The CCRS SWIR Full Spectrum Imager (SFSI): Mission to Nevada June 1995

The following abridged paper, originally appeared in the ERIM Conference on Applied Geologic Remote Sensing, in Las Vegas, Nevada in February 1996

Phoebe Hauff, Spectral International, Inc. Lafayette, CO
Peter Kowalcyczk, Michael Ehling, Placer Dome Exploration Inc, Vancouver, BC
Gary Borstad, Borstad Associates Ltd, Sidney, BC
Gary Edmundo, Richard Kern, North Mining Inc, Reno, NV
Bob Neville, Richard Marois, Canada Centre for Remote Sensing, Ottawa, Ont
Sandra Perry, Perry Remote Sensing for Barrick Gold Corporation, Elko, NV
Richard Bedell, Homestake Mining Company, Sparks, NV
Charles Sabine, Alvaro Crosta, Tomaki Miura, Desert Research Institute, Reno, NV
Greg Lipton, BHP Minerals Canada Ltd, Toronto, Ont
Vladimir Sopuck, Robert Chapman, Cameco Corporation, Saskatoon, Sask
Mit Tilkov, Cominco Ltd, Vancouver, BC
Kerry O´Sullivan, Michael Hornibrook, CRA Exploration Pty Ltd, Bundoora, VIC, AUS
David Coulter, Newmount Gold Company, Denver, CO
Scott Bennett, Western Mining Corporation, Reno, NV

ABSTRACT

The Canada Centre for Remote Sensing (CCRS) has developed an airborne sensor, the SWIR Full Spectrum Imager (SFSI) which detects in the Short Wave range of the solar spectrum from 1220 nm to 2420 nm. The push broom design sensor has the ability to simultaneously acquire the full spectrum at high spatial (to 20 cm) and spectral (10.4 nm) resolution. The instrument utilizes a two-dimensional detector array (a 488 line by 512 pixel PtSi, Schottky barrier photodiode array), refractive optics and a transmission grating with an angular field of view of 9.4 degrees. Any number of bands between a minimum of 22 and the full set of 115 can be recorded. Within these limits, the band combinations can be freely selected.

In June of 1995, a demonstration flight was undertaken in the state of Nevada with the support of the companies listed as authors. The focus of the flight was to obtain a suite of data cubes representing a cross section of well-known mineral deposits and to determine the robustness of the instrumentation. The objective of the mission was to evaluate the applicability of this sensor to detailed alteration mineral mapping and subsequent integration into mineral exploration programs. The sites chosen include Cuprite, extensively documented as a remote sensing hydrothermal test site; Goldfield, a volcanic hosted acid sulfate system; Yerington, a structurally complex porphyry copper deposit; Virginia City, a quartz-sericite-pyrite vein system with advanced argillic pods; Hasbrouck Mountain, sinter and sericite alteration; the original Carlin Pit, as the sediment hosted gold deposit; and Bodie, CA, an example of quartz-adularia-gold veins.

Ground spectral data was collected at most of the sites with the PIMA-II spectrometer to provide an overview of the mineral spectra for each locality. These spectra can be used to define the minerals present in the alteration systems and also imported into many image processing programs to further refine the processed SFSI images and identify spectral components of the images.

This paper will show the results from SFSI a full band set cube obtained over the Occidental Lode system at Virginia City, NV, ground truthed with the PIMA spectrometer, and processed with PCI software.

DATA ACQUISITION

For the June flight, the SFSI sensor was shipped from Ottawa, Ontario to San Jose, California where it was mounted in a twin engine, high-wing AeroCommander aircraft and then flown to Reno, Nevada. 114 data cubes were acquired over some 60 group and proprietary test sites in Nevada.

An unpressurized aircraft was used. The craft flew at 10,000' above the targets, except the highest test sites, to acquire data at the nominal 1 meter cross track resolution. The crew was required to use oxygen over most targets. The ground speed was 120-160 knots. The instrument integration time is 50 msec. This resulted in an along track pixel resolution of 1.2-1.6 m.

The aircraft was guided over the targets using GPS navigation and high altitude aerial photographs. For this test only, no altitude compensation or measuring equipment (to either remove or allow later correction for aircraft roll, pitch and yaw) was installed.

Most data acquisition was between 1200 and 1600 hours solar time. Turbulent winds in the lee of the mountains, heavy cloud cover and the lack of altitude compensation were limiting factors for data acquisition.

At present, in the experimental configuration, the SFSI sensor records data into 34 Megabytes of on-board video memory, and later down loads this to Magneto-Optical storage. When recording all 115 spectral bands at the 50 msec integration time, data cubes are limited to 580 lines of data or 12 seconds in length. Recording fewer spectral bands allows the operator to extend the number of lines acquired to as many as 2142 lines or 42 seconds.

DATA CALIBRATION

Dark Offset Subtraction: The "dark offset" frame is computed from a dark cube acquired in flight and is subtracted from each target frame in the cube.

Radiometric Calibration: This is done using responsivity functions derived in the laboratory. These corrections compensate for spectral imbalances and spatial non-uniformities in the sensor's responsivity.

"Pseudo-reflectance Conversion": Data is divided by the extra-terrestrial solar irradiance. This was done to reduce the range of data so that it can be stored as 8-bit numbers. Several assumptions are made including a zenith sun and a Lambertian reflector.

Slit Curvature Correction: This corrects for the wavelength shift that occurs as a function of view angle. Slit curvature, inherent in the spectral dispersion process, results in a curved slit image for a straight entrance slit illuminated by monochromatic light. In SFSI this causes a view-angle-dependent wavelength shift of up to 10 nm for spectral bands near the outside of the array. Linear interpolation between the two bands nearest to the nominal band wavelength was used.

GROUND CALIBRATION

Ground calibration was done with the PIMA-II field SWIR region spectrometer. Pima has 5 nm resolution, operates from 1300 to 2500 nm with an internal light source. It has a 10 mm sapphire sensor window and is a contact mode instrument which can be taken directly to the outcrop.

At Virginia City, PIMA was used to identify the mineral species present in the test area. The spectra shown illustrate the cross section of minerals: (A) and (B) are lode illites; (C) and (D) are potassium and sodium alunites; (E) shows dickite; (F) is pyrophyllite and (G) is an example of diaspore.

PIMA spectra and ground mapping were extremely important in the calibration process of the SFSI. By knowing the mineral distribution on the ground and by locating the ground points, and the accompanying mineral species at the various points, it was possible to pull the pixels from the SFSI image, compare against the re-sampled PIMA spectra, verify the spectral identifications, and produce the mineral distribution classification images.

DATA PROCESSING

The images presented here went through the following procedures. It is important to note that atmospheric corrections have not yet been applied.

1) The image was georeferenced using a 1:62500 reference map which then allowed ground samples to be tied to the image.

2) Image spectra for each field sample location were compared to PIMA spectra. This was done using the "spectral plot" feature within PCI Imageworks. A 3x3 sample window is used to remove some of the noise within the image. PIMA spectra were convolved into SFSI spectra and saved into a library for comparison with the image spectra, which were also pulled at each sample locality and saved into the same library.

3) The classification shown in the Clay Mineral Map was created using the Spectral Angle Mapper in PCI. This is based on the Spectral Angle Mapping technique developed by J.W. Boardman. Individual mineral classification images were obtained in the same fashion.

4) Other techniques tried included Log Residuals and flat field correction. It was concluded that the atmospheric correction must first be done for these methods to be more successful.

PROJECT APPROACH

1) Extensive geologic background data collected on Virginia City, NV.

2) SFSI Aircraft Flight June 21, 1995

16,000' Flight Line #40	
Cube #56 = full band set	0.5 x 0.8 km
Cube #53 = mini-band set	0.5 x 1.5 km
Ground pixel size	approximately 1 meter

3) PIMA Ground Data Set: collected first for general mineralogy of the area

4) SFSI Pre-Processing:

Dark Offset Subtraction
Radiometric Calibration
Pseudo-Reflectance Conversion
Slit Curvature Correction

5) First Generation Images (Field Check): These images were produced without the slit curvature correction and were used for initial field check for spatial location. PIMA sample localities were marked on the images during field checking.

Figure 1 shows image cube with slit curvature correction (91 kb)

6) Data Integration: PIMA sample identifications were compared against the alteration map created by Don Hudson. The integration of these two data sets was then used to produce images.

7) Field Check: Anomalous areas were field checked again. These turned out to be soil and scree slopes and cutbanks along roads.

8) Mineral Map Products: Initially classification maps for only three minerals, illite, dickite and alunite have been created.

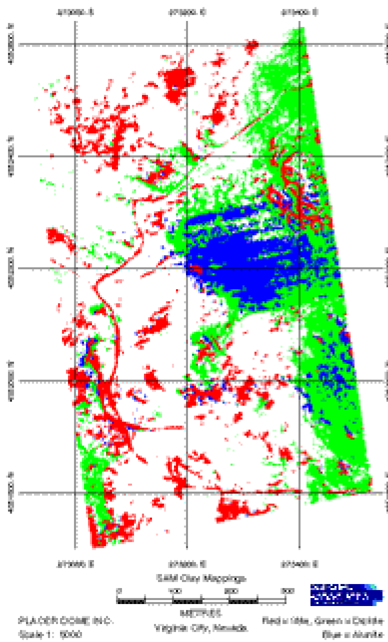

Figure 2 (25 kb)

RESULTS AND CONCLUSIONS

The SFSI system provides hyperspectral data from 1220 to 2420 nm. Test data collected over the Occidental Lode near Virginia City indicates that it has good signal to noise. Mineral maps can be generated with commercially available software from SFSI airborne data. These maps are of high interest to the mineral explorationist as they are direct indicators of mineralizing systems. A small suite of samples collected within the Virginia City cube has shown a strong correlation between anomalous gold and illitic zones mapped in the SFSI data cube. All anomalous samples came from sample sites mapped as "illitic". In hand specimen, 3 of 4 samples marked siliceous, and 2 of 3 samples marked altered were not anomalous in gold.

The SFSI system is a small, cost effective airborne sensor which can map mineral systems at a project scale.