Evaluation and Geologic Validation of EO-1 Hyperion
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The geological community has used hyperspectral imagery acquired with airborne systems since the early 1980s to provide information about minerals on the Earth's surface. Research has proven the ability of airborne hyperspectral systems to uniquely identify and map many spectrally distinct minerals that are important in natural resource exploration and characterization. Modern day airborne hyperspectral sensors provide high spatial resolution, high spectral resolution, and a high signal-to-noise ratio (SNR). They afford both spatially contiguous spectra and spectrally contiguous images that have been unavailable from other sources.

The launch of the EO-1 Hyperion imaging spectrometer in November 2000 introduced a new source of hyperspectral mineral mapping with the first spaceborne hyperspectral sensor. Hyperion has two grating spectrometers: one visible/near infrared (VNIR) spectrometer and one shortwave infrared (SWIR) spectrometer. Data are calibrated to radiance using both pre-mission and on-orbit measurements.

This investigation compared the performance of Hyperion for mineral mapping with the performance of airborne systems, in particular, NASA's Airborne Visible/Infrared Imaging Spectrometer (AVIRIS). Two test sites were used: Cuprite, Nevada, which provided a "winter" dataset, and northern Death Valley in California and Nevada, which provided a "summer" dataset. Cuprite has been used as a geologic remote sensing test site since the early 1980s. Death Valley has been used as an imaging test area since 1983 (Figure 1).

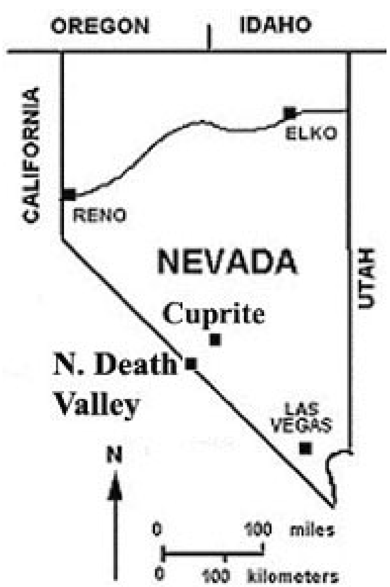

Figure 1. Test sites in Cuprite, Nevada, and North Death Valley, California and Nevada.

The study compared mineral mapping results of AVIRIS data acquired June 19, 1997, with Hyperion data collected March 1, 2001, at Cuprite. AVIRIS data collected on June 9, 2000 were also compared to Hyperion data collected on July 23, 2001 at Death Valley. Figures 2 and 3 show reference images of the two sites. Analysis of a number of Hyperion scenes worldwide indicated a strong relationship between the acquisition time of year and the calculated "in-scene" SNR of the Hyperion data. Figure 4 shows a comparison of Hyperion SNR for "winter" (left) and “summer” data. Figure 5 shows a comparison of AVIRIS June 1997, July 2001 Hyperion, and March 2001 Hyperion data. Calculated SNR for Hyperion SWIR data are higher in the summer and lower in the winter. This seasonal difference, linked to the solar zenith angle, directly affects spectral mineral mapping. Lower SWIR SNR results in extraction of less detail.

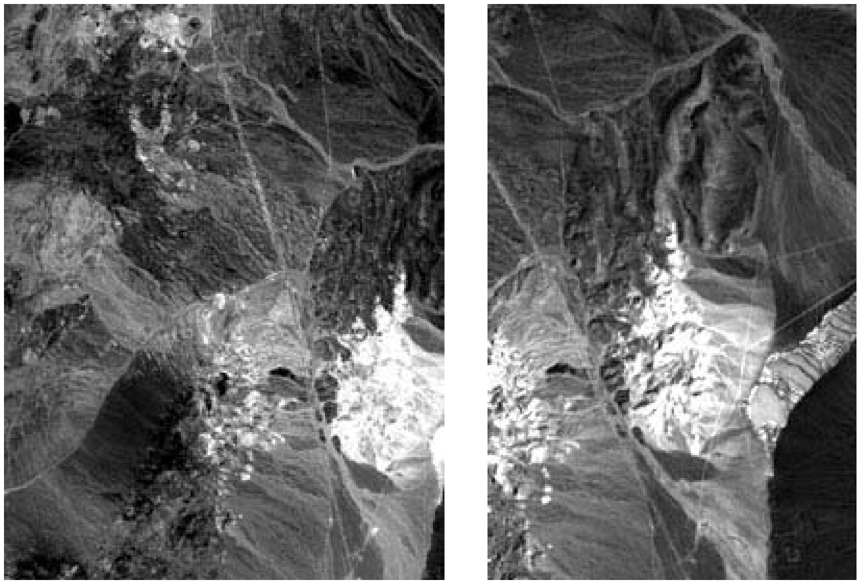

Figure 2. Reference images showing the AVIRIS (left) and Hyperion (right) coverage of the Cuprite, Nevada site.

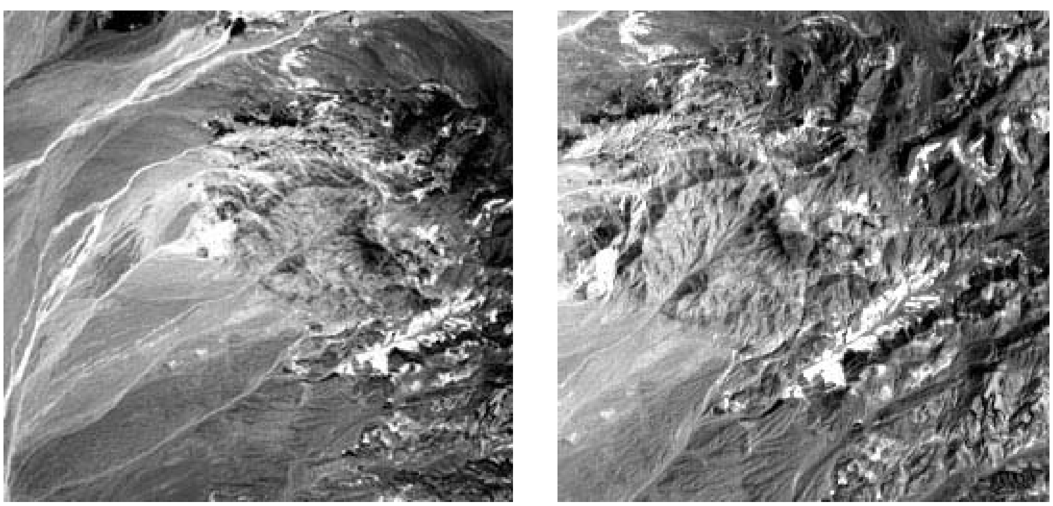

Figure 3. Reference images showing the AVIRIS (left) and Hyperion (right) coverage of the northern Death Valley, California and Nevada, site.

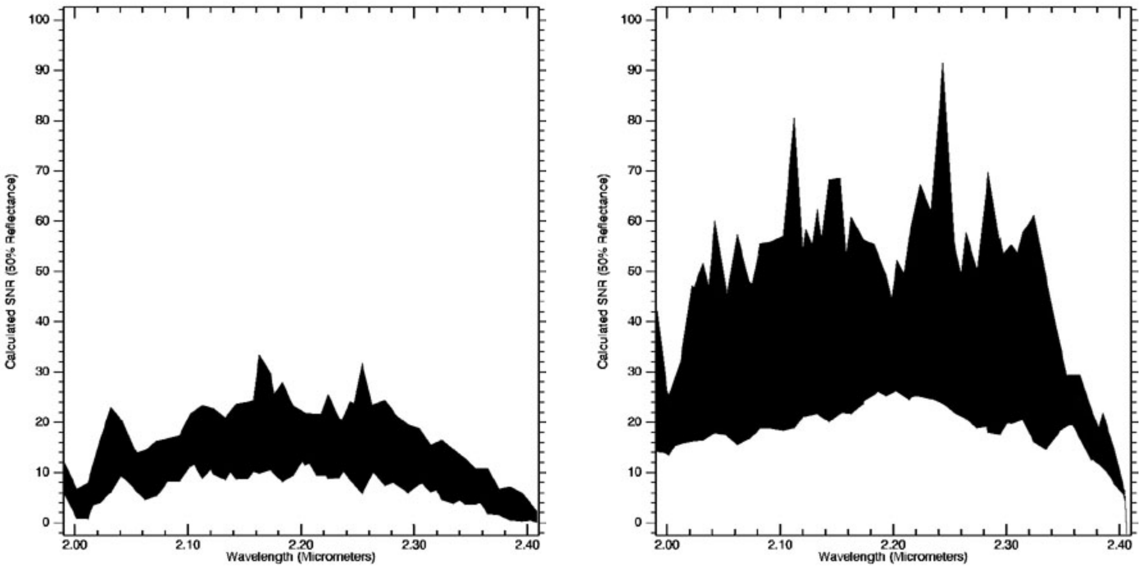

Figure 4. Comparison of Hyperion calculated SNR for "winter" data (left) and "summer" data (right). Filled areas indicate range of SNR for 14 Hyperion scenes.

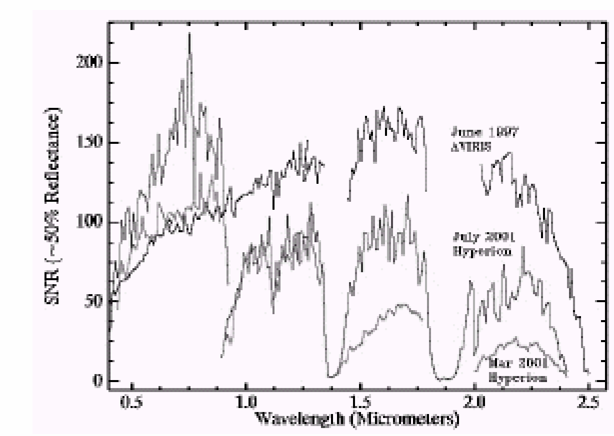

Figure 5. SNR comparisons for June 1997 AVIRIS, July 2001 Hyperion, and March 2001 Hyperion.

Standardized methods developed by Analytical Imaging and Geophysics (AIG) were used to perform the mineral mapping. A key element of this methodology was the reduction of data in both the spectral and spatial dimensions to locate, characterize, and identify a few key endmember spectra that could be used to explain the rest of the hyperspectral dataset. Once these endmembers were selected, their location and abundances could be mapped from the linearly transformed or original data. These methods derived the maximum information from the hyperspectral data themselves, minimizing reliance on *a priori* or outside information.

Preprocessing involved destriping of Hyperion data. AVIRIS data did not require destriping. Atmospheric correction using ACORN software was applied to both AVIRIS and Hyperion data, which were both converted to apparent reflectances. The same standardized hyperspectral analysis methods were used for both AVIRIS and Hyperion data. Hyperion data were then geometrically corrected to match the AVIRIS data, which were used as the base rather than a map.

When spectral bands covering the SWIR spectral range were selected and linearly transformed using the MNF transformation, results indicated that the AVIRIS data contained significantly more information than Hyperion data that covered approximately the same spatial area and spectral range.

Mineral mapping was performed for the Cuprite and Death Valley sites that produced AVIRIS and Hyperion maps (Figures 6 and 7). Visual comparison of the AVIRIS and Hyperion maps for both sites showed that Hyperion and AVIRIS generally identified similar minerals and produced similar mineral mapping results. The lower SNR of Hyperion, however, affected its ability to extract characteristic spectra and identify individual minerals. Hyperion also demonstrated an inability to separate mineral variability and crystal structure differences at a SNR of under approximately 50:1. Analysis indicated that the Cuprite Hyperion data did not allow extraction of the same level of detailed mineralogic information as AVIRIS. Combining minerals to form a basic mineral map, however, resulted in improved mapping with greater than 94% correspondence between AVIRIS and Hyperion at the Death Valley site. In general, considering Hyperion's overall SWIR SNR, it performed very well.

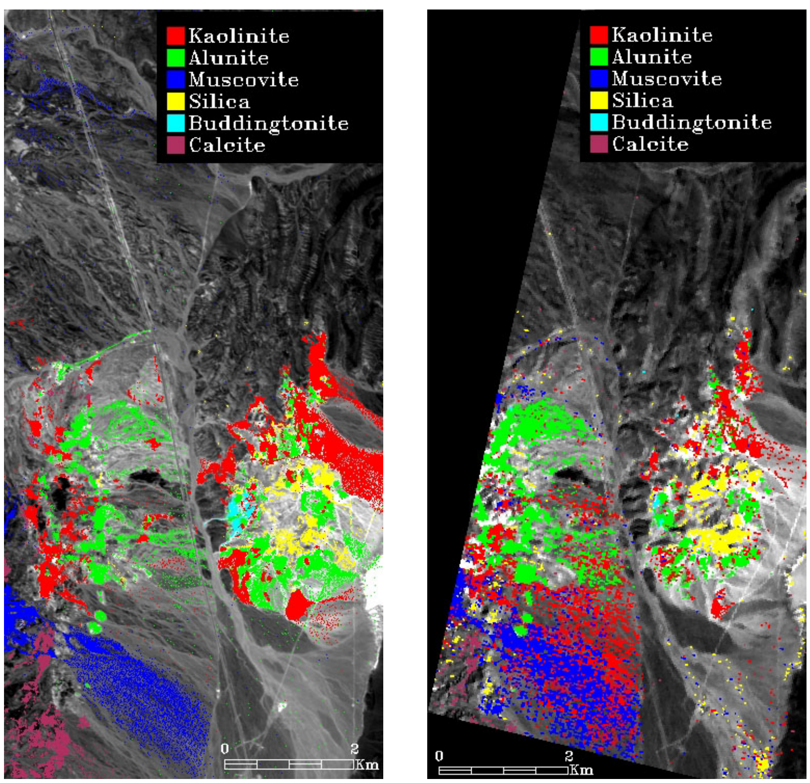

Figure 6. Mineral maps for AVIRIS (left) and Hyperion (right) at the Cuprite, Nevada, site. Colored pixels show the spectrally predominant mineral at concentrations greater than 10%.

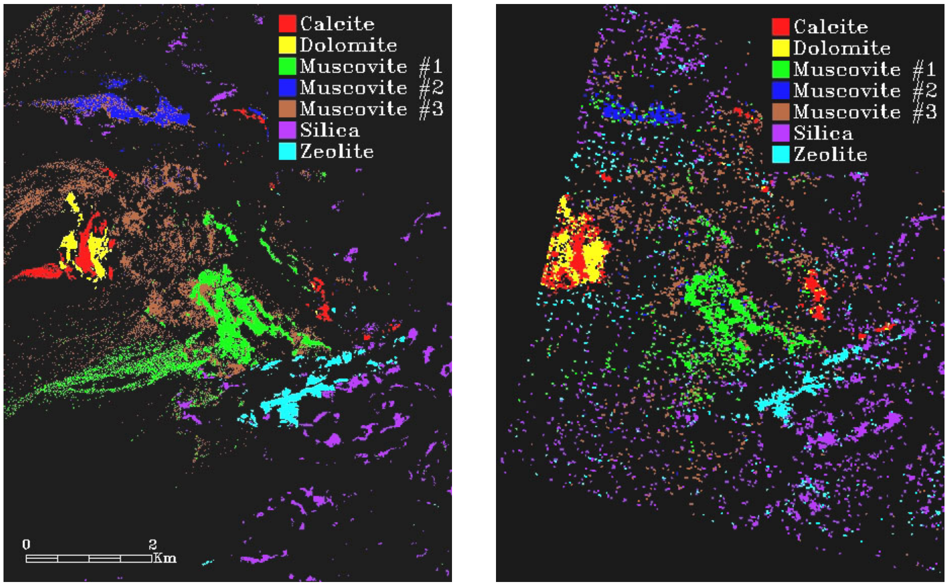

Figure 7. Mineral maps for AVIRIS (left) and Hyperion (right) produced for the northern Death Valley site. Colored pixels show the spectrally predominant mineral at concentrations greater than 10%.

When a "confusion matrix" was used to compare mapping results between Hyperion and AVIRIS, results showed that many pixels classified using AVIRIS were unclassified on Hyperion at both sites, particularly if there were weak mineral signatures. These "errors of omission" are probably explained by the differences in SNR between AVIRIS and Hyperion. Accurate mapping, however, was possible when Hyperion could identify a specific mineral. There were also some "errors of commission" (where pixels mapped as one mineral by AVIRIS were mapped as another by Hyperion). Some pixels unclassified using AVIRIS were misclassified as a specific mineral on Hyperion. Additionally, some pixels classified by AVIRIS as specific minerals were misclassified as different minerals on Hyperion. In general, the highest errors occurred for minerals with more similar spectral signatures. Death Valley Hyperion data were "summer" data and had approximately twice the SNR as that of Cuprite Hyperion data, which resulted in more detail being detected and mapped.

Conclusions:

Hyperion was successful as a technology demonstrator, and results at both sites established that Hyperion SWIR data could be used to produce useful geologic information and remotely map basic surface mineralogy. Comparison of Hyperion and AVIRIS results for both sites generally validated on-orbit mineral mapping and Hyperion performance. It was more difficult, however, to extract information from Hyperion data because of its lower SNR, which was more pronounced in the "winter," when the sun is at a lower zenith angle. The effect of this reduced response was lower data dimensionality than AVIRIS, thus fewer endmembers could be identified and mapped with Hyperion than with AVIRIS. Accuracy assessment and error analysis indicated that with Hyperion data, in many cases, mineral identification was not possible where specific minerals were known to exist. Hyperion also often confused similar minerals that AVIRIS could separate.

The Hyperion data demonstrated that the level of mineralogic information is directly tied to the SNR and confirmed the importance of high SNR for spaceborne hyperspectral sensors. It was recommended that future hyperspectral imaging satellite sensors have significantly higher SNR performance specifications than the current Hyperion for the SWIR region.