THE USE OF HIGH SPATIAL AND SPECTRAL RESOLUTION AIRBORNE IMAGERY FOR ALTERATION MAPPING AND WASTE CHARACTERIZATION AT THE COMSTOCK LODE, NEVADA

David W. Coulter
Overhill Imaging and Cartography LLC, Golden, CO USA

Phoebe L. Hauff
Spectral International Inc., Arvada, CO USA

William Peppin
Spectir LLC, Reno, NV USA

1.0 INTRODUCTION

High spectral and spatial resolution hyperspectral imagery is used to map alteration minerals and chemical substitutions within minerals associated with the Comstock Lode in Nevada. In addition, iron minerals are mapped to highlight locations with high potentials for mineralization and/or acid drainage generation. The high resolution nature of the data facilitates improvements in mineral mapping and survey derived signal-to-noise characterization.

The ore deposits of the Comstock district were emplaced by one of multiple hydrothermal events during the middle Miocene [1]. The main Comstock Lode mineralization selectively exploited the then active N15E (and primarily dipping to the east) Comstock fault which underwent in excess of 500 m of normal displacement [1]. Detailed mapping by [1] identifies twelve overlapping hydrothermal alteration mineral assemblages that are classified as deep low-sulfidation and intermediate depth high-sulfidation packages. Multiple advanced argillic, argillic, and propylitic alteration styles as well as a single potassic style are identified.

The primary alteration minerals in the district that can be identified by VNIR-SWIR remote sensing are: alunite, kaolinite, dickite, pyrophyllite (advanced argillic); illite, sericite/muscovite (argillic); and chlorite, epidote, calcite, zeolites (propylitic). Minerals in the potassic zone are not readily identifiable by VNIR-SWIR methods. The chemistry of the illite/sericite in the district varies and can be identified as wavelength shifts of the 2200 illite minimum [2]. In addition to the primary alteration minerals, supergene iron minerals occur that provide both mineralization and mine waste characterizations.

2.0 METHOD

Prospectir hyperspectral data were collected on August 17, 2006 by Spectir LLC of Sparks, Nevada. Twelve flight lines were acquired parallel to the Comstock Lode with a nominal swath width of 250 m. Ground resolution was nominally 1m and spectral resolution was 4.38 to 4.89 nanometers (nm) (398.48 nm to 953.46 nm) and 6.29 nm (964.1 nm to 2454.98 nm). The data were ortho-rectified by Spectir using onboard GPS/INS and 10m USGS DEM's. Calibration to apparent reflectance was performed using ATCOR 4 and a proprietary empirical method called Virtual Empirical Line Correction (VELC). ATCOR was found to be unstable when applied to the full spectral resolution data and was, therefore, run on a spectrally resampled version of the data (~9 nm VNIR and 12.58 nm SWIR). This resolution is adequate for analysis of the VNIR data but unacceptable in the SWIR. The VELC correction preserves the full spectral resolution and is utilized for the SWIR data.

The specifications of the Prospectir system provide for a Signal-to-Noise Ratio (SNR) of greater than 500 at 60% reflectance. This was verified by calculating the SNR (mean divided by standard deviation) in a moving 3x3 window over data that are masked to 30%-60% reflectance [3]. In high spatial resolution imagery, it is likely that a homogeneous area of at least 3 m x 3 m (in the case of 1 m data) will be encountered by serendipity. In this data set a number of large roof tops and an area of railroad ballast were homogeneous. This approach provided an independent measurement of SNR of greater than 600 for most channels.

Analysis of the data is undertaken using shape based classification and partial unmixing. Spectral curve similarity classification is performed using Spectral Correlation Mapper (SCM) [4]. Partial unmixing is performed using Optimized Cross Correlation Mixture analysis (OCCM) [5]. Absorption band position analysis is performed using Gaussian fitting [6].

Image based endmembers are used for the analyses. These are identified through an iterative process: the likely endmember minerals are selected on the basis of knowledge about the alteration systems and pre-survey field measurements; SCM is run using library spectra of the candidate minerals; the "best" locations identified by SCM are inspected in the image; and the best image endmembers are identified and extracted.

Prior to final analysis, a vegetation mask is generated to eliminate all vegetated pixels. This is primarily done to save time processing since vegetation is not of interest in the study.

The image is split into VNIR (400 nm -1100 nm) and SWIR (2000 nm – 2450 nm) subsets – iron analysis is conducted on the VNIR subset and alteration mineral analysis is conducted on the SWIR subset. The SWIR image is then segmented into illite and non-illite regions. This eliminates some complexities introduced by the Gaussian absorption analysis. The non-illite image is analyzed for alunite, kaolinite, dickite, pyrophyllite, chlorite, and epidote using SCM. The illite image is analyzed by fitting a Gaussian to the illite absorption and OCCM. Finally, the VNIR is analyzed for iron mineral mixtures using OCCM. The results were verified with field measurements using an Analytical Spectral Devices (ASD) Terraspec ^{tm} spectrometer.

3.0 RESULTS

The results of the analyses show that high spatial and spectral resolution data provide high quality mineral mapping for the advanced argillic, argillic, and supergene iron minerals. Propylitic alteration, however, is mapped accurately only in some locations. This is likely due to recessive weathering and soil development that masks many of the propylitic zones. Illite chemistry zoning is seen but is not as simple as described in [2] with localized small scale zoning being more obvious than district wide zoning. High sulfidation zones with high temperature clays (e.g., dickite and pyrophyllite) appear to fall on a trend that is sub-parallel to the Comstock Lode. In at least one location, the 6.29 nm resolution of the SWIR imagery resolved what is identified as illite at resolutions coarser than 10 nm into dickite. In addition, the high spectral resolution of the SWIR permits subtle variations in the location of the illite minimum to be characterized. Finally, the iron mineral map identifies sulfide rich areas which represent possible mineralization and/or dumps that have acid drainage potential.

4.0 REFERENCES

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