

A FIRST LOOK AT AIRBORNE IMAGING SPECTROMETER (AIS) DATA IN AN AREA OF ALTERED VOLCANIC ROCKS AND CARBONATE FORMATIONS, HOT CREEK RANGE, SOUTH CENTRAL NEVADA

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ABSTRACT

Three flight lines of Airborne Imaging Spectrometer (AIS) data were collected in 128 bands between 1.2 and 2.4 μm in the Hot Creek Range, Nevada on July 25, 1984. The flight lines are underlain by hydrothermally altered and unaltered Paleozoic carbonates and Tertiary rhyolitic to latitic volcanics in the Tybo mining district.

The original project objectives were to discriminate carbonate rocks from other rock types, to distinguish limestone from dolomite, and to discriminate carbonate units from each other using AIS imagery. Because of high cloud cover over the prime carbonate flight line and because of the acquisition of another flight line in altered and unaltered volcanics, the study has been extended to the discrimination of alteration products.

In an area of altered and unaltered rhyolites and latites in Red Rock Canyon, altered and unaltered rock could be discriminated from each other using spectral features in the 1.16 to 2.34 μm range. The altered spectral signatures resembled montmorillonite and kaolinite. Field samples were gathered and the presence of montmorillonite was confirmed by x-ray analysis.

INTRODUCTION

Three flight lines of Airborne Imaging Spectrometer (AIS) data between 1.2 to 2.4 μm wavelengths were acquired in the Hot Creek Range in south central Nevada (Figure 1) from a NASA C-130 aircraft on July 25, 1984 at an average of 19,000 feet above mean terrain. Thematic Mapper Simulator (NS001) imagery, Nikon black and white photographs, and Zeiss color photographs were collected simultaneously. The proposed flight lines are shown as dashed lines in Figure 1 and the actual flight lines are shown as solid lines. The flight lines were designed to include as many different carbonate formations as possible. Four limestone formations, three dolomite formations, two shale/argillite formations, one quartzite, one siltstone and three volcanic units ranging in composition from rhyolite to dacite were represented on the proposed flight lines. The primary objective was to use the AIS imagery to discriminate between carbonate units and other rock types, to distinguish limestone from dolomite, and limestone formations from each other.

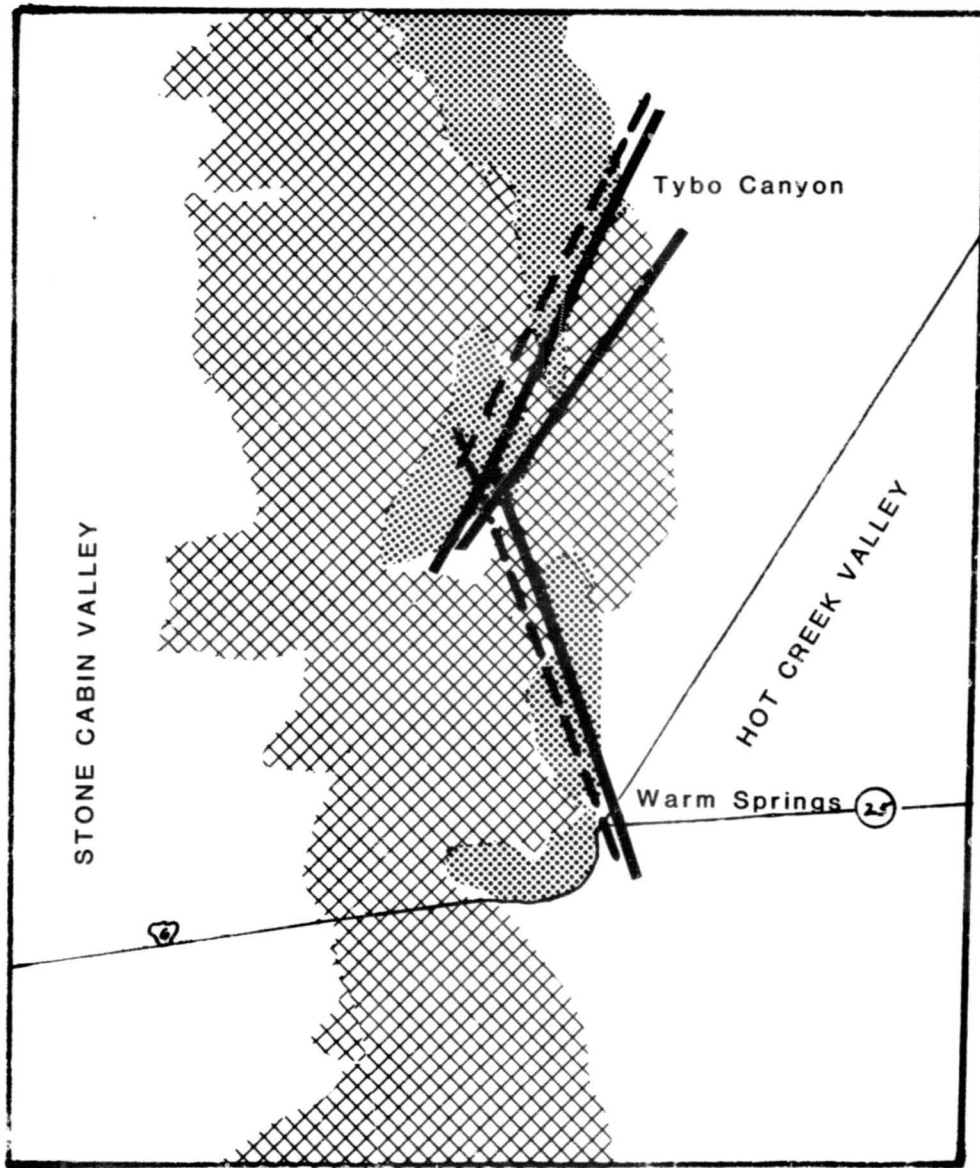
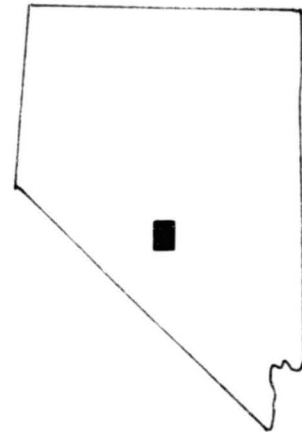
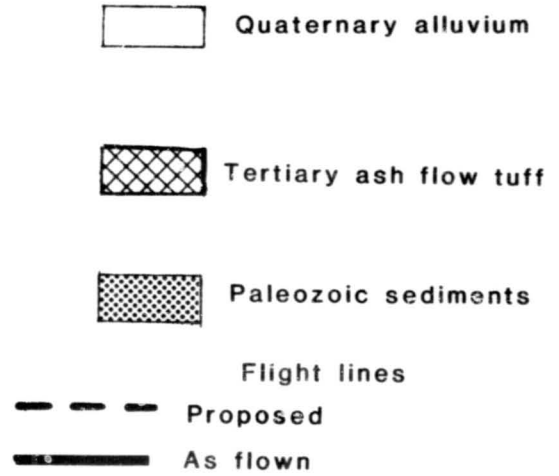


Figure 1. Hot Creek Range AIS Test Site



GEOLOGY OF THE HOT CREEK AIS SITE

In the southern Hot Creek Range approximately 7,500 feet of Paleozoic marine carbonates, sandstones and shales are overlain by 15,000 feet of Tertiary volcanics and volcanoclastics. Seventy-five percent of the Paleozoic section consists of carbonates (Cook, 1966; Quinlivan and Rogers, 1974). During the Devonian-Mississippian Antler orogeny, western assemblage eugeosynclinal rocks were thrust over eastern assemblage miogeosynclinal carbonates and clastics.

The major structural elements of the Hot Creek Range were formed in Cenozoic time and they consist of a broad anticlinal arch and normal faults. Normal faulting occurred concurrent with, and subsequent to, the eruption of large volumes of rhyolitic ash flow tuffs and minor amounts of intermediate lava.

The Cenozoic normal faulting has juxtaposed Paleozoic structural blocks adjacent to each other and to the Tertiary volcanics, and this juxtaposition enables the collection of AIS imagery over many of the carbonate and volcanic units in a short flight distance.

The project area is located in the Tybo mining district, a large producer of silver, lead, gold and zinc prior to 1940 (Kleinhampl and Ziony, 1984) with Paleozoic carbonates being the primary host rocks for mineralization. Alteration has locally affected both the carbonates and the volcanics. The carbonate units have been dolomitized, silicified and stained by ferric iron minerals, while the volcanics have been subject to bleaching, silicification and argillic and propylitic alteration.

AIS AND ANCILLIARY DATA DESCRIPTION, QUALITY AND ANALYSIS PROCEDURE

The proposed AIS flight lines (Figure 1) were designed to include as many Paleozoic carbonate formations as possible, with the highest concentration of carbonate units on the proposed northern line which extends from Tybo Canyon to Rawhide Mountain.

As flown, one northern line passes over almost entirely altered and unaltered volcanics and is cloud-free. The second northern line which passes over a high concentration of carbonate units contains 25% cloud cover and cloud shadows. The southern AIS flight line as flown, extends from just east of Rawhide Mountain southeast to Warm Springs and contains 17% cloud and cloud shadow cover. It passes over Tertiary volcanics, Paleozoic clastic units and some carbonates. Taking into consideration the change in the location of the flight lines and the weather conditions, it was decided to extend the Hot Creek AIS study to include alteration in both volcanics and carbonates in addition to discriminating between carbonate formations.

Thematic Mapper Simulator (TMS) data tapes were analyzed on a VAX/IDIMS system to locate areas of alteration as well as to enhance carbonate formations prior to processing the AIS tapes.

On July 25, 1984 at 1300 hours, 128 bands of AIS imagery in the Hot Creek Range were collected in the scan mode by the sensor over four grating positions. The calibrated wavelength range was 1.16 to 2.34 μm and the band width was approximately 9 nm. Flight lines average about 19,000 feet (5.8 km) above mean terrain; AIS swath width is 1200 feet (370 m); and ground instantaneous field of view or pixel size is about 38 feet (12 m).

For a first look at AIS imagery and ancilliary data, an area of altered rhyolitic and latitic ash flow tuffs in Red Rock Canyon was chosen. The 5x7 Nikon prints taken on the flight and as received from JPL were printed low contrast. We enlarged these to 8x10 and printed them high contrast as suggested by R.J.P. Lyon (personal communication). A mask for the Nikon photos, the width of the flight line (approximately 1200 feet), was produced. The high contrast Nikon enlargements with the mask overlay made it relatively easy to locate position on the AIS imagery when used in conjunction with color aerial photographs.

All 128 AIS bands in the Red Rock Canyon area were examined in strips of 32 by 512 pixels. Raw data and data to which a sun radiance and an atmospheric correction (Solomon, 1984) had been applied, were compared. Both in the raw bands and atmospherically corrected bands, across-track striping is pronounced in the shorter wavelength bands but not in the longer wavelength bands. Along-track striping is prominent in all wavelengths of raw data as a result of uneven detector response. The along-track striping is not present in the atmospherically corrected data and has been removed by the atmospheric correction algorithm.

AIS data were analyzed using SPAM (Spectral Analysis Manager) developed by the Jet Propulsion Laboratory (JPL). Figures 2 and 3 show spectra of the last 32 AIS bands (2.05 to 2.34 μm) of altered and unaltered rhyolitic and quartz latitic ash flow tuffs from the Red Rock Canyon area. The spectra in Figure 2 are not atmospherically corrected while those in Figure 3 are. An absorption feature near 2.2 μm can be seen in the spectra of altered volcanics and becomes much more distinctive after the atmospheric correction has been applied.

A SPAM unsupervised classification function called FIND PLOT searches for pixels with spectra in all 128 bands similar to those of a specified pixel and color codes all such similar pixels on the image. When FIND PLOT is applied to raw AIS data and asked to find pixels similar to those in altered or unaltered rhyolite, the result is colored bands coincident with the along track striping previously discussed. This implies that there is greater similarity among pixels from individual detectors than among pixels from similar geologic entities. However, when the FIND PLOT function is applied to atmospherically corrected AIS data, a correct classification of altered and unaltered volcanics results.

Since altered volcanics can be distinguished from unaltered volcanics in Red Rock Canyon, SPAM library spectra of different minerals with absorptions near 2.2 μm were compared with altered rock spectra (Figure 4) and field and laboratory data were gathered. Some AIS spectra in the 2.2 μm region had signatures that resembled kaolinite and others had signatures that resembled montmorillonite. Although AIS spectra were examined over the entire altered area, only a limited number of samples of altered and unaltered rock along the AIS flight line were collected, examined and x-rayed. A location which appeared to consist of unaltered rock on AIS imagery proved to be a densely welded tuff composed of quartz, plagioclase, K-feldspar and biotite. From x-ray analysis, one sample from the altered area consisted of pure montmorillonite and two others proved to contain the same minerals as the unaltered tuff with the addition of some montmorillonite.

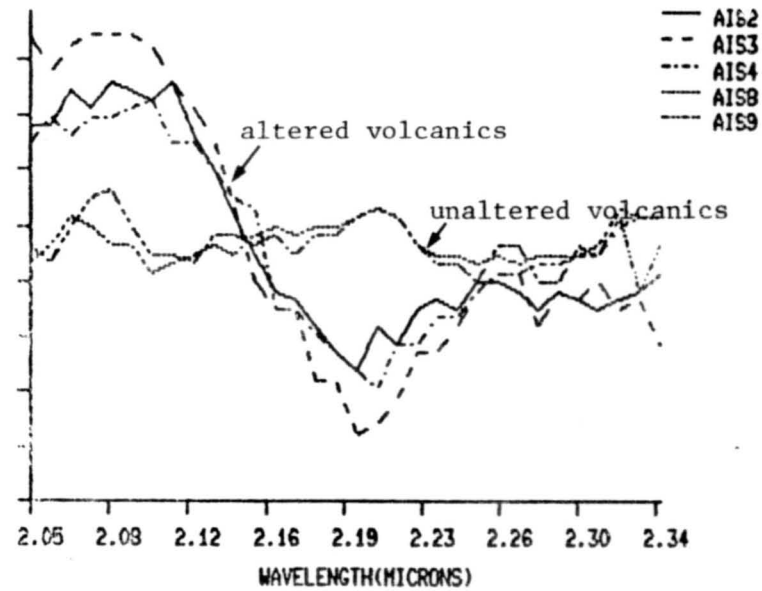
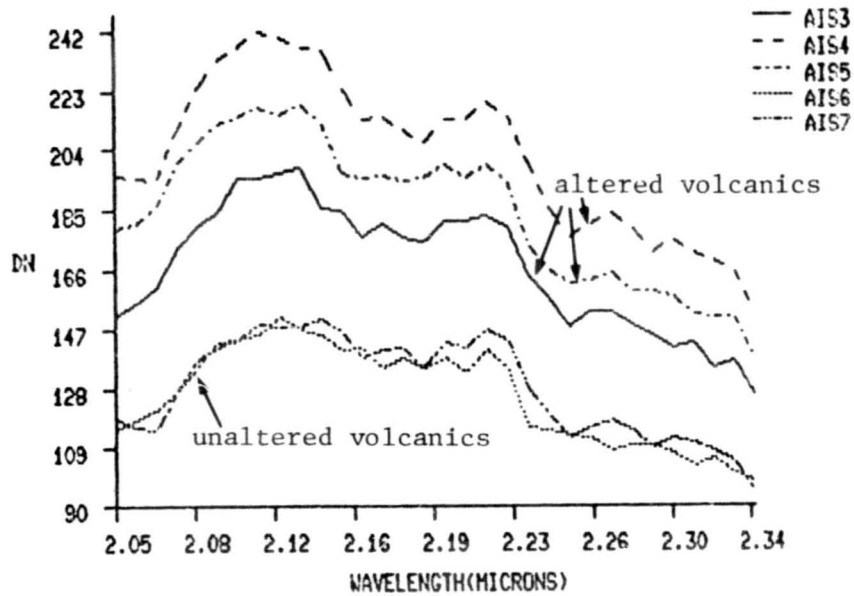


Figure 2. AIS spectra without atmospheric correction.

Figure 3. AIS spectra with atmospheric correction.

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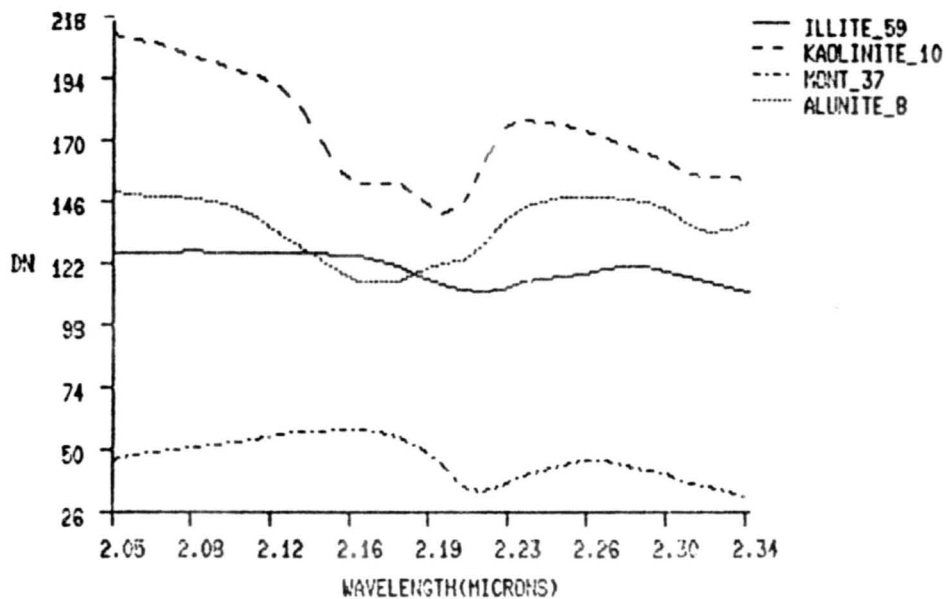


Figure 4. AIS library spectra.

CONCLUSION

AIS spectra of altered and unaltered ash flow tuffs, with and without atmospheric corrections applied, have been examined in the Red Rock Canyon area. It was possible to distinguish unaltered volcanics from altered volcanic rock with AIS spectra. Based on comparison with library spectra, montmorillonite and kaolinite could be present and montmorillonite was found to be present from x-ray analysis.

Flight lines as flown, as compared to flight proposed, contain a lower concentration of carbonate units than expected because of high cloud cover. The Hot Creek AIS study has therefore been extended to include hydrothermal alteration as well as carbonate formations.

Over the next two years we look forward to more detailed studies dealing with both carbonate formations and altered rock in the Hot Creek Range using AIS imagery.

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