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Refining ore exploration using equilibrium thermodynamic modeling

Dariya Quenneville, Ed Bryson, and Danielle Fortin – Department of Earth Sciences – NRCAN TGI-4

Introduction

Geochemical exploration uses measures of metal concentration and sampling of water and solid phase samples (e.g. soils, tills, stream sediments, etc.) to find anomalous values for the metal or commodity of interest. These anomalies can indicate the dispersion haloes of economically viable ore deposits, and therefore provide an indication of which areas deserve further (and more expensive) exploration. This study explores the ability of equilibrium thermodynamic modeling and mineral exploration to better interpret geochemical data. However, chemical weathering, aqueous transport of detrital sediments, and precipitation of secondary minerals are not accounted for in present literature. The determination of metal content within samples taken from mineralized streams running over the Tom and Jason deposits in the MacMillan Pass area of the Yukon Territory, geologic trends will be explored. Furthermore, aqueous geochemistry techniques will be used for the analysis of bulk chemistry, speciation (Fe^{2+}/Fe^{3+}) and morphological characterization of the metal-rich particulate material of the streams for later modelling inputs including the use of the Dionex 600. This research should improve our understanding of metal speciation and mobility in natural aqueous environments, with the goal of refining current exploration methods and extending them to deeply buried ore deposits using equilibrium thermodynamic modeling methods.



Picture 1. Two rivers merging of basic (left) and acidic (right) pH, easily distinguishable by colour differences.



Picture 2. Commonly known as “zinc moss”, this vegetation demonstrates a novel environment, even in extreme conditions.



Site	Timestamp	Barometer (kPA)	Conductivity (uS/cm)	Dissolved Oxygen (mg/L)	ORP (mV)	pH	Temp. (C)
J4AUG3	03/08/2013 17:38	89.94	197.3	8.74	335.12	6.97	12.3
J6AUG4	04/08/2013 17:25	90.03	448.3	10.87	552.30	3.24	12.2
M11AUG5	05/08/2013 15:36	90.49	1607.5	8.25	435.60	2.96	11.5
RC1AUG10	10/08/2013 13:55	90.28	121.9	9.29	250.40	7.66	9.9
J3AUG9	09/08/2013 14:28	89.50	39.2	9.30	367.08	6.96	9.3

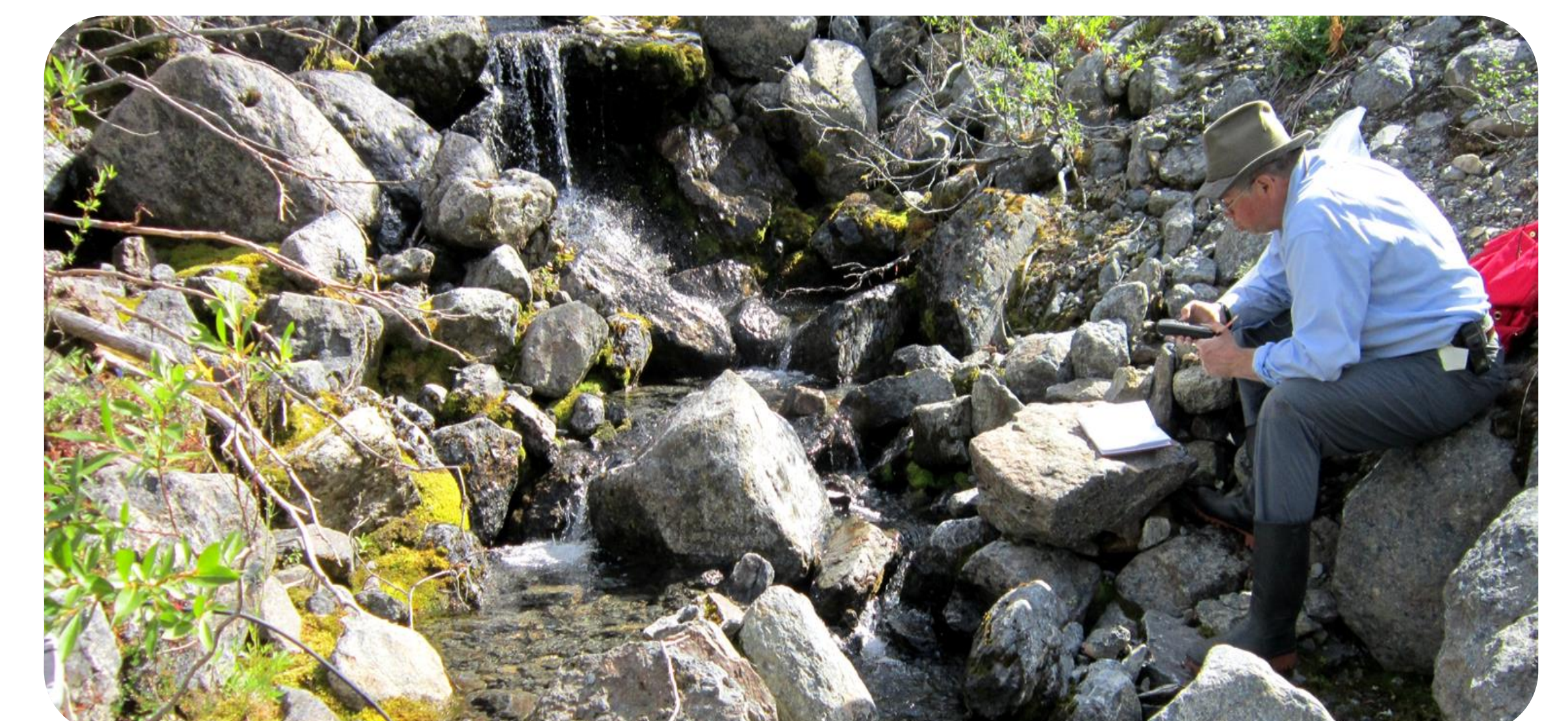
Methods

Samples were taken from various locations along the South MacMillan River up and down stream of the Tom and Jason Pb-Zn deposits throughout August 2013. Both filtered and unfiltered mineralized water samples were collected in HDPE (high-density polyethylene) bottles- 0.45 μ m syringe filtered used to filter samples in the field. Various tests were further conducted with a YSI sampling meter on the stream including measuring pH, Eh, temperature and conductivity. All samples were kept cool after collection. To determine anion concentrations, both filtered and unfiltered unacidified samples were shaken prior to transferring 10 ml of the sample into a falcon tube by pipette. Later, 0.2 ml of trace metal grade ammonium hydroxide (NH_4OH) was added to the falcon tubes containing the sample by pipette in order to basify the samples to approximately pH 11. In order to determine the necessary volume of NH_4OH for basification of all samples of various pH and concentration, multiple attempts using various volumes were conducted and results determined by paper litmus pH indicator strips. Next, a dilution was performed by transferring 1 ml of sample after centrifugation to separate the solid precipitate from the liquid phase and further adding 9 ml of distilled water in order to decrease the concentration of anions to not flood the Dionex.

Contact information: dquen073@uOttawa.ca

Results

Samples with ranging pH (2.8 - 8.4) were basified to a pH of 11 for analysis by ion chromatography. The Dionex 600, allows for the separation of ions from aqueous samples by ion chromatography. Liquid ion chromatography uses ion-exchange resins in order to separate ions based on their individualistic interaction with resin and the equilibrium distribution of the sample components between a mobile (eluent) and stationary phase (resin with columns). The sample components can only migrate through the system throughout the mobile phase, in which the velocity of the sample components migration is a function of the equilibrium distribution. Prior to the analysis, the assumption is made that all anions throughout the sample were successfully replaced by a hydroxyl group. Samples with high conductivity should have elevated anion concentrations and further expect a charge balance, where positive charges equal negative charges, to be present. The thermodynamic modeling is done in phreeqc, a computer thermodynamic model that calculates the stable phases based on inputs. Different anions will cause different mineral and dissolved phases to be stable (ie. you cannot have a sulphate complex or mineral without sulphate!) Results will be received within the next few weeks for further analysis.



Conclusion

Geology can have a significant influence on surface water chemistry, creating novel environments or leading to contamination if exposed through mining. Understanding these processes can help understand our environment, while contributing to prevention and remediation of contaminated sites. Furthermore, discovery of shallow ore deposits has become increasingly rare, and while geophysical exploration methods have positively revolutionized the exploration industry, they are very costly. In addition, several non-economic features have geophysical expressions similar to those of ore deposits leads to many ‘false positives’ that can only be tested using expensive drilling. Chemical weathering and aqueous transport of metals can greatly diminish the chemical signatures in the sediments; but may also provide a unique dispersion vector. In conclusion, the focus of this research project is to improve understanding of metal mobility in natural aqueous environments, vital information absent in current literature, with emphasis to far downstream locations. More specifically, the objectives are to determine the metal content of streams running over deposits in the MacMillan Pass area of the Yukon Territory in order to determine how equilibrium thermodynamic modelling can be used to better interpret geochemical data, and refine exploration efforts.

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