Mapping BC's Golden Triangle Using ASTER Imagery

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Executive Summary

The Advanced Space-borne Thermal Emission and Reflection Radiometer (ASTER) has been found effective for geological mapping applications due to its high spectral resolution in the Shortwave Infrared (SWIR) wavelengths of the electromagnetic wave; frequent revisit cycle and wide swath; and affordability of acquiring images to cover large geographic areas. Using ASTER imagery to map BC's geology, however, faces a few challenges, among others, including complex terrain and dense vegetation coverage. This may partially explain why there are not many documented studies in this regard. This study focuses on testing ASTER's ability on mapping the general rock groups in BC's "Golden Triangle" area, which is chosen for the vibrant exploration and mining activities in its vicinity and good surface exposure of bedrock rock, a prerequisite for any optical remote sensing based-mapping.

The ASTER image covering the area of interest was acquired on Sept. 21, 2005. A rigorous process of image pre-processing was conducted to convert it from raw digital number to orthorectified reflectance, which resulted in a 9-band image incorporating the 3 bands in visible and near infrared (VNIR) and 6 bands in the shortwave infrared (SWIR). The field data were provided by Seabridge Gold Inc. consisting of the following rock groups: Altered and Mineralized; Late Jurassic Intrusion; Jurassic Hazelton; Jurassic Jack Formation; and Triassic Stuhini.

Spectral separability between these groups was examined. It indicated that the "Altered and Mineralized" and "Late Jurassic Intrusion" were not separable statistically and suggests that they need to be merged to form a new group, called "Combined" in this study. The standard supervised classification method was employed for the mapping, which was followed by a cross-validation based accuracy assessment.

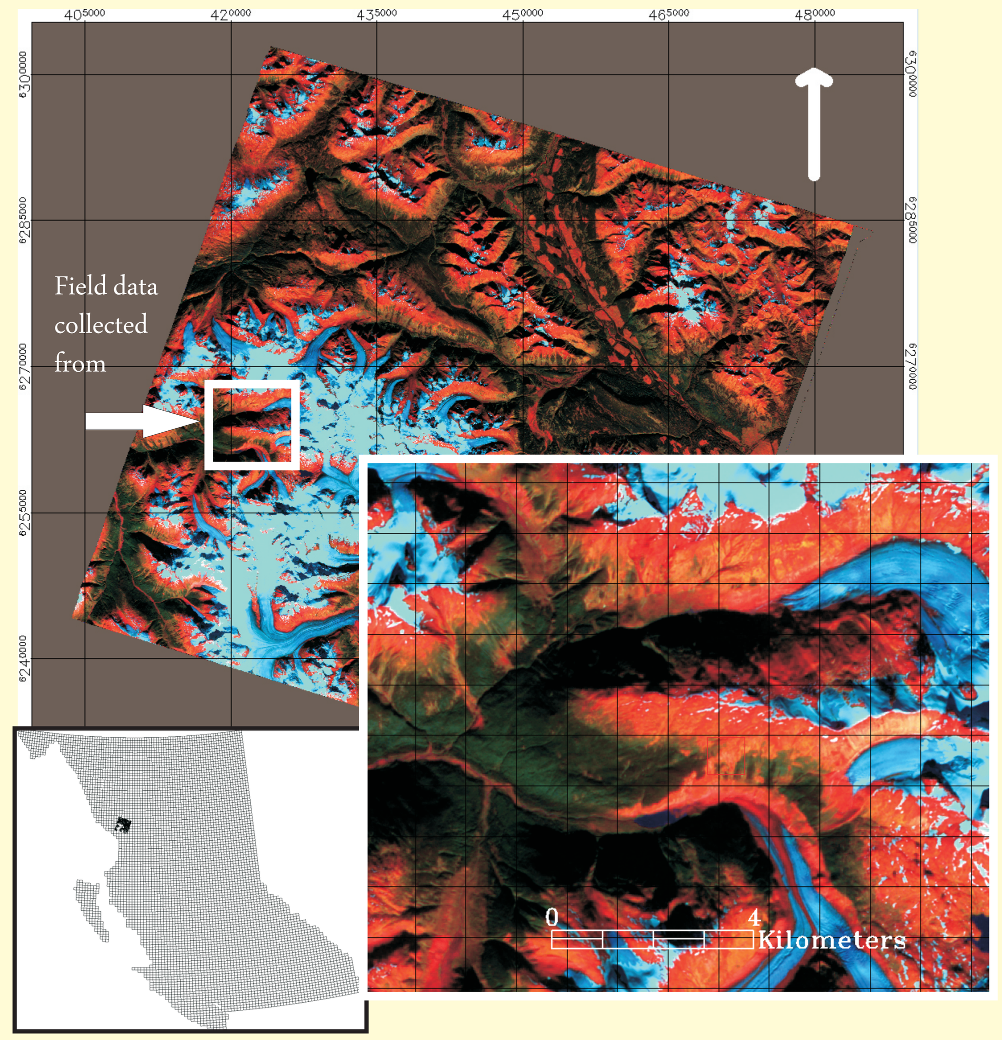
This study demonstrated an approach of using ASTER image to map a portion of BC's "Golden Triangle" with 4 general rock groups, including Triassic Stuhini, Jurassic Jack Formation, Jurassic Hazelton, and the "Combined" which was the combination of "Altered and Mineralized" and "Late Jurassic Intrusion". An average of 79.8% classification accuracy was achieved. The result indicated that ASTER was capable of distinguishing the above general rock groups. Further investigations are needed to determine if ASTER is capable of identifying more detailed rock types in the context of BC's geology, terrain, and topology. Since this study was conducted exclusively using the spectral information extracted from ASTER imagery and employing a standard image analysis method based on a supervised classification, the result and method of this study can be considered as the baseline, upon which other data sources (such as those from geophysical studies) and advanced image analysis methods (such as the decision tree-based classification using both spectral, spatial, textural, and other source of information) need to be incorporated and explored to take advantage of ASTER's full potential for geological mapping in BC.

Area of Interest and ASTER Image

The area of interest chosen in this study is shown in on the right, which centres on the Kerr-Sulphurets mineralized system on mapsheet 104A051 (in BCGS 1:20,000 grid) and covers about 25 mapsheets in total. It is dominated by variably deformed, oceanic island arc complexes of the Triassic Stuhini and Jurassic Hazelton groups. Typical in the Cordillera, the elevation of this area is highly variable, ranging between 0 and 2400 meters.

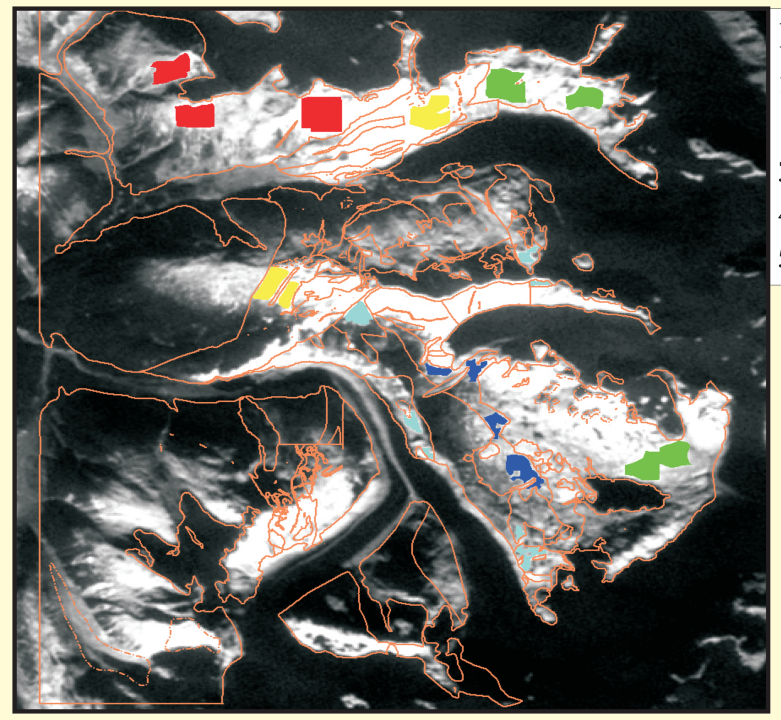
The ASTER image chosen for this study was collected on Sep. 21, 2005. A rigorous pre-processing was conducted to the image as mentioned in (Kilby 2005), including radiometric correction, atmospheric correction, and orthorectification. The pre-processed image is shown on the right in false colour using the following band combination: (red, 2205 nm), (green, 810 nm), and (blue, 560 nm). This combination seems to provide the closest natural view with the exposed rock and soil surfaces shown in brown; forest and vegetation in dark green; and ice and glacier cover in cyan.

The back-looking band and the thermal bands in the package were excluded due to redundancy and low spatial resolution, respectively. This resulted in a 9-band image with the first 3 bands in visible and near infrared (VNIR) and 6 bands in the shortwave infrared (SWIR). The 30-meter SWIR bands were re-sampled to 15 meters to match the spatial resolution of VNIR bands.



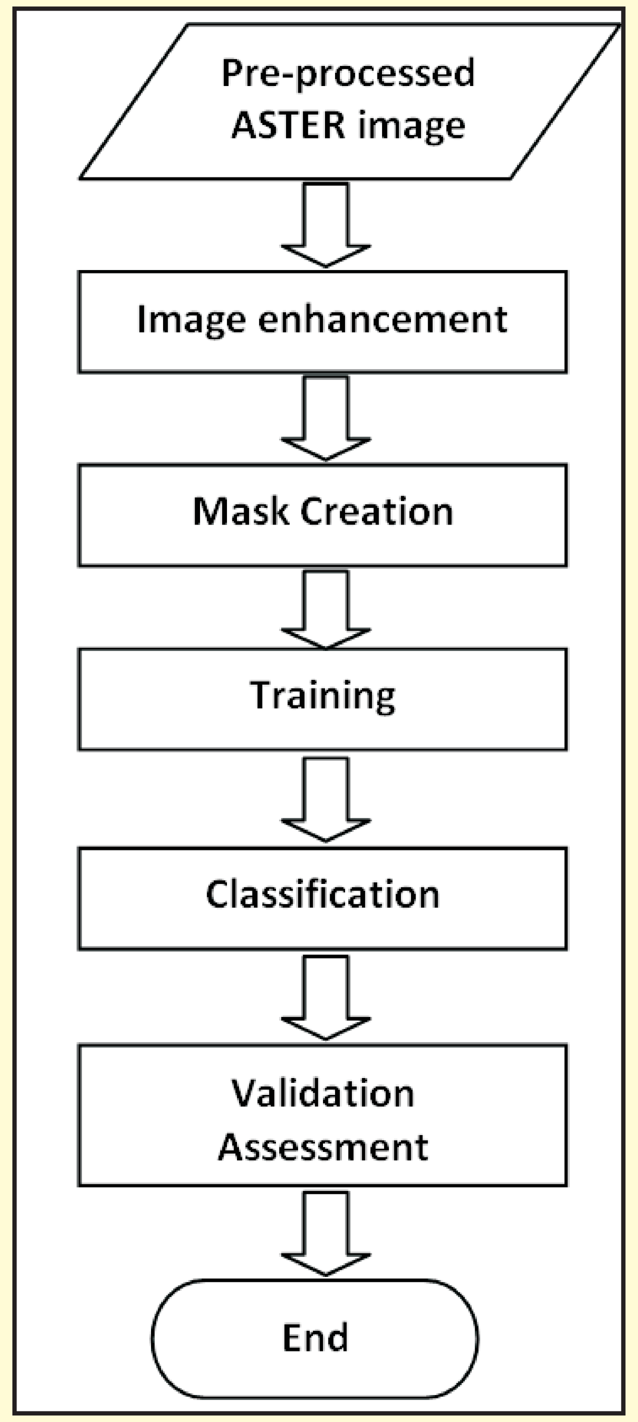
Field Data

Seabridge Gold Inc. kindly provided detailed geological field data , which is composed of the following 5 general rock groups: 1. Altered and mineralized, encompassing the Sulphurets breccia gold zone, Sulphurets leached zone, the upper and lower zone Iron Cap zone mineralization, fine grained intermediate intrusions, , contact zone of porphyritic monzonite, and related rock and alteration types; 2. Late Jurassic Intrusion, including coarsely feldspar porphyritic monzonitic, plagioclase-augite diorite, aphanitic dioritic dykes, coarsely feldspar-hornblende porphyritic intrusions, plagioclase-hornblende diorite to microdiorite or massive andesite, etc.; 3. Jurassic Hazelton Group, composed of porphyritic dacite flow dome complex, green and maroon pyroclastic flow, green and maroon laminated tuff, andesite and basalt, etc. 4. Jurassic Jack Formation, composed of silicified, pyritic, and hornfelsed Jack Formation sediments; and 5. Triassic Stuhini Group, subdivided into undivided Stuhini Group sediments and volcanic and andesite. The above grouping scheme was followed in this study, which employed a standard supervised classification-based image analysis approach to evaluate ASTER's ability on distinguishing the above rock groups.



Pixels selected for training
1. Altered and mineralized in yellow
2. Late Jurassic Intrusion in cyan
3. Jurassic Hazelton in green
4. Jurassic Jack Formation in blue
5. Triassic Stuhini in red

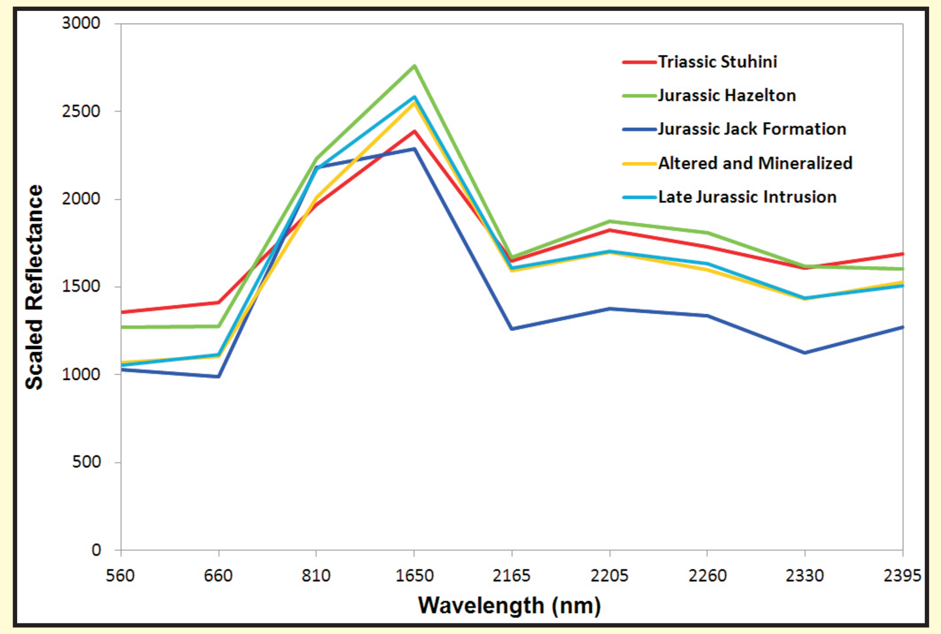
ASTER Image Processing and Analysis



Spectral separability between rock groups

The figure on the right shows the spectral profiles derived from the training pixels. It is apparent that "Late Jurassic Intrusion" and "Altered and Mineralized" are similar across the entire ASTER wavelength range. The Transformed Divergence was also calculated, wherein the divergence value between these 2 groups was small (1.27 as given in the table immediately below the spectral profile figure), an indicator of poor separation between them statistically.

A common approach in classification to deal with inseparable classes is to combine them if no additional information is available. Following this strategy, we combined "late Jurassic Intrusion" and "Altered and Mineralized" and formed a new group, called "Combined Group". We then re-calculated the Transformed Divergence. As shown in the table in the middle, the separation between the 2 groups is improved.



Classification Accuracy

The merging above resulted in a total of 4 classes, instead of 5 initially, which were included in the classification. The classification result was assessed using a cross-validation scheme. It revealed that the overall classification accuracy was 79.8% with a Kappa coefficient of 0.70. The details of the assessment are provided in the table on the bottom. "Triassic Stuhini" was classified with the highest accuracy (89%), while "Jurassic Jack Formation" with the lowest one (73%). The result also shows that portions of "Jurassic Jack Formation" (21%) and "Jurassic Hazelton" (23%) were misclassified as the "Combined Group", indicating that these groups have similar spectral property. Additional information (to the ASTER image) is needed to tell them apart based on the employed classification scheme.

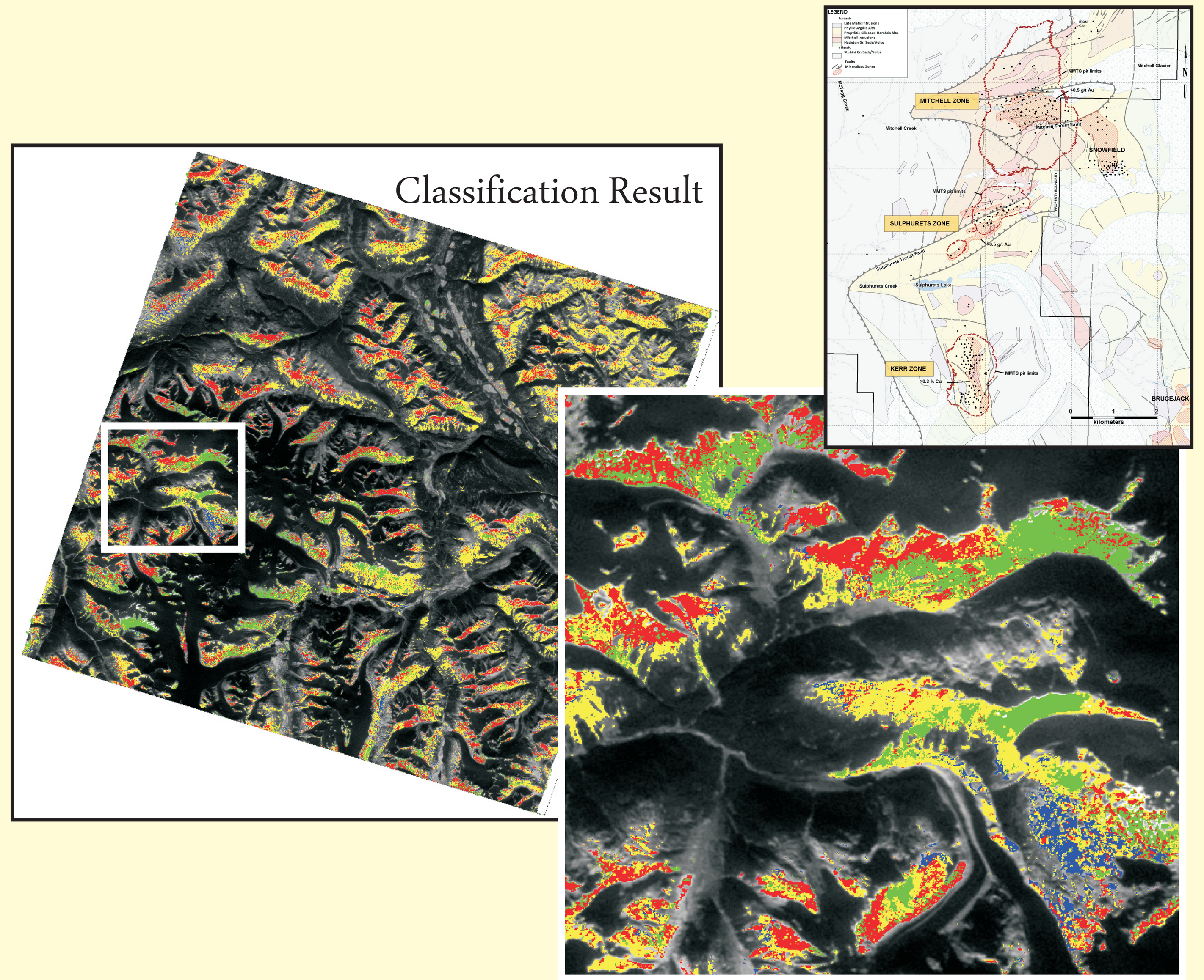
Rock Group	Altered and Mineralized	Late Jurassic Intrusion	Jurassic Jack Formation	Triassic Stuhini Group	Jurassic Hazelton
Altered and Mineralized	—				
Late Jurassic Intrusion	1.27	—			
Jurassic Jack Formation	1.64	1.75	—		
Triassic Stuhini Group	1.64	1.82	1.89	—	
Jurassic Hazelton	1.88	1.85	1.99	1.66	—

Rock Group	Combined Group	Jurassic Jack Formation	Triassic Stuhini Group	Jurassic Hazelton
Combined group	—			
Jurassic Jack Formation	1.78	—		
Triassic Stuhini Group	1.63	1.88	—	
Jurassic Hazelton	1.87	1.99	1.83	—

Rock Group	Combined Group	Jurassic Jack Formation	Triassic Stuhini Group	Jurassic Hazelton	Total
Combined group	226/74%	75/21%	53/5%	0	354
Jurassic Jack Formation	0	263/73%	0	0	263
Triassic Stuhini Group	9/3%	22/6%	930/89%	232/26%	1193
Jurassic Hazelton	71/23%	0	67/6%	676/74%	814
Total	306	360	1050	908	2624

Conclusions

- An average of 79.8% classification accuracy was achieved. The result indicated that ASTER was capable of distinguishing general rock groups.
- Since this study was conducted exclusively using the spectral information extracted from ASTER imagery and employing a standard image analysis method based on a supervised classification, the result and method of this study can be considered as the baseline.
- Other data sources (such as those from geophysical studies) and advanced image analysis methods (such as decision tree-based classification using both spectral, spatial, textural, and other source of information) will be explored to maximize the usage of ASTER and its successors for finer rock group mapping.



Acknowledgments

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References

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