

A SPECTRAL MIXING MODEL APPROACH TO THE ANALYSIS OF THE SPECTRA OF LUNAR SOILS

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Several hundred spectra of the lunar samples from .3 to 2.5 μ m were collected by Adams and coworkers in the early 1970's (1). Many of these spectra are unpublished and in general the data set has been little utilized in recent years for lunar studies with a few exceptions (2,3,4). This neglect has largely been due to the lack of detailed mineralogical and chemical analyses of the soils which inhibits their use as a calibration tool. Despite this shortcoming the sample spectral data base is extremely useful in the study of trends which are likely to be observed in current groundbased or future orbital spectral measurements. The work reported here is a preliminary attempt to use newly developed spectral mixing models to derive mineralogic information from the sample spectra in order to aid the interpretation of remotely obtained spectra of the lunar surface and ultimately to improve the knowledge of the mineralogy of the soils of the landing sites.

Our approach was to generate several three-component mixtures of important lunar minerals and agglutinates for comparison to the sample spectra. The spectral mixing model is described in a companion abstract in this volume (5). The comparison was accomplished by deriving spectral parameters from the sample and model spectra and plotting the lunar and model spectra on variation diagrams of several pairs of parameters. The parameters and their derivation are also described in (5). These parameters are sensitive to the presence of important lunar minerals and to soil maturity to varying degrees.

Lunar highland rock types are defined in terms of the relative abundances of anorthite, olivine, and clino- and orthopyroxene(6). We selected as model endmembers these minerals and the components relevant to the study of the effect of soil maturity on spectral parameters. The spectral data base of (1) was used for the source spectra. With the above minerals, we used two 3-component mixture series calculated by (5): an-ol-opx and ol-opx-cpx. In addition, to study maturity, the system anorthosite, norite, and agglutinate was deemed appropriate to model many highland soils. We calculated this mixture using the methods of (5). The spectra of 15415 and 14421 were used for the first two components, the latter chosen because its band center is short (near .9 μ m) indicating a noritic pyroxene assemblage. The agglutinate component in any soil is formed *in situ* and so cannot be treated as an independent compositional end member. However, agglutinates share the characteristics of low albedo, red continuum slope, and very weak bands. The magnetic separate of soil sample 60601 was used to approximate a general agglutinate component.

The models run are all first iterations and no attempt has been made to improve the fits to the sample data. Despite this, a reasonable correspondence between the two sets of spectra is observed. Figure 1 is a plot of the albedo against the band depth. Figure 1a shows all the sample spectra with albedos less than 50% and band depths less than 20%. This range excludes many ground rock samples but includes most soils. 1b are the data from Apollo 16 only. 1c are the model spectra from the series agglutinate-anorthite-norite. There is not a perfect overlap between sample and model data, yet it is interesting to note that Apollo 16 samples are adequately fit in terms of these parameters with a mixture of anorthosite and agglutinate with little norite. The other landing sites (which include the mare sites) require much more norite and probably other components. Figure 2 plots the two parameters most sensitive to mafic mineralogy: band width and center. Figure 2 shows the sample spectra next to the model series: 2a the agglutinate-norite-anorthite series, 2b the olivine-clinopyroxene-orthopyroxene series, and 2c the anorthite-orthopyroxene-clinopyroxene series. The discontinuous nature of the agg-nor-an series demonstrates the insensitivity of these parameters to agglutinate abundance: most of the mixture spectra plot at the positions of the endmembers. The cpx-opx-ol series shows relatively good agreement with the samples at low olivine abundances. The opx-ol-an series shows a poorer fit emphasizing the importance of clinopyroxene in the samples in fitting many of the sample spectra and the insensitivity of the parameters to the presence of anorthite.

In summary, Figure 1 demonstrates the anorthositic nature of Apollo 16 and the greater abundance of basaltic material at the other landing sites. Figure 2 shows that of the mafic minerals, olivine is lowest in abundance. Though these are not new conclusions, they are derived exclusively from the spectra and on the first iteration of our mixing model. We conclude from this exercise that further work with spectral mixing models may yield success analogous to that found with chemical mixing models with both the sample and telescopic and eventually LO data sets.

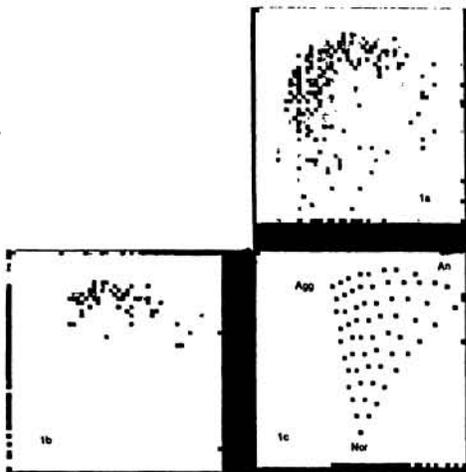


Figure 1. Albedo versus band depth. The origin is in the upper left. Albedo is plotted on the horizontal axis from 0 to 50%. Band depth is on the vertical axis from 0 to 20%. 1a is all the sample spectra, 1b Apollo 16 spectra, and 1c the model spectra from the agg-nor-an series. The An endmember is off the scale to the right. Note the upper part of the sample series is a curved trend from agg to an and is reminiscent of the Apollo 16 trend. The other landing sites are fit best by a much more significant nor component.

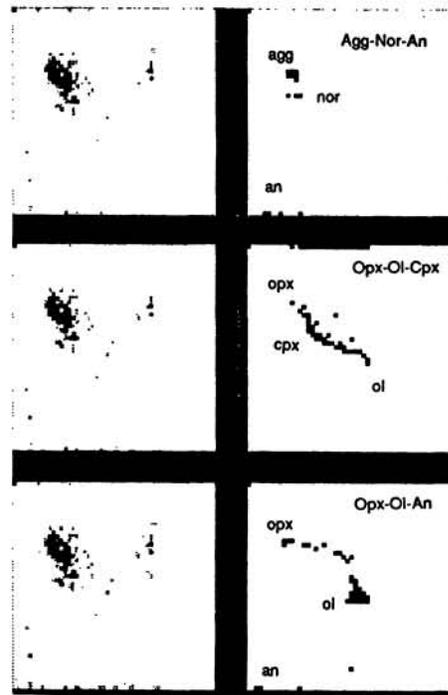


Figure 2. Band width versus band center. The origin is in the upper left. Band width is the horizontal axis from .2 to .8 μ m. The vertical axis is band center from .8 to 1.1 μ m. The left column are all sample spectra. The top right is the agg-nor-an series, the middle right is the ol-cpx-opx series, and the bottom right is the an-ol-opx series. The an endmember is off the scale to the bottom.

References: 1) Adams, J.B., P.M. Bell, J.E. Conel, H.K. Mao, T.B. McCord, and D.B. Nash, *Geochim. Cosmochim. Acta* 37, pp.731-743, 1973; 2) Johnson, P.E., M.O. Smith, J.B. Adams, *Proc. Lunar Planet. Sci. Conf. 15th, JGR 90 Suppl.*, pp. C803-C810, 1985; 3) Jaumann, R., G. Neukem, and B.R. Hawke, *Lunar and Planetary Science XIX*, LPI Houston, pp. 553-554, 1988; 4) Pieters, C.M., *Lunar and Planetary Science XVII*, LPI Houston, pp. 660-661, 1986; Lucey, P.G., M.L. Nelson, and J. Granahan, this volume; 6) Stoffer, D., H-D. Knoll, U.B. Marvin, C.H. Simonds and P.H. Warren, *Proc. Lunar Highlands Crust*, pp. 51-70.