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Hyperspectral sensing in support of mineral exploration in the arctic: example from the Cape Smith Nickel belt, Canada

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Regional geologic mapping in the Arctic is time intensive and costly, primarily owing to poor accessibility, but it is essential for subsequent geologic investigations and to guide mineral exploration activities. Hyperspectral imaging is a promising avenue to facilitate detailed mapping in the Arctic, if issues such as low illumination and lichen cover on bedrock can be addressed. In fact, to date there are little or no demonstrations of spaceborne hyperspectral data used for mineral vectoring and lithologic mapping in the presence of extensive biological coatings (e.g. lichens).

This study investigates AISA optical airborne hyperspectral imagery acquired over the Cape Smith greenstone belt of northern Quebec Canada (62 lat, -75 long). The belt is host to Nickel-Cu-(PGE) mineralization occurring within a series of thick (50-200 m) mafic-ultramafic complexes that outcrop discontinuously. Lichens are predominant on bedrock surfaces, adding to the challenge of remotely mapping packages of rocks (mafic to ultramafic) with inherently low spectral contrast. All of the ores, host rocks, and country rocks have been regionally metamorphosed to lower greenschist facies, but igneous and volcanic structures and textures are extremely well preserved.

The airborne data were acquired with a spatial resolution of 2 meters in late July and early August after solar peak, owing to the presence of extensive snow cover into late June. As such, the solar angle ranged from 39-35 degrees. Radiance data was atmospherically corrected using ATCOR4 with the resulting reflectance data comprising 178 bands (400 to 2500 nm) at a spectral resolution of 10 nm. The survey comprises 100's of flight lines with adjacent lines having an average overlap of 30%. For this study we made use of 30 flight lines, approximately 30 km long and 650 m in width, that coincide with an active exploration and drilling program.

The size of the data set presents numerous challenges beyond the computational intensity of data analysis. The first objective of the study was to overcome within line, and line to line calibration issues, particularly with spectral bands in the shortwave infrared, that result in significant inconsistencies between lines. These inconsistencies prevent the simultaneous analysis of multiple lines, and thus, the continuous mapping of spectrally significant lithologic units. To reduce these inconsistencies we developed a leveling algorithm that effectively minimizes these differences. The result is a near seamless mosaic for the full spectra range, although leveling quality does decrease slightly for bands beyond 2200 nm.

The leveled mosaic enables the second objective of the study, namely the discrimination and mapping of basalt-gabbro-pyroxenite-peridotite-dunite units that commonly occur in close proximity and represent zoned bodies that do not necessarily have sharp contacts. The similar mineralogy between these units complicates their discrimination and mapping. In addition, lichen cover is extensive and common to northern terrains and obscure mineral spectral features, particularly in the visible and near-infrared spectrum. Lichen species vary significantly in their pigments resulting in black, grey, white, yellow, green, and orange lichens. However the spectra of lichen are very similar in the short wave infrared, and thus, variability in spectral shape observed from bedrock samples partially covered by lichen can be principally attributed to the contribution of mineral spectra.

Spectral features were selected from investigations of spectra collected in the field and laboratory spectra

of minerals present in low-grade mafic and ultramafic rocks. A series of normalized multi-band ratios were developed from these features to effectively discriminate and map these units in the presence of lichen. The ratios make primary use of spectral features observed in ultramafic alteration minerals (e.g. serpentine) as opposed to those found in more mafic rocks (e.g. amphiboles). The resulting mapping capability captures the subtle spatial compositional variations related to the zoning of ultramafic bodies, where this zoning has been shown to be directly associated with nickel mineralization. The predictive map distributions of dunite, peridotite, pyroxenite and gabbro/basalt emulate the detailed ground mapping conducted for a subset of the region as part of on-going mineral exploration efforts. These maps can be used to extrapolate the mapping and to delineate new targets to focus exploration. The anticipated availability of EnMap data will represent a unique opportunity to assess the scaling of these findings to satellite observations and evaluate such capabilities for geological mapping of northern regions.