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AVIRIS AS A TOOL FOR CARBONATITE EXPLORATION: COMPARISON OF SPAM AND MBANDMAP DATA ANALYSIS METHODS

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INTRODUCTION

Data acquired with the Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) of the Mountain Pass, San Bernadino County, California, area were analyzed to evaluate the use of narrow-band imaging data for carbonatite exploration. Carbonatites are igneous carbonate-rich rocks that are economically important in part because they are the major source for rare-earth minerals. Because the 224 AVIRIS spectral channels have a nominal spectral resolution of 10 nm, narrow absorption features such as those displayed by the rare-earth elements neodymium (Nd) and samarium (Sm) may be detected.

The Mountain Pass region encompasses a well-exposed sequence of sedimentary, metamorphic, and igneous rocks, including an alkalic carbonatite intrusion. The carbonatite was emplaced in Precambrain granitic rocks that are fault bounded by a thick suite of Paleozoic sedimentary rock, predominantly dolomite. The carbonatite stock, the major source of light rare-earth elements (REE) in the United States, affords the opportunity to test AVIRIS capabilities for detecting REE absorption features. Nd-bearing minerals display narrow, sharp and distinctive spectral features at 580, 740, 800, and 870 nm (Kingston, 1989). Minerals bearing Sm display similarly sharp features near 1090, 1250, 1410, and 1550 nm. The more common REE, lanthanum and cerium, do not display absorption features in the visible/near-infrared region in their natural oxidation states.

RESULTS AND DISCUSSION

This study compares two "curve-matching" techniques designed to locate spectrally similar pixels in an AVIRIS image cube (lines, pixels, channels). The two techniques are the SPectral Analysis Manager (SPAM) binary-encoding approach developed at the Jet Propulsion Laboratory (Mazer et al., 1988) and Mbandmap (multiple band mapping), a least squares band-fitting method recently developed at the U.S. Geological Survey (Clark et al., 1990).

The SPAM software program uses a binary-encoding algorithm to classify materials present in the scene by comparing amplitude and slope similarity of spectral curves point by point. Digital numbers above and below the mean for each reference spectrum are stored as binary values 0 or 1. The spectrum for each pixel is encoded in the same way and compared to the reference spectrum. Materials may be mapped by matching image spectra to plots extracted from the image or to plots selected from a spectral library. Noise in AVIRIS data imparts a sawtooth pattern in the spectra, which commonly leads to spectral mismatches when the binary-encoding technique is used. This sawtooth effect can be reduced by smoothing; however, smoothing seriously reduces the spectral contrast of narrow absorption features, such as the Nd features. At Mountain Pass, the SPAM algorithm was effective for mapping distributions of some materials, like carbonates, which have broad absorption features, but mapping of REE-bearing materials was less successful, being limited to a few of the major mine dumps.

The Mbandmap program allows the discrimination of spectrally unique materials by use of a least squares band-fitting method. Mbandmap clusters materials by fit-comparing calibrated AVIRIS spectra to selected image spectra or to library reference spectra. Multiple absorption bands for each mineral may be compared in a single mapping run. Images showing band depth, degree of fit, and band depth fit are generated. Clark and others discuss details of this technique elsewhere in this volume.

Prior to Mbandmap analysis, AVIRIS radiance digital numbers were converted to approximate ground reflectance by use of laboratory reflectance measurements of samples collected from a highway borrow pit that was easily identified on the image. The Mbandmap reference library consists of laboratory reflectance data of pure minerals as well as representative rock and soil samples collected in the field area. The REE reference sample is a Mountain Pass REE-enriched sample from the U.S. National Museum Collection. The composition of two REE-bearing minerals in this sample, bastnaesite and synchysite, was determined by microprobe analysis. Weight percent Nd averaged 9% in bastnaesite and 8% in synchysite. Because of the lack of a Sm standard, that element could not be examined by microprobe. Comparison of laboratory spectral reflectance measurements of the samples with Nd_2O_3 and Sm_2O_3 spectra corroborated the Nd and Sm composition.

By using Mbandmap, several areas of rare-earth enrichment not previously discriminated by AVIRIS data were identified in the Mountain Pass mine area. One small area of REE response occurs south of the active mining area and may correspond to a carbonatite dike. Spectra extracted from the mapped area display the four distinctive Nd bands between 580 nm and 870 nm. Some of the spectra also displayed Sm bands between 1090 and 1550 nm, although these occur in a wavelength region of greater atmospheric interference. Dolomite, calcite, and muscovite-bearing granite in rocks near the carbonatite were also mapped.

CONCLUSION

SPAM provides the capability to classify spectrally similar materials by comparing image spectra to reference spectra, but it is relatively insensitive to narrow features and to subtle band shape differences. As a result, only high concentrates of Nd-bearing minerals could be identified in the Mountain Pass mine area. However, SPAM is particularly useful for mapping materials that can only be discriminated by overall curve shape, including the relatively featureless alkalic rocks associated with carbonatites. Mbandmap allows improved mapping of carbonate and REE minerals characteristic of carbonatites because shapes and depths of multiple features can be compared simultaneously.

For remote sensing detection of specific REE-absorption features, Mbandmap alone was highly effective. When a more general spectral classification of surface materials is the objective, a combination of the SPAM and the Mbandmap methods should provide increased information.

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