INTEGRATING REMOTE SENSING TECHNIQUES AT CUPRITE, NEVADA: AVIRIS, THEMATIC MAPPER, AND FIELD SPECTROSCOPY

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1.0 Introduction

The Cuprite mining district in southwestern Nevada has become a test site for remote sensing studies with numerous airborne scanners (Abrams et al. 1977; Nobel et al. 1984; Goetz and Srivastava 1985; Carrere 1989; Kruse et al. 1990; and Hook and Rast 1990) and ground sensor data sets (Goetz and Curtiss, personal communication; Shipman and Adams 1987; and Kruse et al. 1990) collected over the past fifteen years.

Structurally, the Cuprite region can be divided into two areas with slightly different alteration and mineralogy. These zones lie on either side of a postulated low-angle structural discontinuity that strikes nearly parallel to US Route 95. Hydrothermal alteration at Cuprite has been classified into three major zones: silicified, opalized, and argillized (Hook and Rast 1990). These alteration types form a bulls-eye pattern east of the highway and are more linear on the west side of the highway making a striking contrast from the air and the imagery. Cuprite is therefore an ideal location for remote sensing research as it exhibits easily identified hydrothermal zoning, is relatively devoid of vegetation, and contains a distinctive, spectrally diagnostic mineral suite including the ammonium feldspar buddingtonite, several types of alunite, different jarosites, illite, kaolinite, smectite, dickite, and opal.

This present study brings a new dimension to these previous remote sensing and ground data sets compiled for Cuprite. The development of a higher resolution field spectrometer now provides the capability to combine extensive in-situ mineralogical data with a new geologic field survey and detailed AVIRIS images. This paper discusses the various data collection methods and the refinement of the integrated techniques.

2.0 AVIRIS Data

AVIRIS data from the 1990 season were evaluated utilizing GenIsis© and ERDAS© software on a personal computer. False color composite images and principal component images were generated using bands selected for optimum mineralogic discrimination. Bands were interactively selected by examination of the AVIRIS spectra on a pixel by pixel basis. Spectra of individual pixels in known altered areas were examined for diagnostic mineral absorption features. Bands were selected which showed maximum variation between alunite, kaolinite, buddingtonite, illite, and iron absorption features. Good mineralogic differentiation can be seen on both the false color composite and the principal component images. Similarity Index maps of alunite, kaolinite, buddingtonite, illite, and iron stained rocks were generated using GenIsis©. The Similarity Index maps gave a more specific indication of the distribution of each mineral and greatly aided the selection of field sampling sites. Figure 1 shows a Similarity Index map of alunite occurrences in the study area.

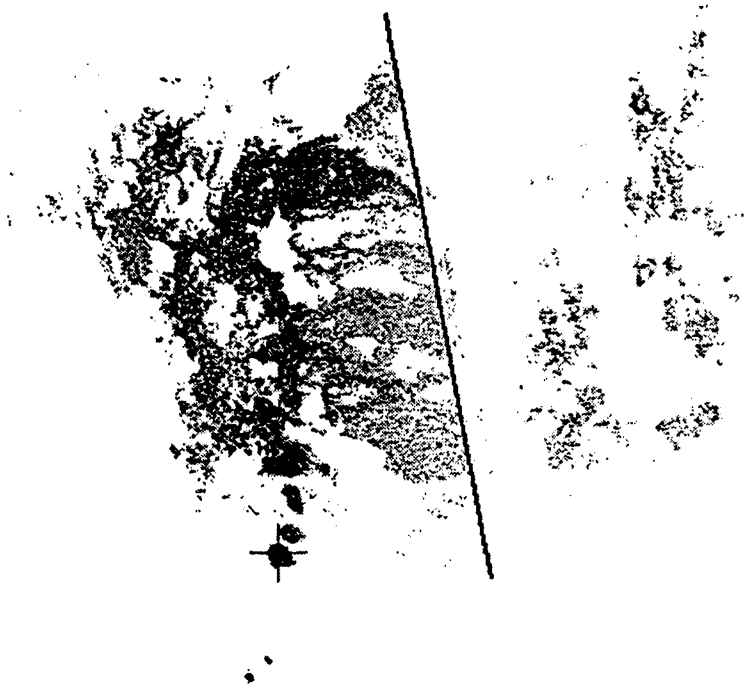

Fig. 1. Similarity Index for Alunite, Cuprite, NV - Darker Values Indicate Increasing Alunite.

3.0 Geologic Alteration Mapping and Sampling

The field sampling for this project was carried out in two separate phases. Thematic Mapper (TM) data were utilized to guide the first phase of sampling. A color ratio composite (CRC) was generated using TM ratios TM5/7, TM5/4 and TM3/1. Scatter plots were generated from TM5/7 vs. TM5/4 and TM5/4 vs. TM3/1. The scatter plots were used as an aid in the classification of the CRC data. A GIS character print map was then generated showing the areas most likely to contain hydrothermal alteration types. The sites delineated in the GIS were then visited and sampled.

AVIRIS data were used to guide the second phase of the field sampling. False color composite images, principal component images, and Similarity Index maps generated from the comparison of spectral plots derived from the AVIRIS data and those in the spectral library were used to guide the sampling to localities showing specific alteration assemblages.

The samples collected from the field visit were analyzed by three different methods. These include spectral analysis utilizing the PIMA-II spectrometer, thin section analysis, and x-ray diffraction.

The analytical results, combined with further field checks and field mapping, were used as an aid in the interpretation of the AVIRIS data. This allowed a refined geologic and mineralogic map of the alteration zones to be created which delineates the mineralogy in a detail not previously presented.

4.0 Field Spectroscopy Data

Spectral ground truthing was done at Cuprite using the PIMA-II portable spectrometer. With an internal light source and 5-7nm resolution, PIMA-II provides near-laboratory quality spectra within minutes and can be used exclusive of solar illumination and under most weather conditions. Therefore, the atmospherically masked bands, at 1.4μm and the 1.9μm, which provide invaluable information on hydroxyl and water content, can now be utilized.

With the field spectrometer, crystalline examples of alunite, buddingtonite, kaolinite, smectite, illite, and opal were observed in the eastern alteration zone, while spectra of illite, dickite, natro-alunite, and jarosite, among other minerals, were collected from the western alteration zone. This method is unique as it provides detailed mineralogy and multiple phase identification capabilities easily and almost instantly in the field. An example of this is shown in Figure 2. Spectrum (A) was collected from the "Buddingtonite Bump" and contains kaolinite, alunite, illite, and buddingtonite, all of which have identifiable features. Spectrum (B) is from the western alteration zone and shows dickite and natro-alunite. The ability to differentiate numerous species and solid solution phases, with confidence, has not been possible in-situ before now.

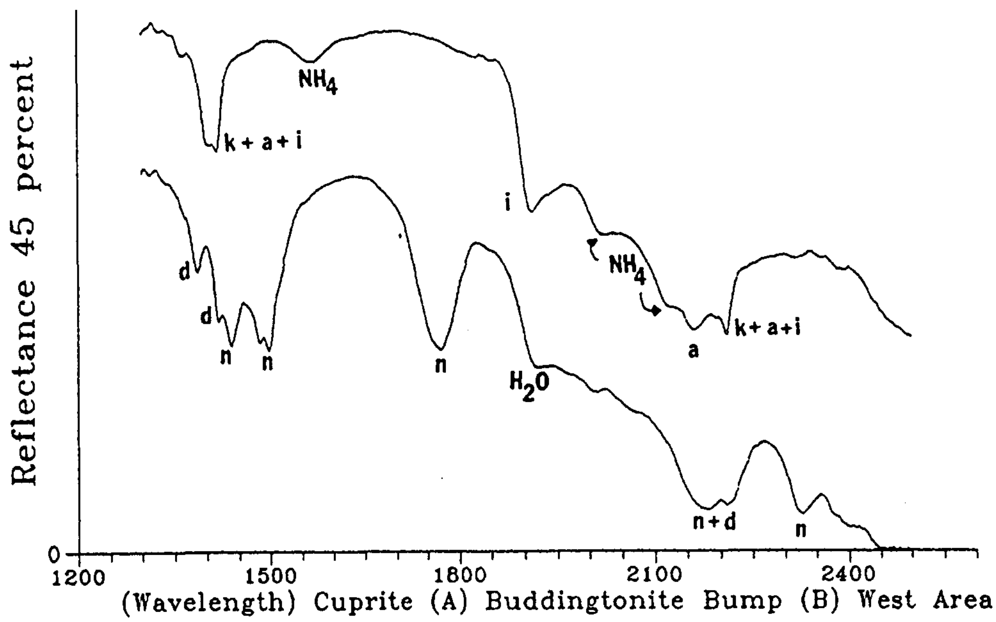

Fig. 2. PIMA-II Spectra from Cuprite, NV. (A) is from the Buddingtonite Bump; (B) from the Alteration Zone West of U.S. Highway 95. Key for the Minerals in the Spectra: K = Kaolinite, A = Alunite, N = natro-alunite, D = dickite, I = Illite. Spectra Collected with the PIMA-II Portable Short Wave Infrared (SWIR) Spectrometer, *Integrated Spectronics, Pty Ltd., Sydney, Australia.*

5.0 Discussion

The field spectrometer provided the ability to investigate the alteration zones distribution and subtle mineralogical changes at Cuprite, in detail not documented before. The ability to discriminate, in the field, ordering and chemical substitution within the mineral series, such as kaolinites and alunites, coupled with the hyperspectral data from AVIRIS and TM alteration mapping offers the field geologist an invaluable tool for sampling, geological interpretation, and exploration.

6.0 References

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