

# Whole Rock $\delta^{18}\text{O}$ and $\delta^2\text{H}$ Isotopic Footprint of the Canadian

## Malartic Deposit, Abitibi sub-province, Québec

Thomas Raskevicius<sup>1</sup>, Georges Beaudoin<sup>1</sup>, Kurt Kyser<sup>2</sup>

<sup>1</sup>Université Laval, Québec, Québec, thomas.raskevicius.1@ulaval.ca, <sup>2</sup>Queens University,

Kingston, Ontario

### Research Question

Can whole-rock  $\delta^{18}\text{O}$  and  $\delta^2\text{H}$  values of hosting Pontiac metasedimentary host rocks map the fossil hydrothermal footprint of the Canadian Malartic deposit? And will the isotopic footprint have applications to real world exploration programs searching for analogous deposits?

### Introduction

The Canadian Malartic deposit is a world class resource of 10.1 Moz of gold. Located in the Superior province of Québec, the Canadian Malartic deposit is dominantly hosted by the metasedimentary rocks of the Pontiac group (Fig 1). The Sladen fault is a splay of the Cadillac-Larder Lake fault system, located within the Pontiac group and near the contact with the mafic to ultramafic rocks of the Piche Group. This structure also seems to have acted as the primary flow conduit for the mineralizing fluid. As a result of fluid-rock interaction, gold has been disseminated throughout country rocks dominantly south of the Sladen fault.

### Methods

144 Samples have been collected from the area surrounding the Canadian Malartic deposit. The majority are being processed at the Queen's Facility for Isotope research in Kingston, ON using conventional  $\text{BrF}_5$  reaction yielding free oxygen [1] and heating samples to 1475°C to liberate  $\text{H}_2(\text{g})$  [2] followed by IRMS for both elements. The Isotope data will be integrated with whole rock lithochemical data in order to map and understand the isotopic variation throughout the deposit's footprint (Fig 1). Presented herein is a comparison of select samples of Pontiac metasedimentary greywackes along the N-S traverse. The two sample sets compared are labeled "Rock" and "Rock+Veins." The set labeled "Rock" represents whole rock samples of metasedimentary greywackes with quartz veining cut away. And the set labeled "Rock+Veins" represents whole rock assay pulps collected circa 2008 by the Canadian Malartic mine including all vein material. The purpose of this work is to (1) gauge the applicability to real world exploration programs and if valuable isotopic data can be retrieved from pre-existing sample libraries, (2) outline the outer limit of the fluid/rock reaction shell, and (3) devise new exploration criteria for similar gold deposits.

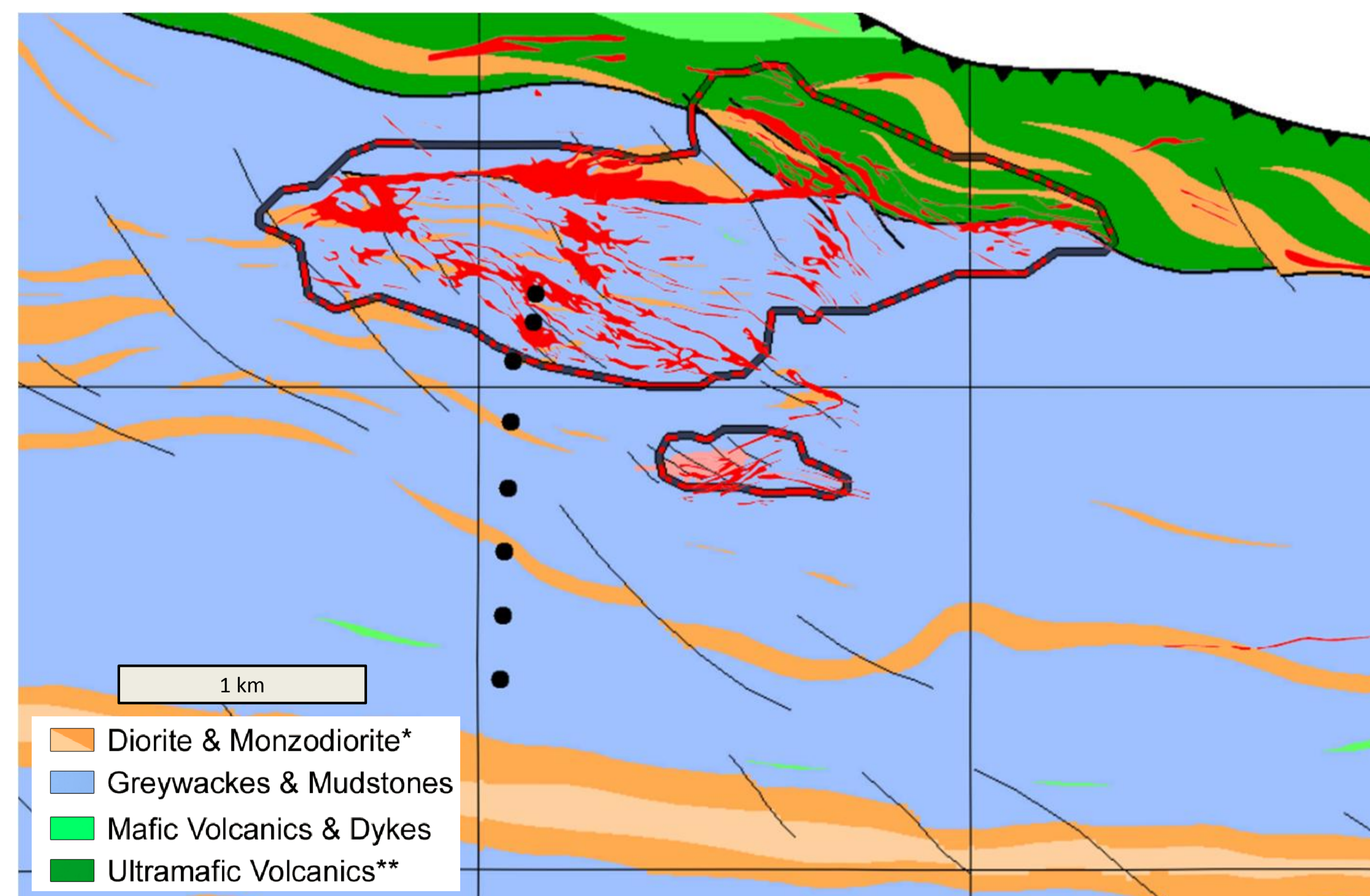


Figure 1: Map of the geology surrounding the Canadian Malartic deposit. Black dots mark sample locations along the N-S transect. Red area encircles the domain >300ppb Au.

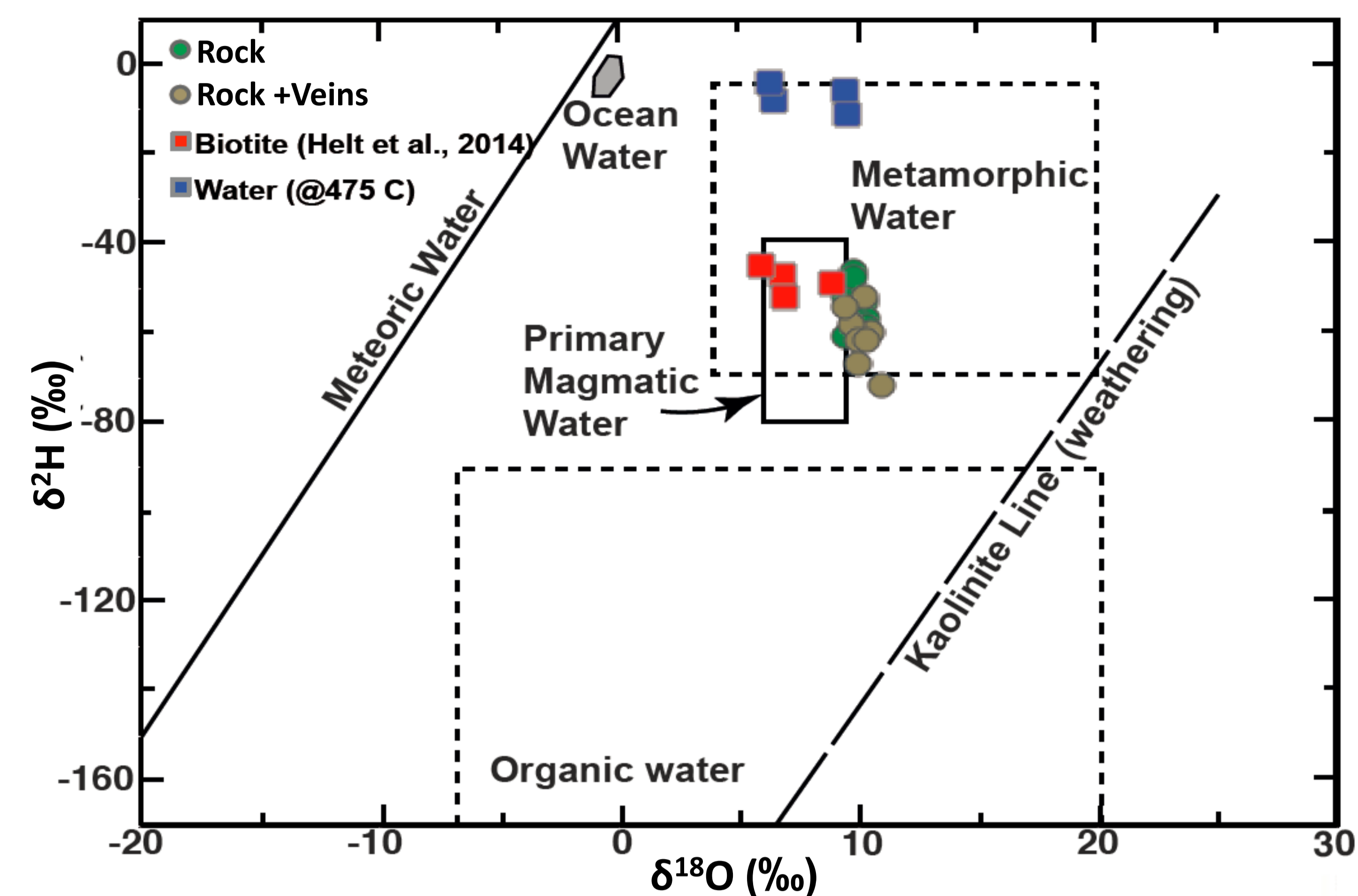


Figure 2: Whole rock O and H isotopic composition of Rock+Vein and Rock samples along the N-S section. Vein biotite from the deposit and the calculated composition of the equilibrated fluid are plotted for comparison [3;4].

### Results

Compared to the calculated Malartic water value, whole rock samples  $\delta^2\text{H}$  values plot at about 50‰ lower and have similar to slightly higher  $\delta^{18}\text{O}$  values (Fig. 2). Whole rock isotopic data from Canadian Malartic's sample library and samples taken for this research are compared to see if quality isotopic data can be retrieved from an existing sample library. There seems to be a systematic difference attributed to by hydrous phases between Rock and Rock+Vein samples. Fig. 3A shows Rock samples are enriched in  $\text{H}_2\text{O}$  by up to 2%. Fig. 3B indicates Rock samples are systematically lower in terms of  $\delta^2\text{H}$  by 5-10‰. Fig. 3C indicates a negative trend of  $\delta^2\text{H}$  with % $\text{H}_2\text{O}$  throughout the footprint of the deposit. Spatial variations are similar with distance from the deposit for both sample sets.  $\delta^{18}\text{O}$  variations out from the deposit are not significantly different between the two sample sets. The most obvious differences are observed in  $\delta^2\text{H}$  and % $\text{H}_2\text{O}$  data. Fig. 3E indicates that samples within the Malartic pit have markedly lower  $\delta^2\text{H}$  values than samples from the footprint, and that there exists a negative trend between in  $\delta^2\text{H}$  and distance from the deposit. Both Fig. 3E and 3F show that spatial  $\delta^2\text{H}$  and % $\text{H}_2\text{O}$  variation is mirrored in the two sample sets, but, Rock samples are systematically lower in terms of  $\delta^2\text{H}$  and higher in terms of % $\text{H}_2\text{O}$ . In both cases, there appears to be a domain of low % $\text{H}_2\text{O}$  within 1.5 km of the deposit (Fig. 3F). Current work on the remaining 128 samples will extend the study area beyond the one transect enabling the surface mapping of fluid-rock interaction and alteration of the footprint.

### Discussion

Given biotite is the dominant hydrous mineral in our whole rock samples, hydrogen isotopic fractionation between the rock and calculated fluid should be close to the fractionation between biotite and the fluid. (i.e. for hydrogen  $\Delta_{\text{rock-fluid}} \approx \Delta_{\text{biotite-fluid}}$ ). Overall, the observed hydrogen isotopic fractionation between the fluid and whole rock samples is about -50‰ which puts the temperature of equilibration at 400°C [5]. The temperature of 400°C concurs with the difference between whole rock and fluid  $\delta^{18}\text{O}$  values, as the fractionation between plagioclase (a proxy for the whole rock) and fluid is small at that temperature. The variability in whole rock  $\delta^2\text{H}$  indicates that rocks throughout the footprint have equilibrated with Malartic water between 350°C-400°C. The higher  $\delta^2\text{H}$  values of rocks proximal, but outside the pit suggest either an increase in temperature (and less fractionation) towards the deposit, or equilibration with another fluid (Fig. 3). Similarly low  $\delta^2\text{H}$  values from in-pit samples suggest lower temperatures or, more likely, interaction with another fluid imparting a lower  $\delta^2\text{H}$  value.

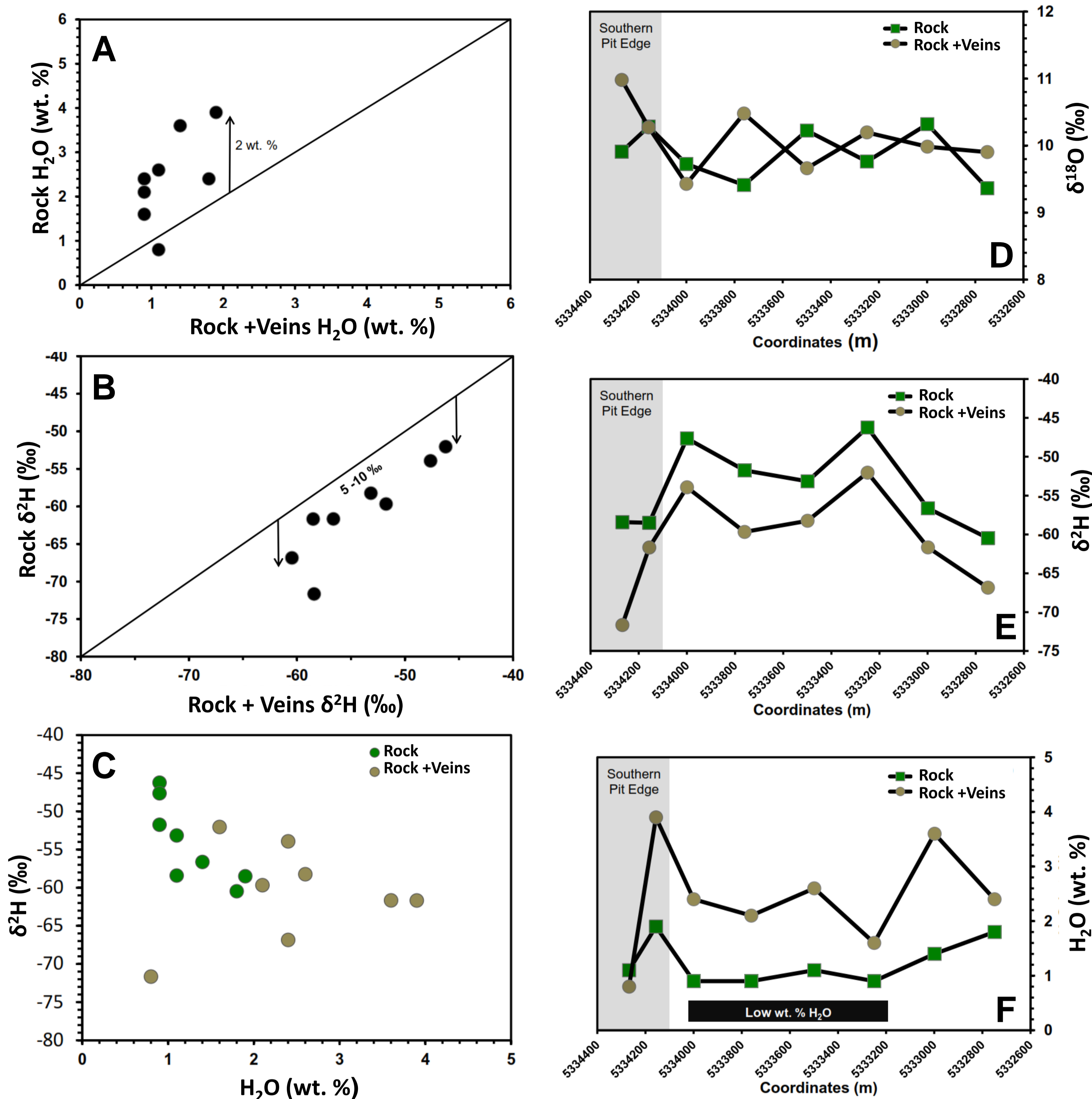


Figure 3: Comparison of whole rock isotopic and wt%  $\text{H}_2\text{O}$  data from Rock+Vein and Rock samples. (A) Rock+Vein versus Rock wt%  $\text{H}_2\text{O}$  data. (B) Rock+Vein versus Rock  $\delta^2\text{H}$  comparison (C) Plot of % $\text{H}_2\text{O}$  vs.  $\delta^2\text{H}$  for both sample sets. (E) Spatial variation of  $\delta^{18}\text{O}$  data along the N-S section (F) Spatial variation of  $\delta^2\text{H}$  data along the N-S section. (F) Spatial variation of wt%  $\text{H}_2\text{O}$  along the N-S section.

### Discussion Cont.

Compositional differences between Rock+Vein and Rock sample sets may be ascribed to their sample size and constituent material. Rock+Vein samples are larger (>1.5m cores) and contain veins, Rock samples are smaller <75cm cores that have had vein material cut away. The systematic increase in  $\delta^2\text{H}$  observed in Rock+Vein samples may be attributed to the presence of hydrous phases such as vein biotite with a high  $\delta^2\text{H}$ . The decrease in % $\text{H}_2\text{O}$  observed in Rock+Vein samples may be explained by dilution of hydrous phases with an increase of quartz veins. Moreover, in all cases, the data from Rock samples is significantly more variable (Fig. 3D,E, and F) Increased variability may be a reflection of the significantly smaller sample size as compared to Rock+Vein samples.

### Conclusion

The isotopic composition of samples from the Malartic footprint could have equilibrated with the Malartic fluid reported by previous studies [3;4] at a temperature range from 350°C to 400°C. Additional samples will help to elucidate the source of observed variation in whole rock isotopic composition throughout the footprint. General isotopic trends over the N-S transect out from the Malartic deposit are mirrored in both Rock and Rock+Vein sample sets. Hydrogen isotopic composition wt%  $\text{H}_2\text{O}$  content are similar for the two sample sets, although data points are systematically shifted due to the presence of vein material. The comparison suggests that particularly with respect to hydrogen isotope systematics, that valuable data can be sourced from existing sample libraries. However, in order to fully understand the fluid rock interaction and the controls on whole rock isotopic variation vein free samples are better suited. The mapping of the isotopic footprint and of the fossil hydrothermal system surrounding the Canadian Malartic deposit will be determined using whole rock vein free samples.

### Acknowledgments

Many thanks is given to Stephane Perrouy and Nicolas Gaillard who were involved with sampling compiling the supporting data for this project. Also, acknowledgement is given to the long list of researchers and sponsors involved with the CMIC and NSERC who made the Footprints research network possible. *CMIC-NSERC Exploration Footprints Network Contribution 044*

### References

- [1] Clayton RN Mayeda TK 1963 Geochim. Cosmochim. Acta v.27 p.43-52
- [2] Sharp et al. 2001 Chem Geol v.178 p.197-210
- [3] Helt K. et al. 2014 Econ Geol v109 p713-735
- [4] Beaudoin G & Raskevicius T 2014 Econ Geol v109 p2067-2071
- [5] Suzuoki T & Epstein S 1976 Geochim. Cosmochim. Acta v40 p1229-1240
- [6] Matsuhsia et al. 1979 Geoch. Cosmochim. Acta v43 p1131-1140
- [7] Bottinga Y & Javoy M 1973 Earth Planet. Sci. Lett.v20 p250-265