Recognition of Hydrothermal Alteration Using Airborne Hyperspectral Imagery and Gold Favourability Mapping in the Hope Bay Volcanic Belt, Nunavut

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Introduction

This study incorporates two increasingly imporant fields in the resource industry: remote sensing (RS) and mineral potential mapping (MPM). Hyperspectral RS is currently being used in arid dry regions of the world such as Australia, Africa, Central America(Mexico, Southwest America), South America (Peru, Chile). However, the techonology is not currently being utilized to the same extent in the arctic regions due to vegetation, lichen, snow and overburden cover.

Mineral potential mapping has been a longstanding practice in the resources industry, with the continued increase in computing power allowing for more rapid creation of mineral potential maps. We combine alteration maps of hydrothermally altered rocks gleaned from airborne hyperspectral data with lithologic and structural data to produce a mineral potential map.

Our study area is part of the Hope Bay Volcanic Belt (HBVB), an Archean greenstone belt that forms part of the Slave craton. The study area contains the Boston deposit, one of the larger shear zone-hosted orogenic (lode) gold deposit in the HBVB.

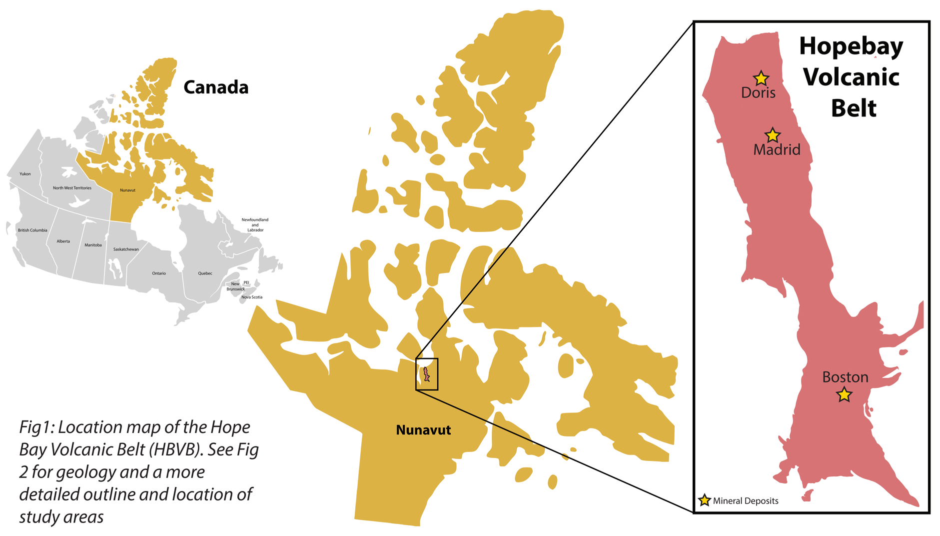


Fig1: Location map of the Hope Bay Volcanic Belt (HBVB). See Fig 2 for geology and a more detailed outline and location of study areas

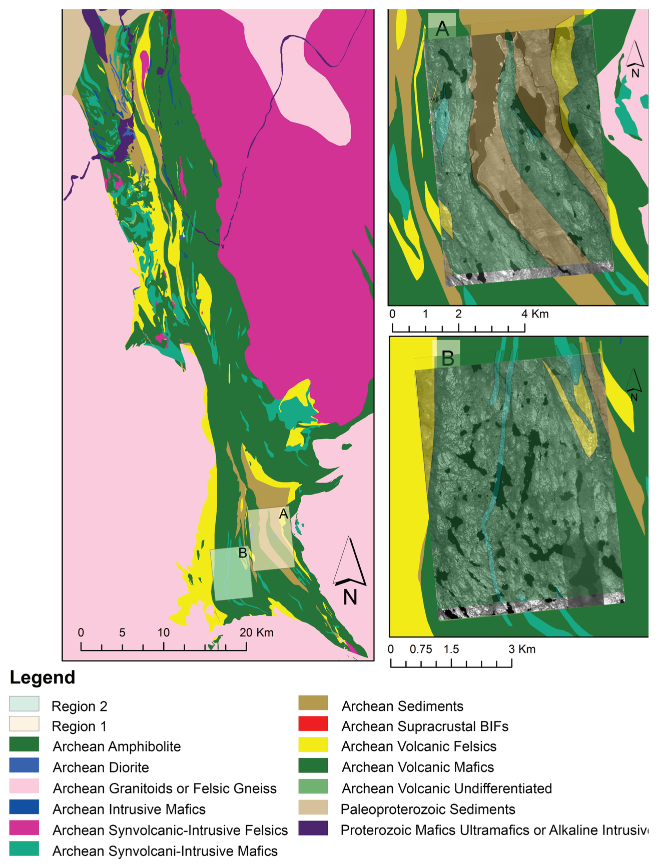


Fig 2: Simplified geology map showing location of study regions A and B. Region A: contains the Boston deposit; region B is located to the south west of the Boston deposit, and contains no known deposits (modified from Stubley, 2005).

Our study only makes use of publicly available information such as mineral spectra and geological data; no ground-truthing fieldwork has been conducted.

Methodology

The following objectives were set for this study:

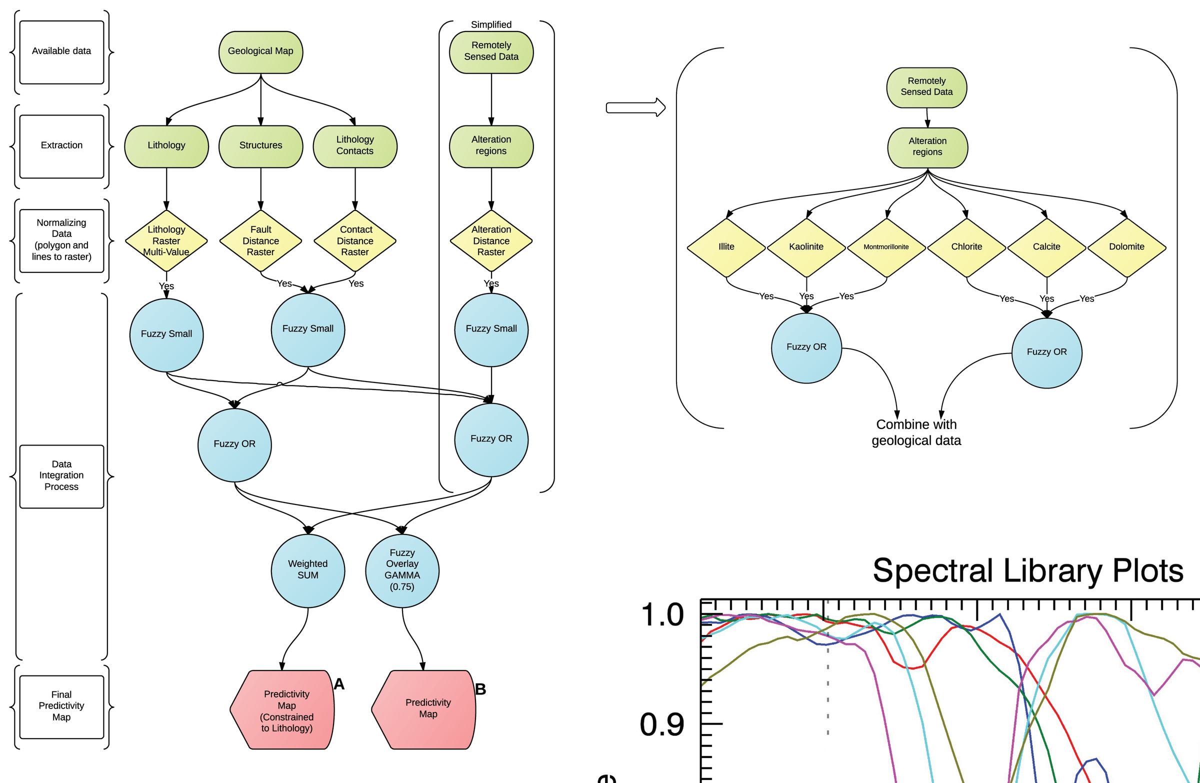
i) Use pixel-based and sub-pixel-based methods to analyze the hyperspectral data to determine which method results in an optimal classification of hydrothermal alteration minerals.

ii) Accurately identify and delineate zones of hydrothermally altered rocks through identification of hydrothermal minerals in wallrocks associated with orogenic (shear zone-hosted) gold mineralization.

iii) Create normalized euclidean distance rasters of hydrothermal alteration zones.

iv) Incorporate hydrothermal alteration distribution raster maps with available geological data to produce a Au predictivity map.

The shortwave infrared portion (2000-2450nm) of the electromagnetic spectrum was analyzed to identify hydrothermal alteration minerals.



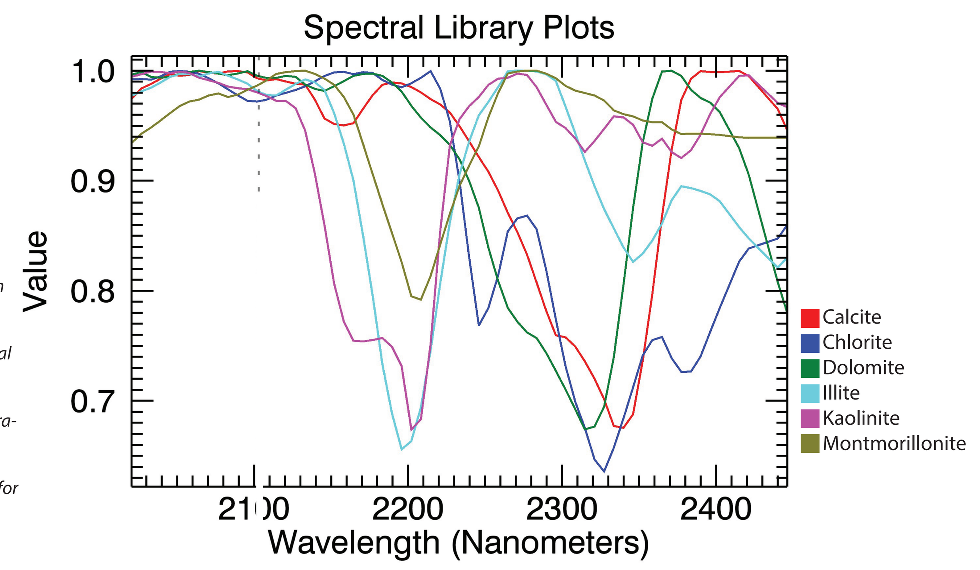


Fig 3 (above and top right): Flow chart showing the procedure used to produce mineral potential maps after obtaining hydrothermal alteration information from airborne hyperspectral data. Green rectangles indicates input data, yellow diamonds are normalizing procedures, blue circles are data integration functions applied to normalized data , and red blocks indicate the resultant product, mineral potential maps.

Fig 4 (bottom right): Shortwave infrared spectral plot of the six hydrothermal alteration minerals pertinent to this study. The 2000nm - 2400nm region is one of the principle regions for identifying clays with associated hydroxyl groups (Al-OH, Mg-OH and Fe-OH) (Hunt et al., 1979). The region also has a distinctive signature for carbonates (CO_3) The spectra have been normalized (continuum removed). The spectra are from the USGS Spectroscopy Library (Clark et al., 2007).

Results

Remote Sensing

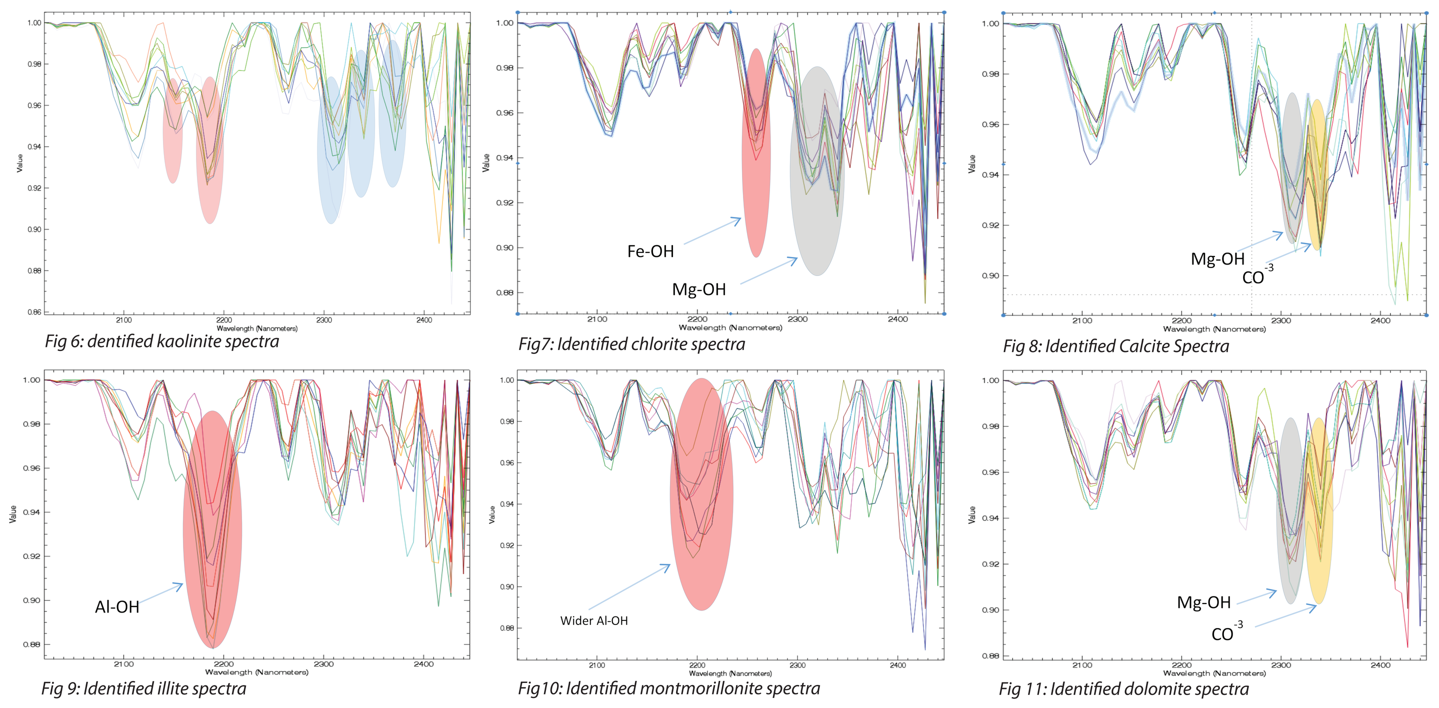


Fig 6: dentified kaolinite spectra; Fig7: Identified chlorite spectra; Fig 8: Identified Calcite Spectra; Fig 9: Identified illite spectra; Fig10: Identified montmorillonite spectra; Fig 11: Identified dolomite spectra

Figs 6-11: Each plot shows spectra of ten random pixels for each identified hydrothermal mineral based on a sub-pixel-based classification method. Statistical analysis showed that the sub-pixel-based method was better suited to identify clays than the pixel-based method, whereas the carbonate minerals showed similar results for both methods.

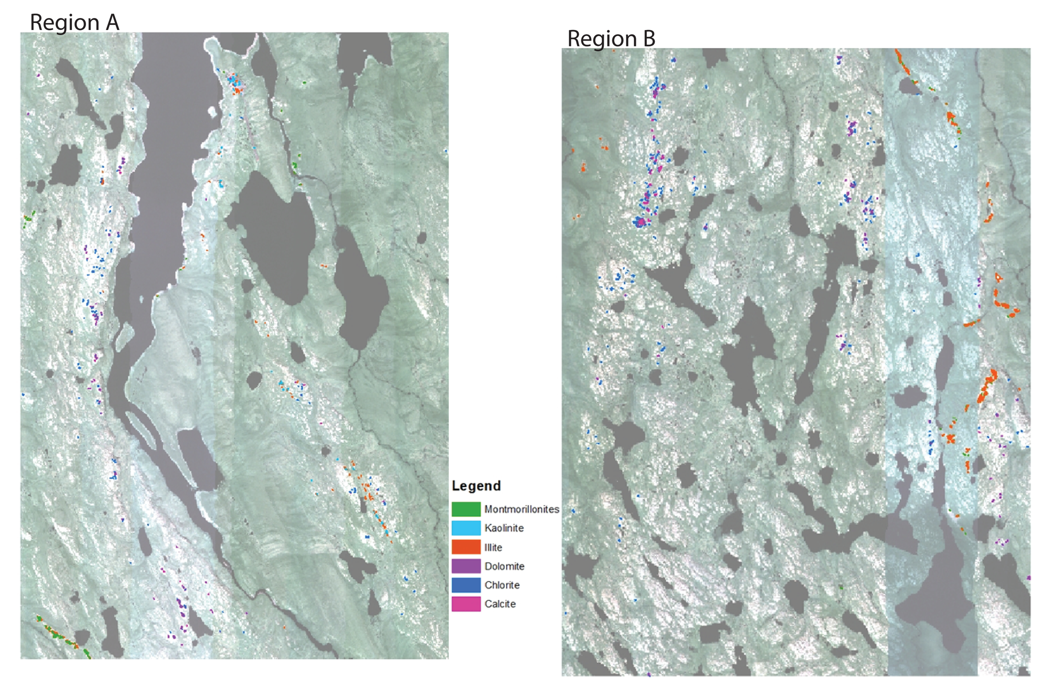


Fig 12. (above left) and Fig 13. (above right): Hydrothermal alteration mineral distribution maps overlayed on airborne RGB data used in the initial analysis for the two study regions A and B.

Absorption regions used to identify hydrothermal alteration minerals are as follows: illite , 2180-2228nm; chlorite, 2235-2255nm and at 2320-2355nm; dolomite at 2140, 2320-2328nm; calcite at 2156, 2340-2345nm; kaolinite contains a doublet feature between 2150-2215 and 2160-2206; and montmorillonite which has an absorption feature in the same range as kaolinite however the doublet feature is absent leading to a wide absorption trough.

Predictive Mapping

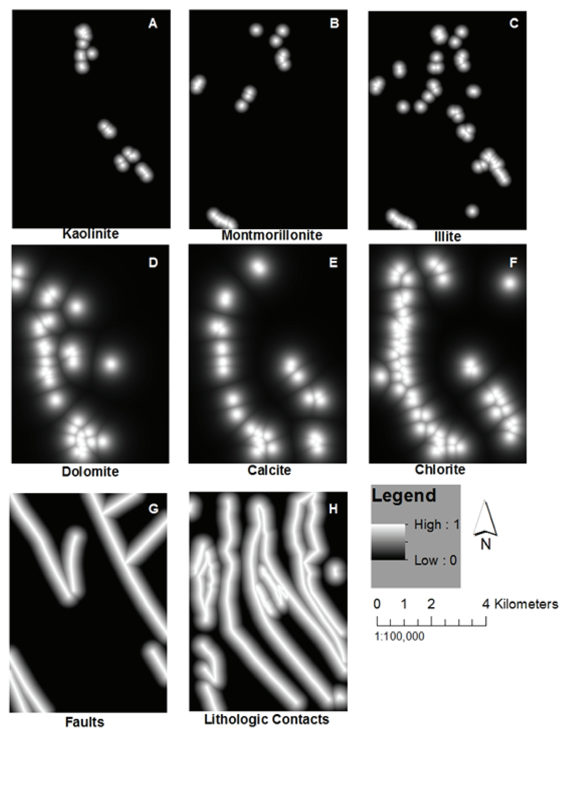


Fig 15: Favourability criteria maps for region A, created using an Euclidean distance function; the rasters act as a decay function. High favourability regions are lighter while low favourability regions are darker

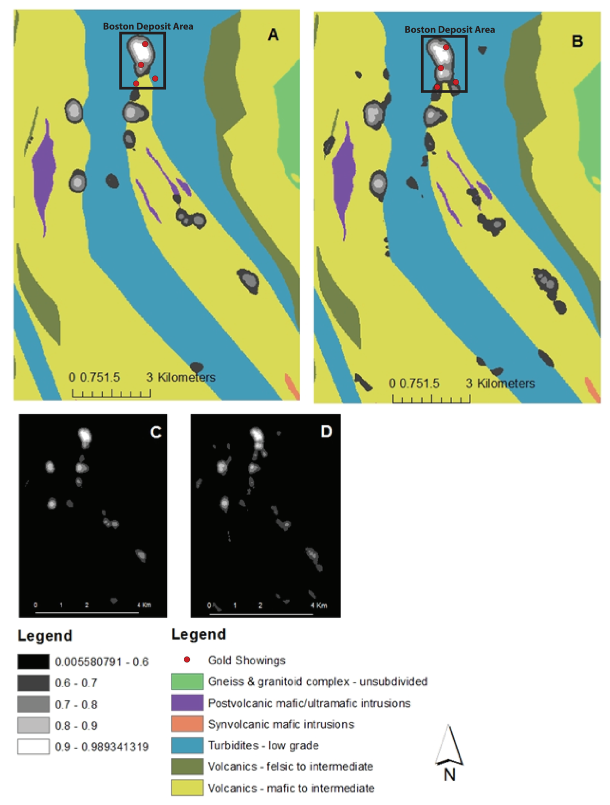


Fig 16: Au potential maps (C & D) overlayed on lithology map (A & B). (A,C) dispalys the fuzzy gamma model while (B&D) show the weighted sum model. Both models show similar regions of high gold favourability. High favourability regions are lighter while low favourability regions are darker

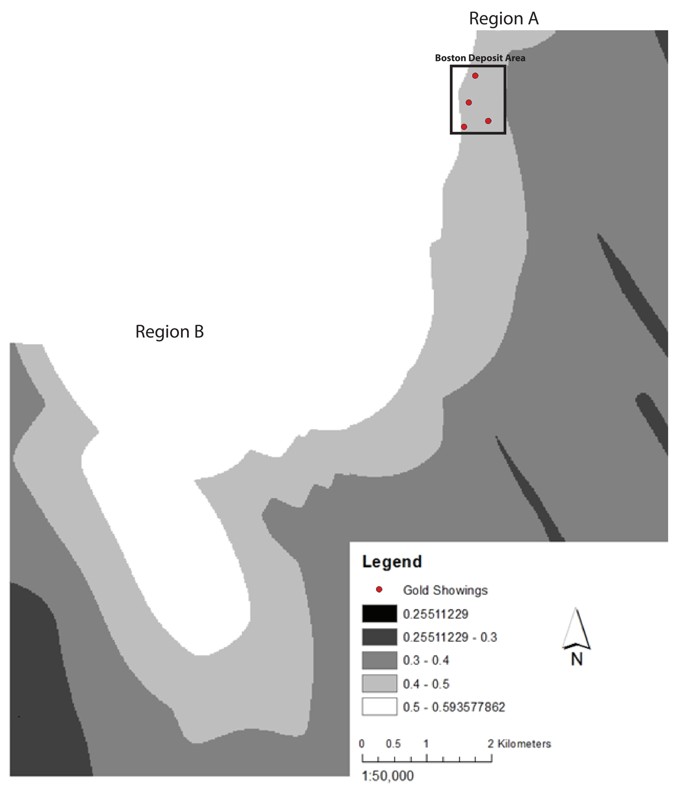


Fig 17: Normalized Chung and Franklin (2012) mineral (Au) potential map for regions A and B. Although the locations of known Au showings lie within a region of reasonably high potential, the precision of identifying potential deposits is quite poor. High favourability regions are lighter while low favourability regions are darker. Primarily created using WOE where weights were determined from similar deposits.

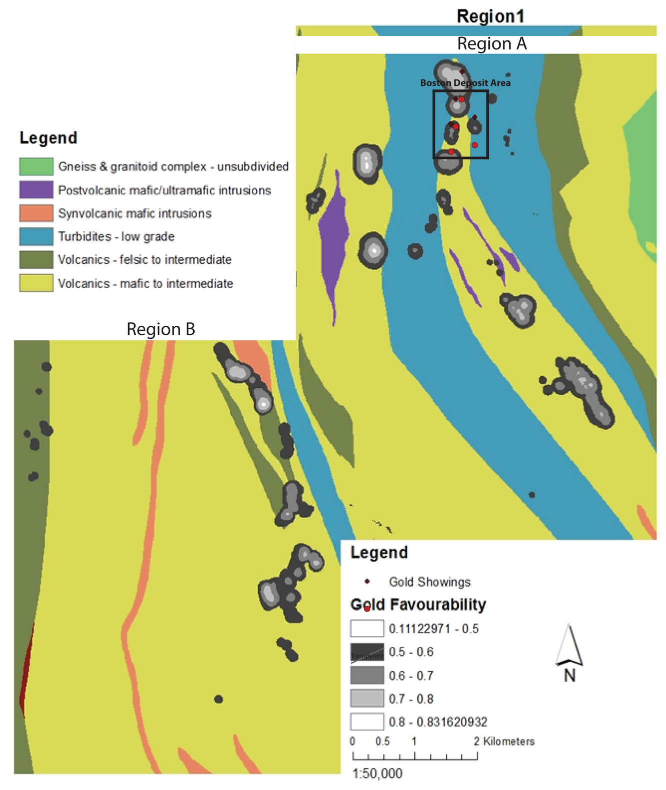


Fig 18: Hydrothermal alteration data integrated with the Chung and Franklin (2012) mineral (Au) potential map for regions A and B. The map shows a much higher accuracy for identifying potential regions for exploration, The data was integrated using the weighted sum function. High favourability regions are lighter while low favourability regions are darker.

Figure15 shows favourability criteria of Region A, used to produce the mineral potential maps in Fig 16 (C & D) these are overlayed onto lithology in Fig 16 A & B. Favourability criteria include: hydrothermal alteration mineral distributions, as determined from airborne hyperspectral data using a sub-pixel-based method, faults and lithologic contacts. Data was combined in two ways; weighted sum with weights derived from literature (Fig 16, B/D) . The other is a fuzzy gamma method with weights derived automatically from a decay function(Fig 16, A/C). The decay function represents a natural trend. The Fuzzy gamma method shows a much more natural representation of regions of high mineral potential rather than the weighted sum method which can skew results if improper weights are chosen. However for this study it appears that the weights derived from literature are more accurate in determining mineralization. Multiclass buffers were used rather than a binary representation of hyperspectral data to represent decreasing strength of alteartion halos extending into the surrounding regions.

Conclusions and Future Work

•Our study shows that the areal distribution of hydrothermal alteration minerals associated with mineral deposits can be mapped using airborne hyperspectral data (3 m spatial resolution) in this arctic region by analyzing the shortwave infrared (SWIR) portion of the spectral data. Areas with key hydrothermal alteration minerals can then be the focus of follow-up exploration. It should be noted that our study did not include ground-truthing field measurements, and any similar studies using airborne hyperspectral data to identify mineral deposit-related hydrothermal alteration minerals should include such data to validate the results.

•Regions of high favorability in our study correspond well to known Au showings.

•Integration of the hydrothermal alteration mineral distribution maps produced from the hyperspectral data together with the Chung and Franklin (2012) mineral potential map of the areas studied produced a better prediction map than the latter alone.

•Use of both the visible part of the electromagnetic spectrum to identify iron rich zones and the infrared part of the spectrum to identify clays would provide a more thorough analysis and give additional information to use in a mineral prospectivity map, as clays are a key hydrothermal alteration mineral species associated with orogenic Au and other hydrothermal mineral deposits.

•Integration of geochemical and geophysical data though a neural network aproach is likely to result in even better prediction maps than those presented here.

•Future method development should focus on spectrally distinguishing carbonate minerals, as they are a prominent part of the hydrothermal alteration mineral suite for orogenic gold and a number of other hydrothermal ore deposits.

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