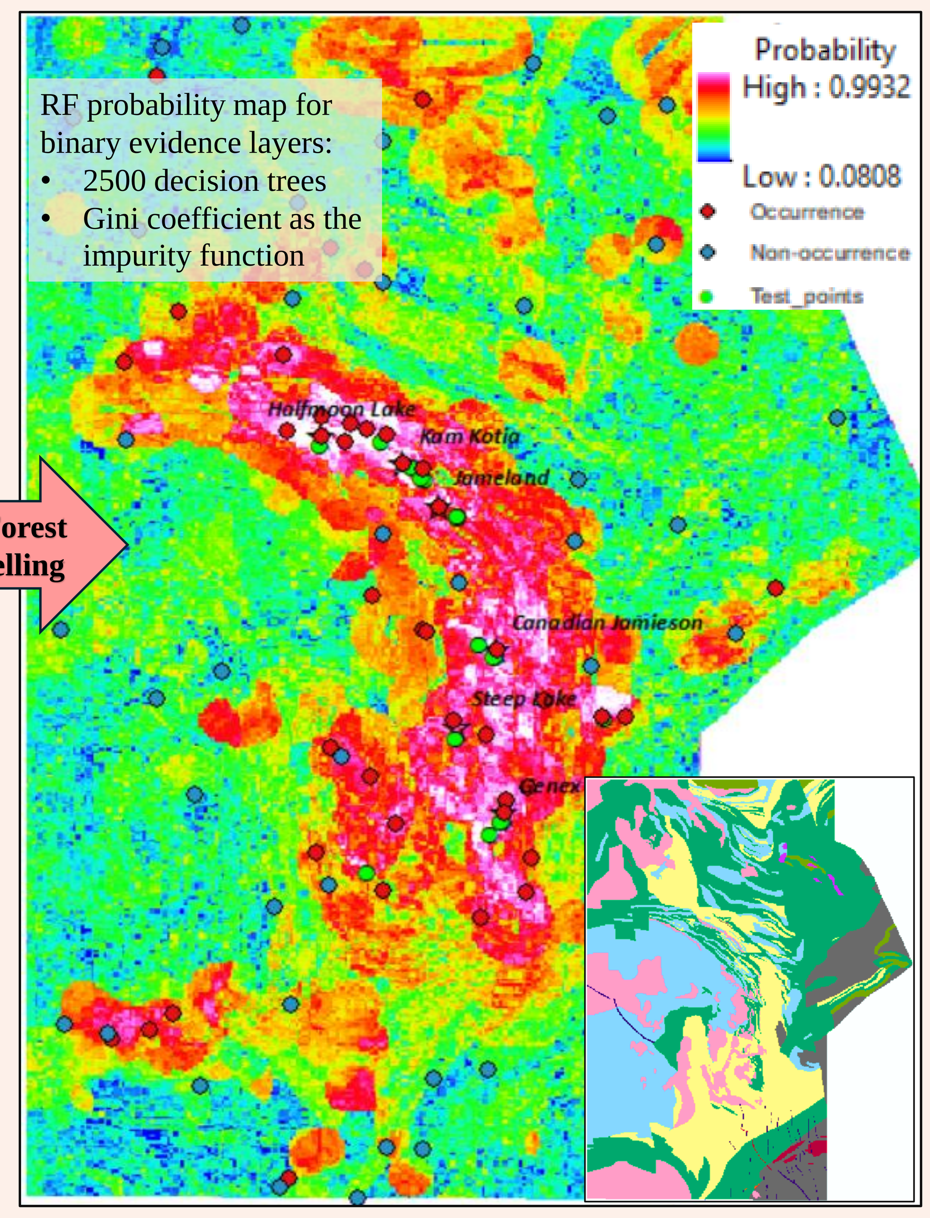

Fig. 7. An RF probability map, with 86.8 % overall accuracy, accurately predicts known mineralization sites and suggests new areas that may be of potential for VMS.

5. Conclusions

- Mafic and felsic rock geochemistry reveals a **favourable setting for significant VMS mineralization**.
  - Contaminated MORB signature: shallow-rifted setting, high heat flow, interaction with existing hydrated crust.
  - Fe-Ti mafics: restricted to the immediate hanging wall of VMS mineralization.
  - Felsic rock signatures: within-plate signatures, HFSE and REE enrichment, and high-silica FIII-FII affinities.
- Evidence layers show **good spatial relationships with known VMS mineralization sites**.
- Preliminary **RF prospectivity maps accurately predict known VMS sites** and outline new areas.
- Next: finalize RF modelling and evaluate model performance using area-under-curve in Area-Frequency curves

References

- Barrie (2000). Geology of the Kamiskotia area. OGS Study 59.
- Hathway *et al*. (2008). *Economic Geology*, *103*(6), 1185-1202.
- Pearce (2008). Lithos. Vol. 100, pp. 14-48.
- Lesher *et al*. (1986). *Canadian Journal of Earth Sciences*, Vol. 23, pp. 222-237.

Acknowledgments

This work has been funded by the Metal Earth at MERC and NSERC Discovery grant to SMB. The project has also been supported by IEP and Melkior. The lithogeochemical database for this project was prepared by Timothy Barrett.