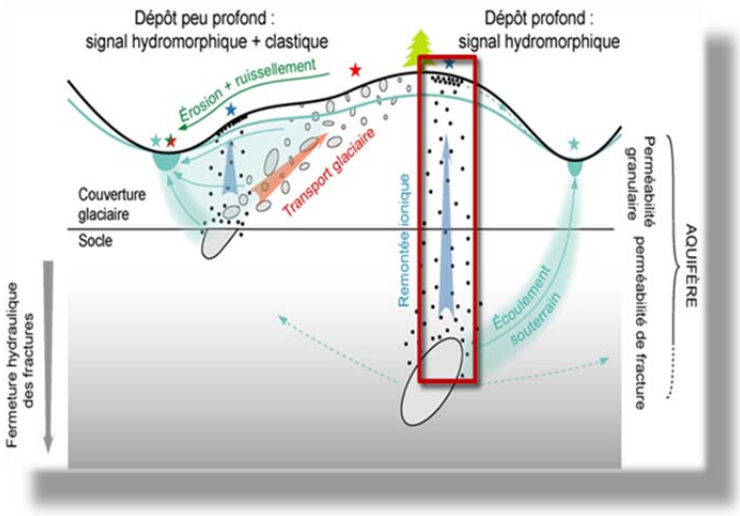
2010-07: Detecting deposits under glacial overburden using the MMI method: synthesis, case studies, perspectives

Mobile Metal Ions (MMI) is a proprietary method falling into the SWE category (Selective and Weak Extractions) and targeting the exogenous metallic phase of the sampled environment, transported from its source in dissolved form in the phreatic system (hydromorphism). Importing the MMI method from Australia to Canadian contexts reveals two critical problems: 1. the ability to accumulate detectable metal concentrations in the soil since the last deglaciation; 2. the typical inconstancy of boreal pedogenic profiles. Particular attention was paid in this study to the following two points: 1. pH anomalies in the soil and resulting chain reactions; 2. impact of the great variability in the sampled pedogenic level on the obtained results, in other words, the influence of soil composition (mineral phases, metals) on MMI levels.



An illustration of different anomaly dispersion processes in a secondary environment.

The accumulation of H^+ ion concentrations in soils located directly above sulphide deposits is itself an exploration tool. The Cross Lake VMS in Ontario located under 30 metres of glacial fluvio-lacustrine sediments is an example. Here we can see major visible redistributions of various soil components susceptible to pH-Eh variations, forming so called indirect metal anomalies generated by a local redistribution of elements in the soil.

A quantitative analysis of the correlations between two metal concentrations obtained using MMI and traditional Aqua Regia methods (AqR) was carried out on 814 samples collected on 8 traverses in the Timmins and Kirkland Lake districts (MRD 200). The comparison of the MMI and AqR concentration profiles and the MMI content *vs* AqR content binary diagrams shows a very marked positive correlation with respect to base metals Cu, Ni, Zn and precious metals Au, Ag. These correlations are also very clearly visible in principal component (PC) analysis. For base metals, the first factor of PC analysis (≈ 50% of the variability) is similar to the degree of pedogenesis (Al, Fe gain and Ca, Mg, K loss), which also relates to the nature of the pedogenic level sampled. Moreover, base metal content obtained using AqR correlate extremely well with the clay index ($\sum Al_{norm}$, K_{norm}, Mg_{norm}), which implies that they are concentrated in the phyllosilicates in the soil and proves that they are endogenous. **It follows from these observations that the concentration in endogenous metals exerts a dominant control on the MMI concentrations for both base and precious metals.**

Different secondary controls are identified for each element, essentially involving the pH and the presence of carbonates. The analyses of three separate case studies (Ontario, British Columbia) show positive correlations for Cu, Ni with pH, and negative correlations for Pb, Zn. Furthermore, MMI-Zn contents are systematically and very significantly anti-correlated with the carbonate content in the

sample, which appears to be an artefact of the MMI-A analytical protocol; the acid extraction is neutralised by the presence of carbonates (protocol modified in 2008).

Therefore the identification of an exogenous signal in the MMI results need to be processed to overcome the so-called external controls (that is to say, not directly related to the underlying mineralisation). The influence of endogenous metal content can be processed by a simple linear MMI-*X* / AqR-*X* normalisation. In contrast, the non-linear and non-universal nature of the relationship between MMI levels and pH or carbonates requires the use of multivariate regression. It is recommended here to simultaneously process all external controls within the same multivariate regression, using the following independent variables: AqR-Al and -K (phyllosilicates), AqR-Ca and -Mg (carbonates), AqR-*X* (endogenous metals), pH and/or MMI-Ca and -Mg. This type of processing was carried out on two witness surveys conducted directly above known deposits: the Cross Lake zinc-bearing VMS and the Mt Mulligan copper porphyry (British Columbia). For Cross Lake we show that the MMI-Zn apical anomaly is perfectly reproducible using a combination of the investigated variables. Therefore, there is a purely indirect anomaly. H^+ is the only direct anomaly. Signal processing at Mt Mulligan reveals two clearly visible MMI-Cu anomalies directly above the suboutcropping mineralised zone, anomalies slightly or not observable in the raw signals.

Every observed MMI-Au anomaly where the source of the gold could be identified is situated in a context of surface showings with absent or proximal glacial sediments, which confirms that the metals sampled are endogenous (clastic transport or not transported). **Therefore, the advantage of the MMI method over conventional methods in gold exploration is not proven in the cases studied** (MRD 200 data; Tommy vein deposit, Larry vein and Ted vein deposits, British Columbia).

Project 2010-07: Summary	
Objectives	• To assess the effectiveness of the MMI method for mineral exploration in Canada.
Results	• Effectiveness of implanting the MMI method in Canada is hampered by critical points: o Widespread presence of very recently transported overburden. o Variability of pedogenic profiles and drainage conditions. • Sampling depth appears to be the main source of variability for MMI signals: o "Fixed depth" sampling protocol is called into question. o Soil composition must be processed to differentiate exogenous signals. • Endogenous metal concentrations (clastics) exert excellent control on MMI levels. • Base metals: secondary controls are non-linear and different for each metal, involves carbonate content and pH. • Base metals: protocol proposed for analytical processing using multivariate regression on variable pH and soil composition (phyllosilicate content, carbonates and endogenous metal concentration). • Base metals: analyses using conventional methods (AqR) must be carried out in conjunction with MMI surveys to conduct analytical processing. • Routine measurement of soil pH recommended, (Eh, loss on ignition, conductivity) for direct exploration and processing. • Au: the advantage of MMI over conventional methods (AqR) was not proven in the cases studied.
Innovations	• Detailed analysis of case studies on the MMI results and validation of methodologies.