

APPLICATION OF A STRATEGY FOR INTERPRETATION OF MULTISPECTRAL
REFLECTANCE DATA FROM PLANETARY SURFACES

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Analysis of the spectral properties of reflected light (spectral reflectance) of planetary surfaces is the chief means by which surface mineralogy and petrology can be remotely sensed. We will demonstrate the use of multivariate techniques, such as principal components analysis (PCA), as described in (1), on laboratory reflectance spectra of lunar samples.

Our analysis is performed on approximately 280 lunar soil and rock samples obtained at 9 sites by Apollo and Luna sample return missions. These samples include whole soils as well as magnetic and size separates. These spectra are taken from 350 to 2500 nm at 10 nm resolution on a modified Beckman DK-2A spectrophotometer with a halon-coated integrating sphere. For comparison, we also analyze 20 telescopic spectra (2,3) of the Copernicus crater and surrounding maria and rays. The data were taken at 8 km spatial resolution and 20 nm spectral resolution between 700 and 2000 nm.

Since the spectra in general represent intimate mineral mixtures, the spectral reflectances are modeled by a nonlinear combination of the reflectances of their components (endmembers). Therefore, the first step in the analysis is to convert the reflectance spectra into single-scattering albedo spectra by the method described in (4). Next we perform PCA on the complete data set in order to determine:

- 1) How many linearly independent sources of variation exist in the spectra?
- 2) What likely endmembers are being mixed?
- 3) What physical processes are effecting the mixing?
- 4) What spectral bandpasses are optimally discriminating between endmembers from remotely sensed data?

The lunar sample spectra are sampled at only 30 evenly spaced wavelengths between 700 and 2000 nm for PCA. In Fig. 1 we show the results of the analysis for the 280 lunar sample spectra. Likely endmembers are chosen from the lunar samples themselves. Two criteria were used to select endmembers:

- 1) The endmembers must be located at a vertex in the PCA plots.
- 2) The endmember must be realizable from all available information.

As indicated in Fig. 1, the endmembers chosen in this analysis were a mare basalt (10020), anorthosite (15415), the pyroxene fraction of (12063), an agglutinate (15221, magnetic separate), and an opaque (terrestrial magnetite). The first three of these endmembers are lunar rock chips. These endmembers account for 99.994% of the variance among the lunar sample spectra analysed. Although several endmember combinations could have accounted for equally large variances in the data set, the eigenvectors of the endmembers alone closely match those derived from the entire data set. Additional spectral variations are possibly due to particle size differences among the samples as well as systematic errors in the spectrophotometer. Axis 1 of Fig. 1 is correlated with albedo (the relative proportions of mare basalt and anorthosite) and axis 2 with spectral slope (reflecting agglutinate abundance).

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An independent analysis of the telescopic data is performed using endmembers from the lunar spectral data set. These endmembers also closely match patterns of variation for the telescopic data set. Results from the PCA analysis indicate that both linear (5) and nonlinear spectral mixing of endmembers is a dominant source of variation in the data set.

In conclusion, our analysis of 30-point lunar spectra gave us quantitative information regarding composition, type of mixing, and other effects (such as particle size) that determine the dominant structure of the reflectance data. This provided a test of the methodology described in (1) by comparing abundance determinations with known mixtures.

References

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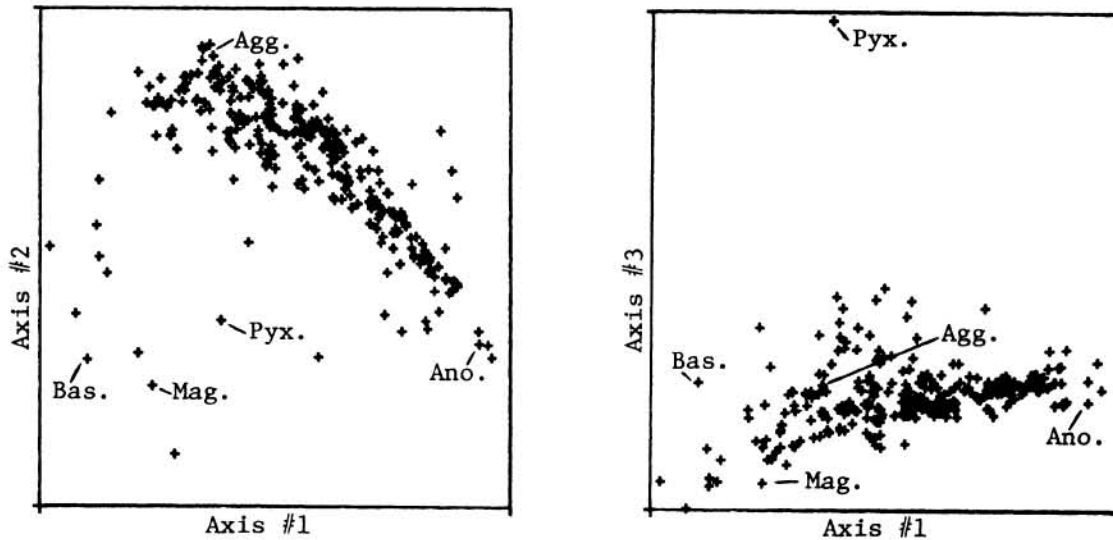


Fig. 1. Spectra of 280 lunar sample spectra rotated to the three principal axes defined by PCA. Endmembers chosen from this data set are labeled.