

Hyperspectral Imagery Demonstration Project, British Columbia

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Introduction

Remote sensing has become a successful tool in mineral exploration in many parts of the world. Early use of Landsat imagery and other multispectral instruments has allowed regional exploration to move swiftly to areas of interest. More recently, the use of hyperspectral tools, with up to 250 discrete readings per spectrum collected at each discrete sample area on the ground, has been able to further assist exploration and mapping of geology and mineral alteration at various scales down to detailed deposit scale.

In British Columbia, the use of remote sensing in mineral exploration has lagged behind other mineral provinces due to the extensive cover of forests. However, the newer instruments allow collection of data at discrete points of a few metres and can collect useful spectra wherever outcrops can be discerned, along forestry roads, in areas of dry brush and above the treeline. A variety of images from within BC has been acquired over the last several years from a number of multi- and hyperspectral instruments over mines and other areas with potentially interesting geology. These images have been processed and placed on the MapPlace website, along with a number of basic tools to enable explorationists to evaluate the usefulness of this type of information in the search for new mineral deposits.

This project is the first by Geoscience BC to acquire remote images by selectively flying areas of high interest with a hyperspectral instrument in order to obtain images for on-line analysis by the exploration community.

Background

The Hyperspectral Imagery Demonstration Project, sponsored by Geoscience BC, provides examples of airborne hyperspectral images taken at high spectral and spatial resolution over typical exploration and mining sites in BC. This new imagery is available through the MapPlace website of the BC Ministry of Energy, Mines and Petro-

leum Resources (BC Geological Survey, 2007). Ten flight lines of hyperspectral data covering six sites have been added to the 68 Landsat 7, 239 ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer), 1 Hyperion and 1 AVIRIS (Airborne Visible/Infrared Imaging Spectrometer) images already available for online analysis through MapPlace's Image Analysis Toolbox (IAT; Kilby et al., 2004; Kilby, 2005; Kilby and Kilby, 2006a, b, 2007). Enhancements have been made to the IAT to provide additional analysis capabilities. A spectrum viewer provides the ability to examine the image spectrum at any image pixel. A reference library of mineral spectra has been added to the Spectral Angle Mapper (SAM) tool to allow SAM mapping of images using the United States Geological Survey (USGS) Spectral Library (Clark et al., 2007) spectra or image-obtained spectra.

Following a request for proposals, SpecTIR LLC (SpecTIR, 2007) was selected to provide the hyperspectral imagery. The imaging spectrometers utilized in the collection were the AISA (Airborne Imaging Spectrometer for Applications) Eagle, sampling the visible and near infrared (VNIR), and Hawk, sampling the shortwave infrared (SWIR), the sensors being combined in the AISA DUAL sensor package (Specim, 2007). The imagery was collected on August 1, 2007.

ITRES Research Limited (ITRES, 2007) offered to collect some imagery as part of a field test of their constructed sensors. Two sites were selected in the Rocky Mountains near Golden, BC. The collection was performed on July 12, 2007 utilizing their SASI 600, sampling the SWIR, and TASI 600, sampling the Thermal Infrared (TIR). The SASI 600 shortwave infrared (SWIR) data from this collection will be provided to this project at some future date.

Survey sites were selected to provide realistic examples of conditions likely to be encountered during exploration in BC (Figure 1). The six sites collected by SpecTIR included two sites with active surface mines with good bedrock exposure of known alteration characteristics (Gibraltar and Mount Polley). One flight line sampled an underground past producer, Blackdome, that has moderate exposure and well-known geology. Another flight line covers an area of known alteration above the treeline, the Limonite occurrence in the Taseko Lakes area. The Prosperity deposit was

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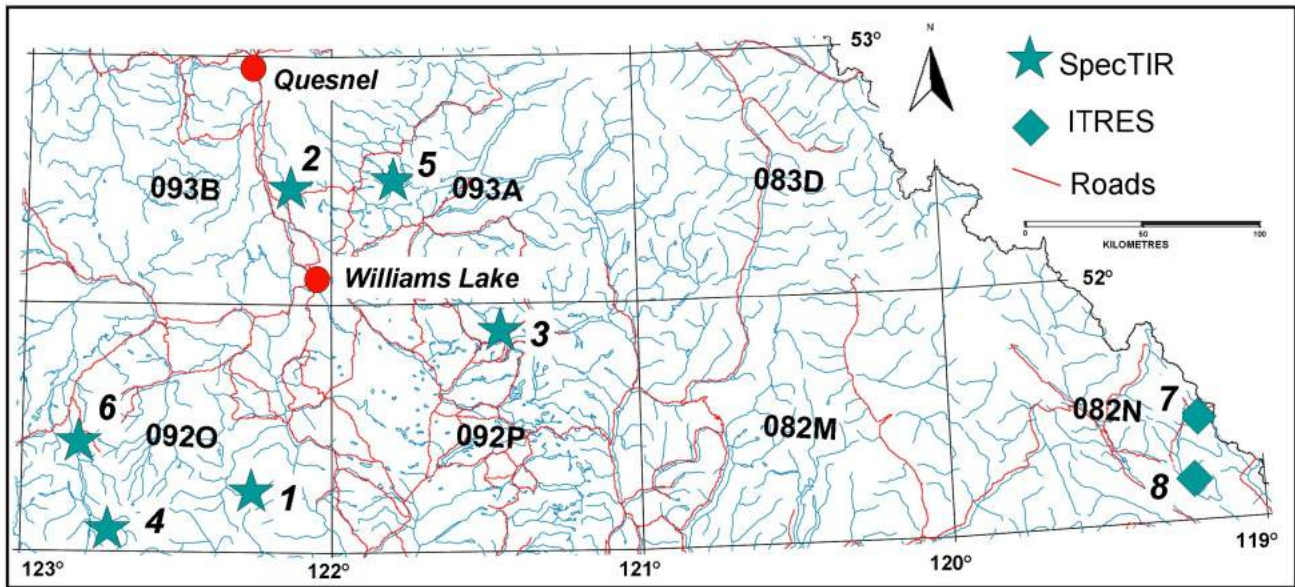


Figure 1. Locations of the eight demonstration sites: 1) Blackdome, 2) Gibraltar, 3) Lang Lake, 4) Limonite, 5) Mount Polley, 6) Prosperity, 7) Kicking Horse, and 8) Ice River.

sampled with another line to provide an example of an area with active exploration and limited exposure. The sixth flight line sampled a heavily vegetated area in the Lang Lake region. The combination of sites provides a variety of surface exposure conditions, geology and deposit types.

The two sites flown by ITRES during their instrument testing flight included past producers and prospects at Kicking Horse Pass and Ice River. The Kicking Horse site includes carbonate rocks that hosted Mississippi Valley–type deposits, and the Ice River site includes carbonatite and skarn deposits of the Ice River complex.

In the IAT, the hyperspectral imagery is orthorectified and atmospherically corrected. This allows any analysis to be immediately integrated with the existing geological information contained in MapPlace, such as geological maps and mineral occurrence, geophysical and geochemical data. The original image data can also be downloaded for offline processing in image-analysis software. The information is available in radiance and reflectance values, and is provided in BIL format.

Hyperspectral Imagery

Field spectrometers are now in common use during exploration programs where the identification of alteration mineralogy is essential to the unraveling of the mineralization process. Hyperspectral imagery is simply an extension of this technique to the generation of imagery with an imaging spectrometer. Hyperspectral imagery has been defined as “the acquisition of images in hundreds of regis-

tered, contiguous spectral bands such that for each picture element it is possible to derive a complete reflectance spectrum” (Goetz, 2002). Imaging spectrometers have been mounted on a wide variety of platforms, such as spacecraft, aircraft, motor vehicles and workbenches. Spatial sample spacing commonly ranges from a couple of millimetres (core loggers) to tens of metres (Hyperion).

The SpecTIR sensors sample the electromagnetic spectrum in a continuous manner with 178 bands (VNIR and SWIR). The ITRES sensor collects 100 continuous bands in the

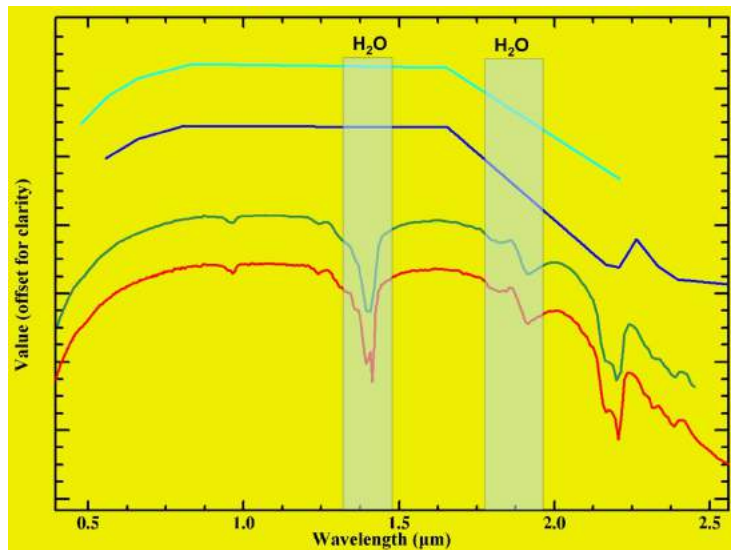


Figure 2. Comparative spectral plot of spectra obtained from three sensors: SpecTIR (green), ASTER (blue) and Landsat (cyan). The library spectrum for kaolinite is shown in red. The inflexion points on the Landsat and ASTER spectra mark the locations of their bands. Note the distinctive absorption feature at ~2.2 µm. Shaded ‘H₂O’ areas indicate regions of the electromagnetic spectrum blocked by atmospheric water.

SWIR portion of the spectrum. The other major image types included in the IAT, Landsat and ASTER, are multispectral imagers that sample only a limited number of bands, 6 and 9 respectively (within the VNIR and SWIR). Figure 2 illustrates the spectrum that would be obtained by these three sensors. It is obvious that only the SpecTIR hyperspectral sensor provides enough readings to accurately define the complete reflectance spectrum of the mineral being examined.

SpecTIR Imagery

The hyperspectral imagery obtained for this project by SpecTIR LLC was collected on August 1, 2007 from a fixed-wing aircraft flying approximately 1155 m above the ground surface. A sun elevation angle of about 56° was available on this date at the latitude of the sites. The resulting imagery has a pixel size and ground sample distance (GSD) of about 1.5 m. The images are 296 samples (pixels) wide. The full width at half maximum (FWHM; i.e., bandwidths) for the 178 bands ranges from 9.1 to 12.6 nm. Individual flight lines ranged from 4.2 to 18.7 km in length, requiring between 2 800 and 12 500 scan lines respectively. This sample density results in about 21 million individual spectra being collected during this project. The imagery is provided in radiance and reflectance values. The atmospheric correction used to convert the data from radiance to reflectance was performed by SpecTIR using the ATCOR4 commercial software that employs the MOTRAN4 radiative transfer code. The raw reflectance output spectra were then modified and polished to remove any model- or sen-

sor-related artifacts with proprietary SpecTIR techniques. Orthorectification solutions for the imagery were also provided using information obtained from the onboard GPS/INS sensor.

The AISADUAL sensor package of imaging spectrometers was used to collect the image data from two adjacent ranges of the electromagnetic spectrum. The AISA Eagle was used to collect 59 bands of information from the VNIR range of the spectrum (0.4–0.95 μm), and the AISA Hawk was used to collect 119 bands from the SWIR range (0.967–2.45 μm). A full description of this instrument package is available from the manufacturer, Spectral Imaging Ltd.

ITRES Imagery

The hyperspectral imagery obtained for this project by ITRES Research was collected on July 12, 2007. The details of this collection and subsequent processing are not yet available, but the sensor used was the SASI 600, which collects 100 bands between wavelengths of 0.95 and 2.45 μm, with a bandwidth of about 15 nm.

Survey Sites

Six sites were selected for inclusion as hyperspectral demonstration locations. The sites were located in the interior region of the province and include a variety of surface exposure conditions and geological environments (Figure 1). The IAT contains Landsat and ASTER coverage for all these sites and the ability to compare capabilities between the different image types. Most of the sites have detailed

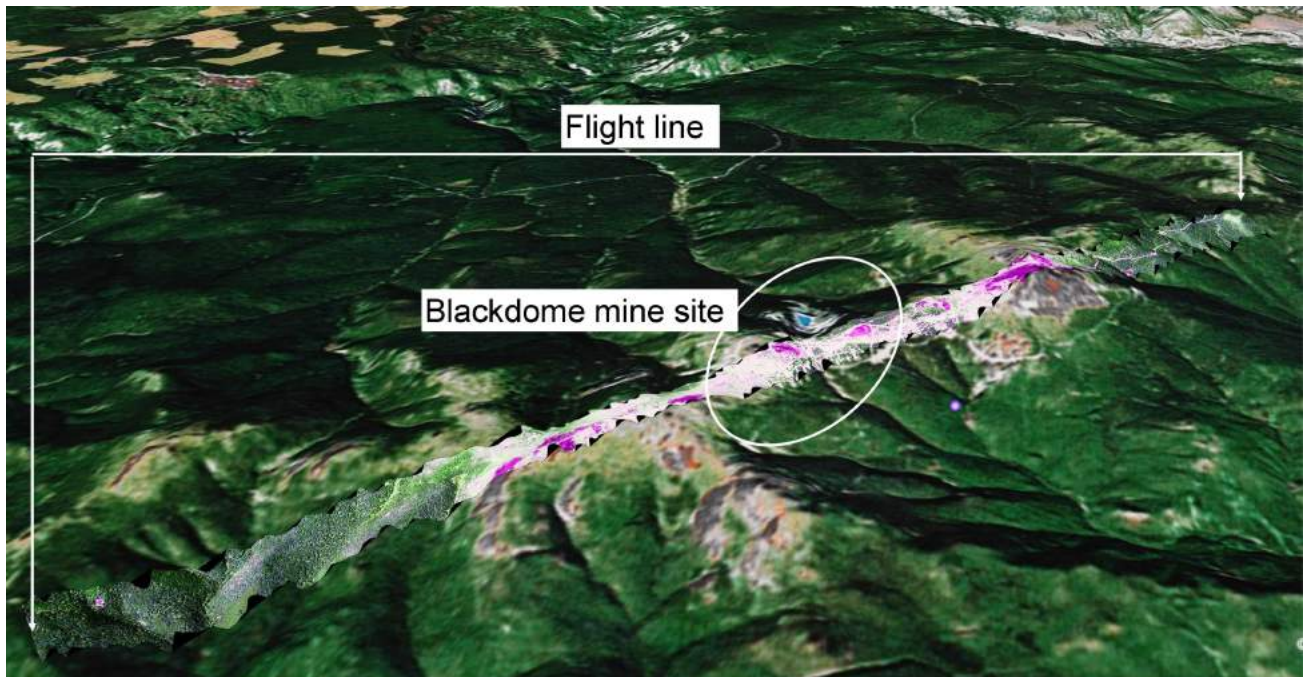


Figure 3. Blackdome hyperspectral false-colour image draped over Google™ Earth terrain. Ellipse marks the area of the mine's surface disturbance. Image is about 11 km wide.

exploration information available in the form of BC Mineral Assessment Reports, and all have regional geology, geochemistry and geophysical information available for reference in MapPlace.

Blackdome

The Blackdome site is centred on the mine site at 51.314°N, 122.50°W. The one flight line collected for this site is 11 km long, about 400 m wide (Figure 3) and has a bearing of about 200°. The site includes the Blackdome past-producing epithermal Au-Ag vein deposit and the Midas epithermal Au-Ag showing, MINFILE 092O 053 (MINFILE, 2007). The flight line includes the transition from heavily forested to alpine vegetation. Surface topography ranges from 1700 to 2220 m. South of the mine site, the flight line covers terrain that is undisturbed; north of the mine site, it parallels the main mine access road. The geology covered by the flight line includes Early–Middle Tertiary volcanic and associated volcanoclastic sedimentary rocks cut by small intermediate to mafic dikes. A significant fault is also present in the southern portion of the flight line. The varied exposure types and presence of a significant epithermal system should prove to be a very interesting site for hyperspectral analysis in the BC context.

Gibraltar

The Gibraltar site is centred on the producing Cu-Mo porphyry open pit mine at 52.514°N, 122.273°W, MINFILE 093B 012 (MINFILE, 2007). Three overlapping flight lines

were collected at this site to provide coverage over an area measuring 9.6 km long by about 1 km wide. In addition to the active mine site with its good rock exposure, the flight lines include areas of typical logging and mineral exploration features (Figure 4). The lines are oriented north-south to take full advantage of the solar illumination. The flight line is underlain by the Early Jurassic Granite Mountain batholith. All three phases of this batholith are imaged by these flight lines: the Southern Border phase; the Mine phase tonalite and Northern Border phase; and the Granite Mountain phase. The surface topography is relatively subdued, with the average elevation being about 1200 m. This site offers the opportunity to examine very good exposures of this deposit, with its well described alteration minerals and structures.

Lang Lake

The Lang Lake site is a single flight line centred at 51.93°N, 120.9°W. The line is oriented approximately north-south and is 18.7 km long and about 400 m wide (Figure 5). There are five known showings and one prospect within 1 km of the flight line. There are a number of very interesting copper, molybdenum and gold Regional Geochemical Survey (RGS) stream sediment values in the area of the flight line. The northern portion of the line is underlain by Triassic–Jurassic plutonic rocks of the Takomkane and Thuya batholiths. The southern portion is underlain by Late Triassic basalt flows. A number of faults crosscut the flight line. The recently released Bonaparte East multiparameter geophysical survey (Miles et al., 2007) provides detailed infor-



Figure 4. Gibraltar hyperspectral false-colour image draped over Google™ Earth terrain. The hyperspectral image is a mosaic constructed from the three individual lines flown over this site.

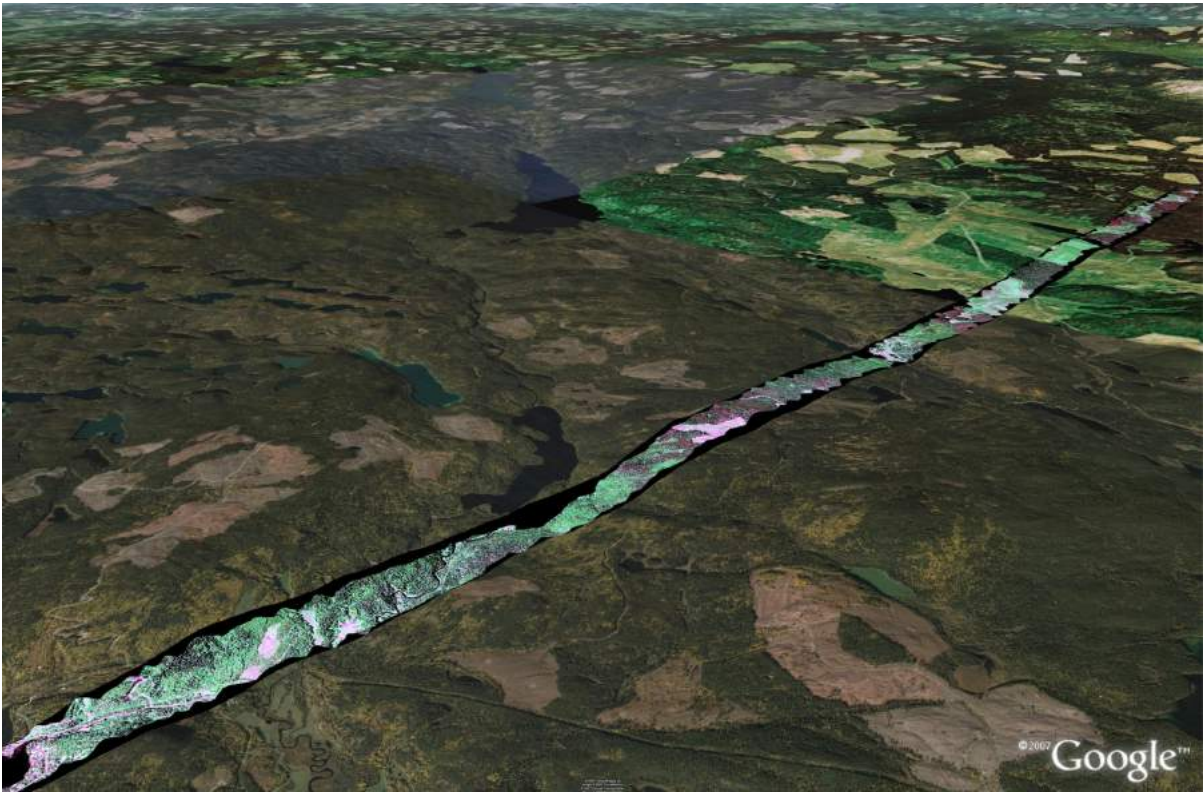


Figure 5. Lang Lake hyperspectral false-colour image draped over Google™ Earth terrain. The image is about 12 km wide. The high-resolution Google Earth background image in the lower part of this figure is not properly registered (about 300 m too far west). Google Earth is used here to show the topographic relief.

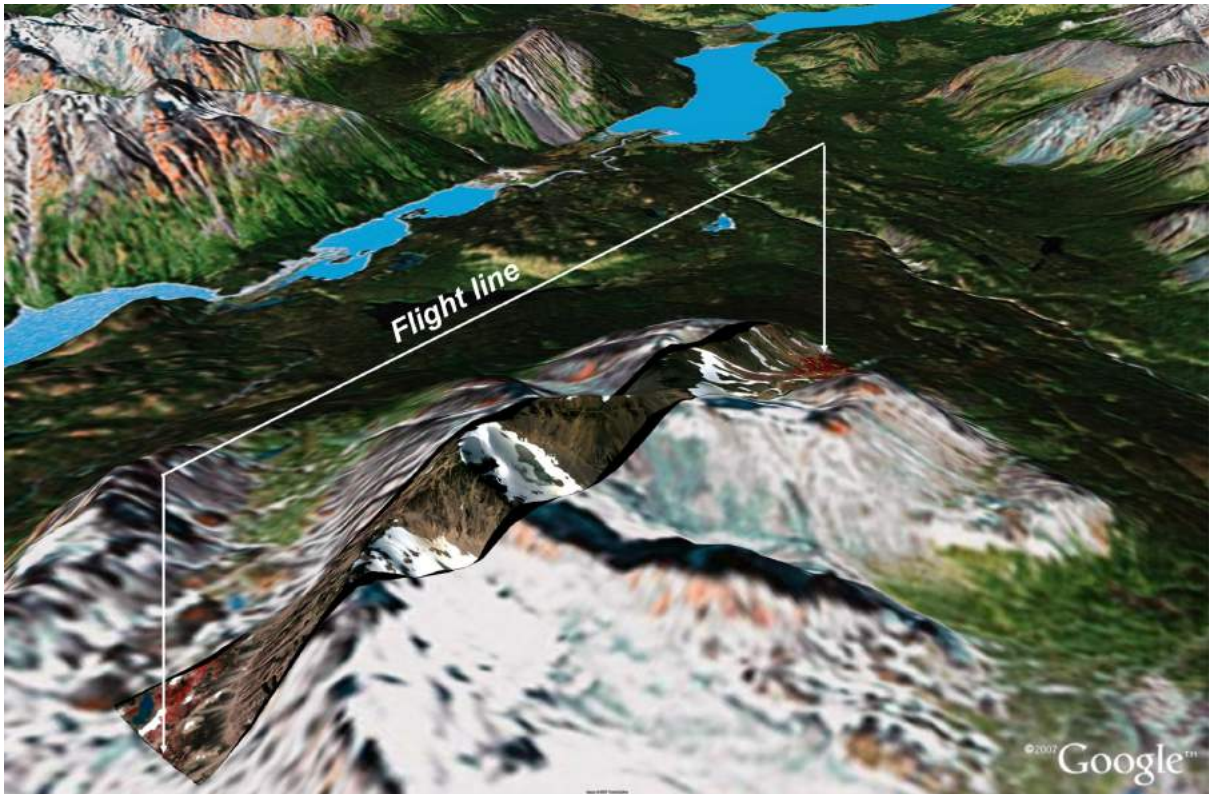


Figure 6. Limonite site hyperspectral false-colour image draped over Google™ Earth terrain. Taseko Lakes can be seen in the upper portion of the image. The red in the hyperspectral image represents chlorophyll-bearing vegetation.

mation for the entire flight line. This site was selected as an example of typical poorly exposed terrain in the interior portion of the province. The area has been partially logged and heavily infested with mountain pine beetle. Rock exposures are limited to man-made surface disturbances associated with logging and along water features. The combination of interesting geochemistry, good geophysics and poor surface exposure at this site will provide a good test of the capabilities of hyperspectral imagery.

Limonite

The Limonite site is a single flight line centred at 51.086°N, 123.4756°W, MINFILE 0920 010 (MINFILE, 2007). The line is oriented north-south and is 4.2 km long and about 500 m wide (Figure 6). The line samples typical alpine exposures of variably altered rock types. Elevation along the flight line ranges from 2000 to 2670 m. Significant copper and gold RGS stream sediment values are present in streams draining the area of the flight line, and known porphyry mineralization has been discovered in the area. This site is the only one to include small glaciers and snow fields. The northern portion of the line covers Late Cretaceous volcanoclastic strata of the Powell Creek Formation and the southern portion is underlain by Late Cretaceous granodioritic intrusive rocks of the Coast Plutonic Complex. The central portion of the line is underlain by a Late Cretaceous–Early Tertiary feldspar porphyry. This site provides an excellent example of typical alpine terrain to be found in the province. It also samples the contact of the Coast Plutonic Complex and contains obvious visible alteration minerals.

Mount Polley

The Mount Polley site, MINFILE 093A 008, was sampled with three overlapping flight lines centred on the Mount Polley producing alkalic porphyry Cu-Au open pit mine at 52.55°N, 121.6345°W (Figure 7; MINFILE, 2007). The lines are oriented north-south, and are about 12 km long and cover a width of about 1.0 km. They cover areas of the Early Jurassic Nicola Group volcanoclastic rocks and the deposit-hosting felsic Jurassic–Triassic Polley stock. Propylitic and potassic alteration are present around the mineralization, and a zone of garnet-epidote alteration has been noted between these two zones. Beyond the mine workings, the surface is well vegetated. Various ages of logging and mineral exploration roads and drill sites provide ground exposures in these vegetated areas. Information from a recent, high-resolution, helicopter-borne, multiparameter geophysical survey is available for the area covered by the flight lines (Shives et al. 2004). This site will provide a good example of alteration mineralization associated with alkalic porphyry deposits, as well as including areas at various stages of reforestation and some mineral exploration features.

Prosperity

The Prosperity site is a single north-south flight line centred on the Prosperity Cu-Mo porphyry deposit at 51.466°N, 123.630°W, MINFILE 0920 041 (MINFILE, 2007). The line is 6.3 km long and about 500 m wide (Figure 8). The area sampled by this flight line is an example of very poor exposure, with the northern portion being covered with Pleistocene–Holocene alluvium and till, while the southern portion is covered with Miocene–Pleistocene Chilcotin

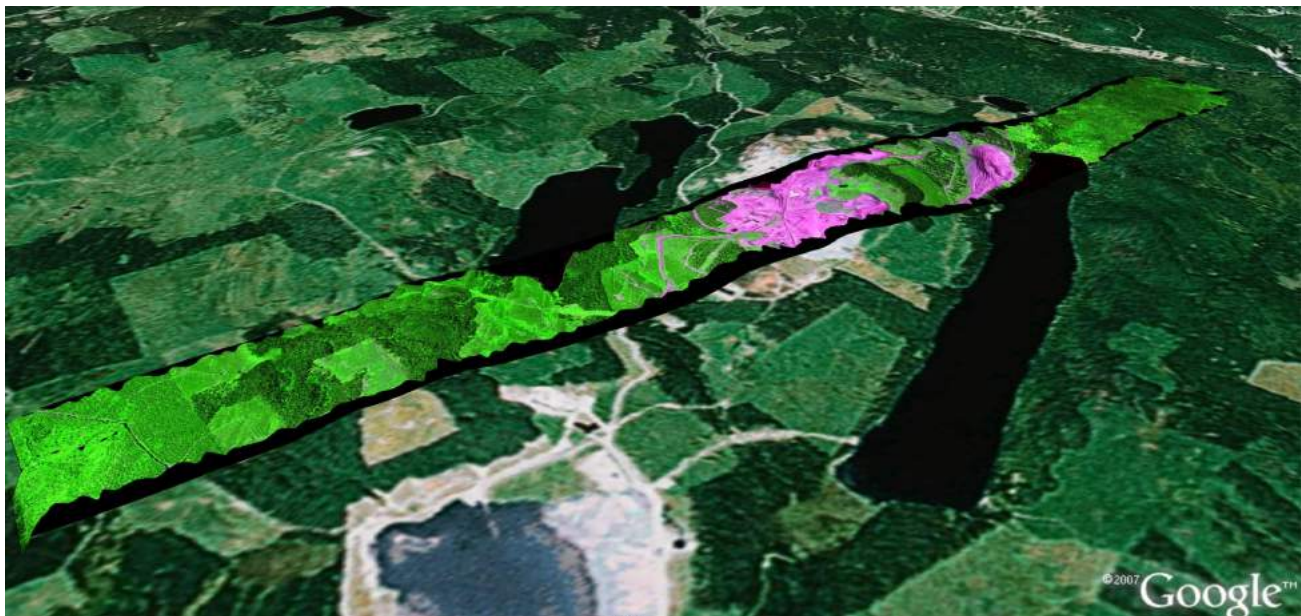


Figure 7. Mount Polley hyperspectral false-colour image mosaic draped over Google™ Earth terrain. The hyperspectral mosaic is constructed from the three individual images collected over this site. Bare rock exposure appears pink in this false-colour image.

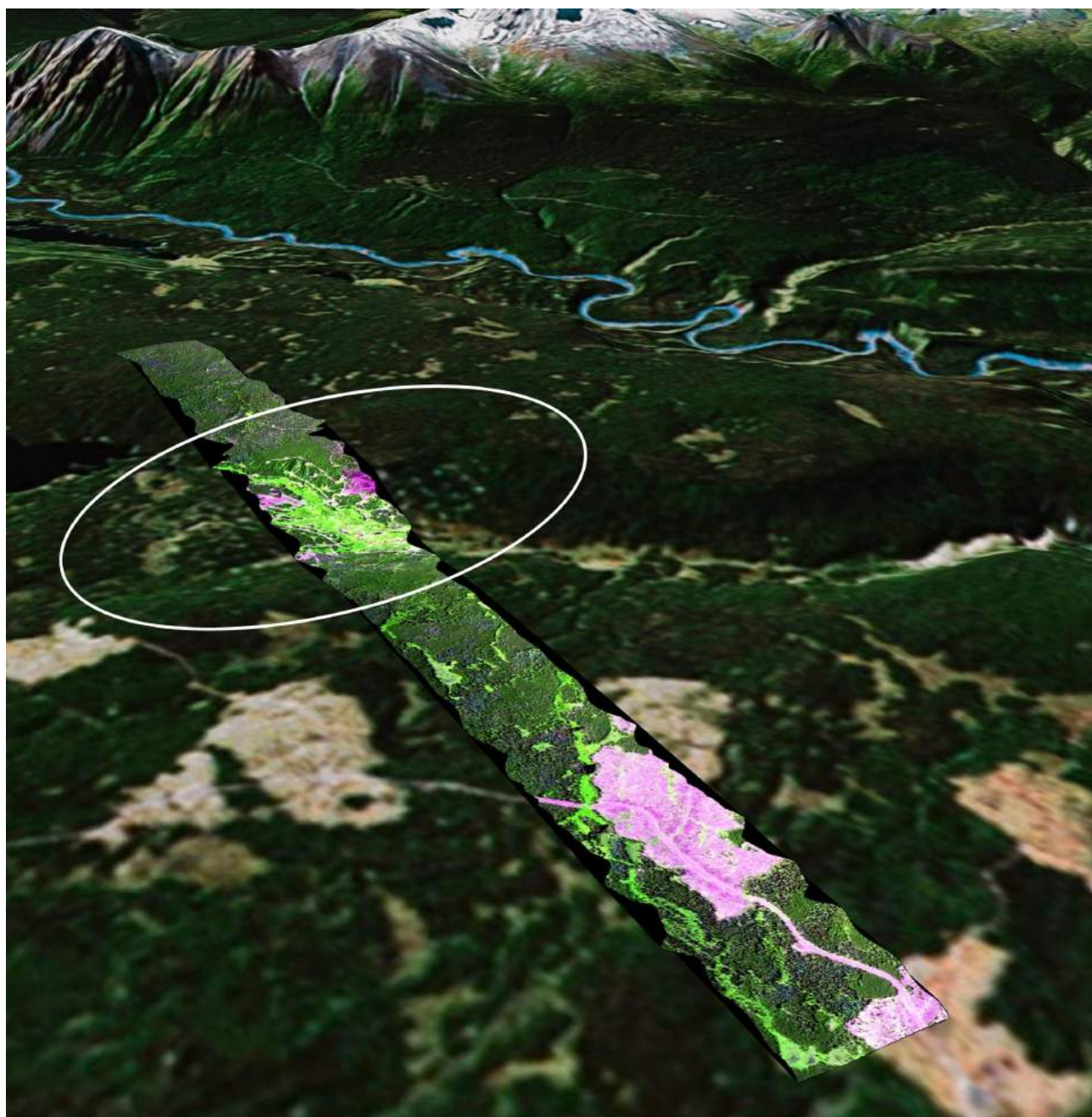


Figure 8. Prosperity hyperspectral false-colour image draped over Google™ Earth terrain. The ellipse marks the area underlain by the deposit. The regular pattern of exploration drill sites can be easily seen on the background Landsat imagery, as well as in the hyperspectral image.

Group alkaline volcanic rocks. Some ground exposure is available in the form of logging and exploration roads, and drill sites. There are several excellent copper and gold RGS stream sediment values in drainages crossing the area of the flight line. The site has been well documented and there is a recent (1995), high-resolution, multiparameter geophysical survey available (Shives et al., 2005). This site was selected to investigate the potential of hyperspectral imagery to provide additional information in an area with thick cover.

Kicking Horse

The Kicking Horse site is centred on the Kicking Horse past-producing Pb-Zn mine at 51.424°N, 116.445°W, MINFILE 082N 020 (MINFILE, 2007). The deposit is located within a thick succession of massive to thin-bedded limestone and dolomite of the Middle Cambrian Cathedral Formation. The site falls within Yoho National Park but provides a good example of a carbonate-hosted deposit that could be found elsewhere in the province.

Ice River

The Ice River site is located west of the Ice River in Yoho National Park, centred about 57.17°N, 116.46°W. The site samples the ultrabasic Ice River intrusive complex and associated skarn deposits. Carbonatite is present within the imaged area. The site is above the treeline and should provide an example of some very interesting mineral assemblages.

Image Analysis Toolbox Enhancements

New Imagery

The SpecTIR hyperspectral image data can be interactively analyzed in the same manner as the previously existing Landsat, ASTER, AVIRIS and Hyperion data. The images are named S1 through S10 and their footprints can be toggled on and off with the 'SpecTIR' button on the initial IAT tool panel. Access to the downloadable SpecTIR hyperspectral data is through the 'SpecTIR Download' button (Figure 9). A new download button for the ITRES imagery will be added when the imagery becomes available.

The downloadable SpecTIR data will be available in radiance and reflectance values. The image data will be in Band Interleaved by Line (BIL) format. The images will be divided into data cubes that can be readily downloaded. The cubes will be 296 pixels wide and contain 178 bands. The number of scan lines in each data cube will be decided fol-

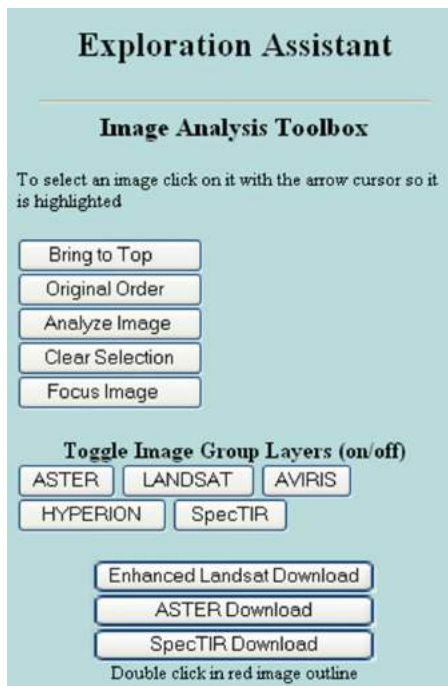


Figure 9. Introductory IAT panel in the Exploration Assistant map on MapPlace. The new SpecTIR hyperspectral imagery can be accessed for online analysis or downloaded through the two new buttons on this panel.

lowing analysis of download speeds obtained through the final server configuration. The orthorectification solution will be provided in ENVI's (Environment for Visualizing Images) Input Geometry (IGM) format that provides the co-ordinates (UTM Zone 10, WGS-84) for each image pixel resulting from the orthorectification process.

SpecTIR hyperspectral imagery available for online analysis is orthorectified and atmospherically corrected. In the IAT, it is essential that the imagery is orthorectified so it can be integrated with all the supporting GIS data available in MapPlace. The downloadable image cubes are available in the raw form with accompanying files to enable orthorectification.

New Tools

Two new capabilities have been added to the IAT to enhance its analysis capabilities. These new capabilities can be used with the Landsat, ASTER, ITRES and SpecTIR datasets.

Spectrum Viewer

The ability to view the spectrum from a specific image pixel or a sample from the included USGS Mineral Spectral Library has been added to the Spectral Angle Mapper (SAM)

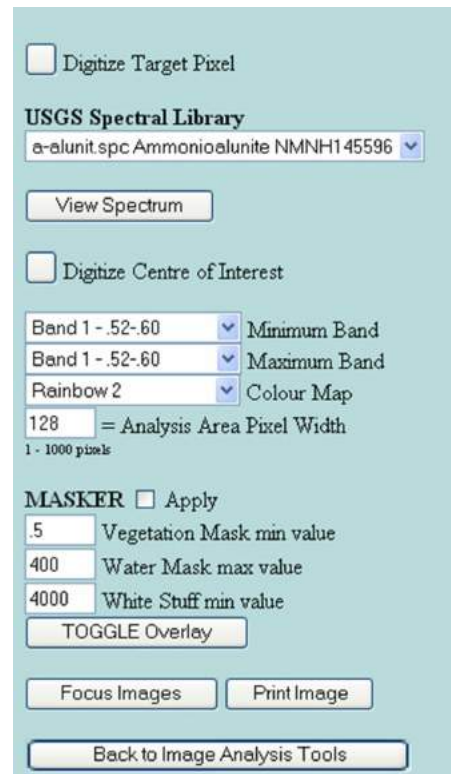


Figure 10. New layout of the 'Spectral Angle Mapper' panel. The 420 entries in the USGS Mineral Spectral Library are available through the pull-down selection box. The 'View Spectrum' button produces a spectrum plot of the selected spectrum.

tool. Once a target pixel has been digitized from the image being analyzed, or one of the library spectra has been selected, the 'View Spectrum' button can be clicked to present a display of the spectrum (Figure 10). The 'Minimum Band' and 'Maximum Band' selection boxes can be used to select the range of contiguous bands to be displayed in the spectrum plot. The selected spectrum, from the image or spectra library, can also be used to perform a SAM analysis on the image simply by clicking on the 'Digitize Centre of Interest' button and then clicking on a point on the image. The ability to view image spectra is a very powerful capability in the interactive investigation of an image (Figure 11).

Spectral Library Reference

The USGS Mineral Spectral Library has been added to the IAT to provide known reference spectra for comparison with spectra from images contained in the IAT. The detailed spectra contained within this library have been resampled to correspond to Landsat, ASTER and SpecTIR bandwidths. The appropriate resampled library is loaded when any of these three image types is being analyzed. The USGS Spectral Library contains laboratory-obtained spectra from 420 minerals. The spectra span the range from 0.3951 to 2.56 μm . As a result of the library spectra only sampling the VNIR and SWIR range of the electromagnetic spectrum, the TIR (Thermal Infrared) bands of ASTER and Landsat are not represented and are not dealt with when comparing to the USGS Spectral Library. The spectra obtained from the spectral library are in reflectance values. Both the ASTER and SpecTIR imagery have been converted to reflectance or relative reflectance values and, as such, the spectral shapes are comparable.

Summary

Eight sites in southern BC have been sampled with high spatial and spectral resolution hyperspectral sensors. The resulting hyperspectral imagery is available for online analysis and integration with other mineral exploration data in MapPlace or downloading for offline analysis. The

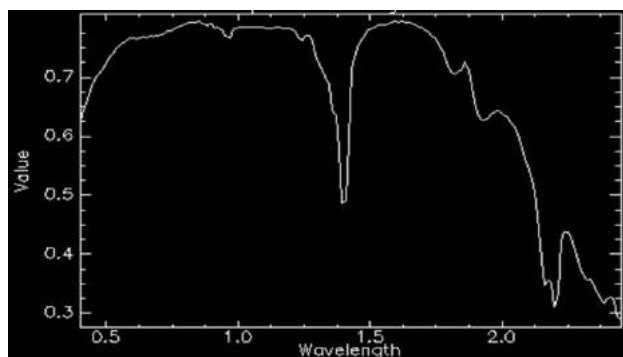


Figure 11. Spectrum plot for kaolinite (kaolin1.spc Kaolinite CM9) from the USGS Spectral Library. This spectrum has been resampled to match the SpecTIR band positions and widths.

purpose of the project was to provide examples within British Columbia of high-quality hyperspectral imagery to allow the exploration community to assess its value in a number of varied situations. As such, the selected target sites include a range of surface and geological characteristics common in BC.

Modifications were made to the IAT to enhance the analysis capabilities of this online toolbox.

This progress report was prepared just as the final data products from SpecTIR were received and ITRES imagery was expected. Additional analysis of the imagery will be performed during the life of this project to highlight the capabilities of this exploration tool.

Acknowledgments

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