

GLOBAL IMAGES OF MG-NUMBER DERIVED FROM CLEMENTINE DATA. P.G. Lucey¹, J. J. Gillis¹, and D. Steutel¹,
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Introduction: The Mg number (Mg^*), the ratio of Mg to the sum of Mg and Fe on an atomic basis, is an important discriminator in defining and understanding lunar rocks. Mg^* is also the most important control on the spectral properties of lunar mafic silicates. For stoichiometric orthopyroxene and olivine, Mg^* is mathematically linked to the Fe content that controls the overall reflectance and intensity of absorption. The changes in band centers and shape that accompany the structural changes as Fe substitutes for Mg along the solid solution series have long been recognized; these changes are highly correlated with Mg^* . In clinopyroxene, the strong effect of Ca on structure makes this element important, but Mg^* has the dominant effect on reflectance and a comparable effect on spectral shape [1]. Because the visible and near-IR spectral properties of lunar soils are dominated by mafic minerals, Mg^* has a dominant effect on spectral properties of lunar soils. Understanding the relationship between soil spectral properties and composition is incomplete without explicit treatment of Mg^* .

The dominance of Mg^* also suggests that if the compositional properties of the lunar surface can be otherwise constrained, Mg^* can be derived from lunar spectral properties. In an ongoing effort to map the mineralogy of the Moon using Clementine data, we produced a spectral model of the Moon based on the work of Bruce Hapke, and including the Mg^* dependent spectral properties of mafic minerals. We have found that at Clementine spectral sampling and resolution, Clementine data cannot unambiguously define a lunar composition; modeled spectra of many compositions produce spectra identical within the noise of the Clementine data set. However, these compositions show strong variations in the elemental composition defined stoichiometrically, including Fe and Ti. By adding these remotely measurable constraints (Fe and Ti content) compositions are highly constrained, and we find that Mg^* is uniquely defined.

Data: Clementine collected 11 band multispectral data at 100-200 spatial resolution for most of the lunar surface [2]. The US Geological Survey produced a global mosaic sampled at 100-m/pixel for five of these wavelengths from between 400 and 1000nm (Eliason et al. 1999). From this mosaic we produced a 1 km resolution mosaic for this analysis. The portion of the data used is for all longitudes, and latitudes less than seventy degrees.

Analytical Model: The mapping approach uses a radiative transfer model to precompute spectra of 286

different lunar compositions at 10% intervals covering the system plagioclase-olivine-clinopyroxene-orthopyroxene in which lunar highlands rocks are classified [2]. This model, first employed by [3], integrates empirical measurements of the complex optical constants of lunar component materials with a radiative transfer treatment widely used in planetary science [4]. For this study, optical constants of mafic silicates are from [5], iron-bearing glass from [6], plagioclase from [7], and elemental iron from [8]. This methodology for lunar spectral studies was validated by [9] and by [10]. The version employed by [3] and here includes varying the Mg^* of the mafic silicate minerals, an essential capability for modeling lunar spectral properties.

To the 286 compositions we add ten levels of intensity of space weathering corresponding to optical maturity from 0.3 to 0.5. Mg -number is varied from 50 to 90 in 9 intervals. This process results in just over 20,000 model spectra forming a large lookup table against which the lunar multispectral measurements are compared.

The mapping methodology is to compare each measured lunar spectrum to this lookup table, and assign the composition of the closest match using total absolute difference between model and measured spectra as a criterion, provided the average error is less than 0.5%. Spectra are normalized prior to comparison because local changes in lighting geometry influence the model absolute reflectance in an unpredictable way. (Note that this system does not include the lunar mineral ilmenite that is common in some lunar basalts. The distribution of basalts with relatively high ilmenite contents is restricted (Elphic et al. 2002) so this mineral was excluded from the analysis to save processing time.

The comparison was done separately for each Mg -number, so that for each location 10 analyses are reported. We then compute the stoichiometric Fe content for each model composition from the abundances and Mg^* of the four minerals. The measured (Clementine or LP) FeO content is subtracted from the model stoichiometric FeO as a function of Mg^* . We find that in almost all cases the model-minus-measured FeO is a linear function of Mg^* , and where this line crosses zero (zero difference between model and measured FeO) we take as the Mg^* of that location.

The resultant image is shown in Figure 1.

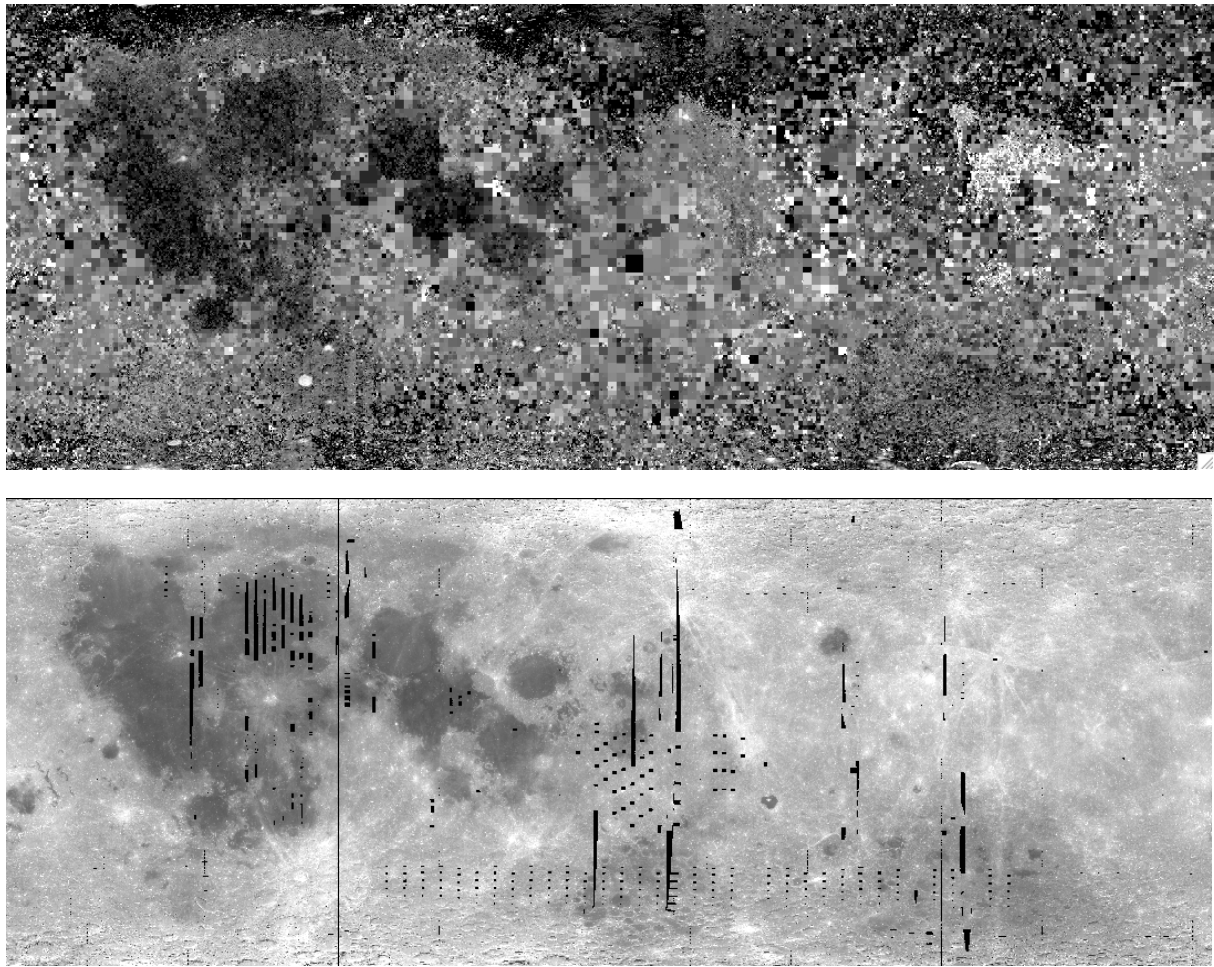


Figure 1. Top: Image of mafic mineral Mg* stretched from 50 to 90. Bottom: Clementine 750nm reflectance.

Discussion: The major features evident are the strong distinction between mare and highland, the former showing low Mg* and the latter generally higher; a large northern highlands unit with low Mg*, and an Mg* high north of South Pole-Aitken basin. Mare units are not universally low, mare Frigoris in particular has elevated Mg* relative to other mare. The strongest variations in the highlands occur in plagioclase rich, low FeO units, that exhibit values ranging near 50 to near 100 in coherent units. The craters Tycho and Aristarchus also exhibit high Mg*; these gabbroic anomalies may indicate more extensive Mg-rich material at depth. Deposits within SPA are unremarkable relative to surroundings, and share the intermediate Mg* of most of the highlands.

References:

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