**Cation Substitution in Copper Bearing Minerals with Particular Focus on the Copper Deposits of Michigan's Keweenaw Peninsula**

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**Introduction:**

The Keweenaw Peninsula in Northern Michigan is home to the world's largest deposit of native copper, and has been extensively mined for over a century. Copper rarely forms in its native state (not chemically bound with other elements), which makes the Keweenawan copper deposits exceptionally unique. The major geologic feature of the Keweenaw Peninsula, is a 1.1 billion year old failed rift system, known as the Midcontinent Rift. Although the Midcontinent rift extends over 2,000 km down into Kansas, through the Lake Superior Region, and back around into Michigan's Lower Peninsula, it is only exposed in the Keweenaw area. The volcanic rocks produced during this rifting event, along with the Copper Harbor Conglomerate (a sedimentary layer directly overlying the volcanics), now host these abundant native copper deposits. During the formation of the copper ore (leaching from the copper-rich parent rock, mobilization of the cupriferous hydrothermal fluid, and final precipitation of minerals into their host rocks), other metals such as silver, lead, zinc, tin and titanium can become incorporated into the mineral crystal structure by substitution of the copper cation. Knowing that silver is present in significant amounts in the copper deposits of the Keweenaw, we wondered whether the distribution of trace metals in these copper minerals is consistent throughout this location. Our project seeks to determine if copper samples from the Keweenaw Peninsula have a distinctive chemical signature which we could compare with copper from other locations around the world, and could be used to possibly identify locations of unknown copper samples.

**Methods:**

We are examining several copper and copper sulfide samples using a portable X-Ray Fluorescence analyzer. This allows us to determine the precise chemical composition of the minerals, including trace elements. We take 10 readings from each sample, record the data in a spreadsheet, and then analyze to look for correlations. We are establishing a base dataset of copper mineral chemistry from samples from Calvin's geology department mineral collection, also looking at copper minerals from several locations outside of the Keweenaw including Butte, Montana and Superior, Arizona for comparison. However, our main study will be on the excellent copper samples from the Dice Mineralogical Museum collection on Calvin's campus. In late August, we will also take a field trip to the Keweenaw Peninsula to collect additional samples.

**Results to Date:**

Our preliminary results tend to show correlations between the ratios of zinc/lead and copper/silver in analyzed keweenawan copper. There is a direct correlation between silver and lead, and copper and zinc, and an inverse correlations between silver and zinc, and copper and lead. These ratios could prove useful in identifying chemical signatures of these copper samples.

**Personal Benefit of Research:**

Researching at Calvin has been very beneficial to my personal and professional development. This job has been an excellent opportunity to work in my field, and to see what work in geologic research would be like in graduate school or professionally– an option I am now seriously considering. This job has helped develop and focus my specific interests in geology, which will be valuable to me as I apply to graduate schools this upcoming semester.