

LUNAR HIGHLAND MINERAL MAPS INTEGRATING THERMAL AND NEAR INFRARED MULTISPECTRAL IMAGING. P.G. Lucey¹, B.T. Greenhagen² and the LRO Diviner Lunar Radiometer Experiment Team, ¹Hawaii Institute for Geophysics and Planetology, 1680 East West Road, POST 602, Honolulu, HI 96822; ²Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA; Email: lucey@higp.hawaii.edu

Introduction: Multispectral thermal imaging data from LRO's Diviner Lunar Radiometer Experiment have been used to remotely detect silicic minerals and seek candidates for mantle exposures [1,2]. The compositional capability relies on characterizing the position of the Christiansen Feature (CF), a spectral feature sensitive to silicate mineralogy. The CF is an emission maximum near 8 microns that for silicates that is related to the position where the real index of refraction equals one in pure minerals. The wavelength of the CF in rocks is close to the average of the CFs of the constituent minerals, weighted by their modal abundances [3]. Because the CF is a single parameter, specific minerals are not uniquely detected (except at the extremes), but the CF is a powerful constraint on mineralogy. The CF is complementary to near-IR spectroscopy, which is most sensitive to the relative abundances of the mafic minerals but less sensitive to the abundance of plagioclase where mafic minerals are only moderately abundant. Incorporating the CF as a constraint greatly increases confidence in plagioclase-mafic ratios. Mineral maps have been developed from near-IR data alone (Clementine) with only FeO as an independent constraint, furthermore, these maps were derived from the least mature 5% of the lunar surface and interpolated to a continuous grid [4].

Here we present new mineral maps at 16 pixel per degree resolution (about 2 km at the equator) that combine the spectral constraint of the CF and near-IR spectral properties to produce refined mineral maps.

DATA: Global CF mosaics were produced by topographically projecting and binning Diviner thermal emission data at 16 pixels per degree. The CF for each bin was calculated using the method of Greenhagen et al., [1], which estimates the CF position from a quadratic fit to Diviner's three 8-micron channels' data. The global CF mosaics were normalized to equatorial noon illumination conditions using the method of [5]. Because global mosaics from SELENE or M3 (level 2) were not available for the production of these preliminary maps, Clementine data were used for this proof of concept. Clementine data have significant limitations, among them km level deviations from the current cartographic reference used by Diviner (and LROC and SELENE), but multiple studies have shown these data

contain useful spectral information and were the basis for prior global mineral maps.

METHOD: The previously published mineral maps used a multistep process that readily allows adding of the CF constraint. The process begins with calculation of a lookup table of spectra computed from Hapke theory over the system plagioclase, olivine, orthopyroxene and clinopyroxene at 10% steps in composition. Ten lookup tables are produced, each with constant Mg-number for all mafic minerals, with the tables covering a range of Mg from 50 to 90 at 10 unit intervals. The prior method [4] tested each unknown spectrum against each table selecting the best match, yielding a best match at each Mg-number. The final answer was selected by computing the stoichiometric iron content of each best fit model, and selecting the Mg-number fit showing the closest agreement of stoichiometric iron and remotely determined iron content. For this project, the best fit is sought not over the entire lookup table, but only from those compositions that have model CF values within .04 microns of the measured CF of the unknown location, so therefore all solutions are consistent with Diviner measurements. The 0.04 microns range permitted is the approximate uncertainty in the current CF data. The final values for Mg-number and mineral modal abundance is still selected based on the best agreement for calculated stoichiometric iron and measured iron for that location

Because the lunar CF shows some dependence on space weathering [1], we correct the CF for this effect using the optical maturity parameter OMAT:

$$CF_{\text{corrected}} = CF_{\text{uncorrected}} + (OMAT - 0.4)$$

Table 1. Christiansen Feature values used	
Anorthite	7.85
OPX	8.12
CPX	8.13
Fo90	8.76
Fo80	8.84
Fo70	8.92
Fo60	8.99
Fo50	9.08

This correction shifts the CFs to the approximate units and range of pure minerals. Anorthite, orthopyroxene, and clinopyroxene CF values were taken from [6]. The change in CF position for olivine with composition was taken from [7] and tied to the the Donaldson-Hanna et al. value of forsteritic olivine. Model CF values are determined from the values in Table 1, weighted by the modal abundance input into each model.

RESULTS: Unsurprisingly, the dominant mineral is plagioclase, with a global modal highlands abundance of 80 %. This value is higher than derived from previous global mineral maps, but the derived abundance of aluminum (Al_2O_3) content of 28 wt.% is well within the range of previous estimates [8,9,10]. This alumina value is much less than that estimated for the crust by [11], but they included the apparent increase in plagioclase content with depth in the upper crust based on ubiquitous detection of anorthite in a large sample of craters larger than 35 km.

Of the mafics, orthopyroxene is widespread in the highlands as expected (but in contrast to previous maps that appeared to overestimate clinopyroxene abundance [4]), and similar to previous work, olivine is widely distributed at low abundances, consistent with the need for a stoichiometric olivine component in geochemical mixing models (12). Clinopyroxene, at this global scale, appears confined to the maria; however, we have not examined the many locations where isolated outcrops of clinopyroxene are reported in the highlands [13,14,15].

The Mg-number map derived from the process is in general agreement with the Lunar Prospector GRS-derived data of Prettyman et al.[16], with a slightly lower average highland Mg of 70. As expected, maria values are much lower, near 50. Interestingly, the Mg-number we report, and that of Prettyman et al., is at the high end of ferroan anorthosite (FAN) Mg-values, superficially suggesting the presence of more magnesian anorthositic material than the Apollo collection. However, if FAN is as mafic poor as suggested by Ohtake et al. [11] our Mg-number estimate would be dominated by that of the mafic contaminant that causes lunar surface iron to be higher than pure anorthosite, not the anorthosite itself. There is one critical caveat regarding these interpretations: The derived Mg and plagioclase content is sensitive to the specific CF value assigned to anorthite, which is in turn derived from terrestrial minerals measured in a simulated lunar environment[6]. Considerable ground truth effort will be required to lend confidence to these results.

CONCLUSIONS AND FUTURE WORK: The above results are broadly consistent with prior work, but new data can substantially improve many aspects of the data product. Data from M3 and the SELENE Multiband Imager and Spectral Profiler data are better geometrically controlled, have higher signal to noise, and spatial resolution than Clementine data. Also, the important space weathering correction currently depends on an algorithm that includes reflectance as an input; and the Clementine data are not normalized for topographic shading so there is significant error. Finally, ground truth both for validation and algorithm

refinement is required by study of the CF and near-IR properties of individual sampling sites as done by [18]

References:

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