COMPOSITIONAL GROUND TRUTH OF DIVINER LUNAR RADIOMETER OBSERVATIONS.
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Introduction: The Moon affords us a unique opportunity to "ground truth" thermal infrared (i.e. 3 to 25 μm) observations of an airless body. The Moon is the most accessable member of the most abundant class of solar system bodies, which includes Mercury, astroids, and icy satelites. The Apollo samples returned from the Moon are the only extraterrestrial samples with known spatial context. And the Diviner Lunar Radiometer (Diviner) is the first instrument to globally map the spectral thermal emission of an airless body. Here we compare Diviner observations of Apollo sites to compositional and spectral measurements of Apollo lunar soil samples in simulated lunar environment (SLE).

Diviner Compositional Observations: Diviner, onboard NASA's Lunar Reconnaissance Orbiter, has made the first global, high resolution, thermal infrared measurements of lunar silicate mineralogy [1]. Diviner has three spectral channels near 8 μm designed to characterize the mid-infrared emissivity maximum known as the Christiansen feature (CF) [2]. The CF occurs when the refractive index (real part) of a material approaches the refractive index of the surrounding medium AND absorption is relatively low ($n \approx 1$, $k \approx 0$). The CF is tied to the fundamental vibrational band and shifts to shorter wavelengths with increasing polymerization of the SiO_4 tetrahedra[e.g. 3,4]. For example, lunar maria that are rich in olivine and pyroxene have longer-wavelength CF positions than lunar highlands, which are rich in plagioclase [1].

Diviner's 8-μm channels span the CF of lunar soils measured in SLE, 7.95 to 8.50 μm [e.g. 6]. Also, a parabola closely approximates the shape of the CF when measured in the lunar environment [1]. Therefore, to determine the position of the CF, we solve the quadratic formula for Diviner's three 8 μm channels ($y = A x^2 + B x + C$). It is important to note that the calculated CF value is similar to but distict from the CF position, which is the *actual* peak in emission [1]. Diviner CF values show a strong dependence on solar incidence angle with CF values decreasing for both higher latitudes and local times away from noon that is likely caused by surface roughness induced anisothermality [1,6]. For this study we normalized the CF values to approximate equatorial noon using the method of Greenhagen et al., 2011 [7].

Simulated Lunar Environment: In the lunar environment (characterized by a fine particulate surface and vacuum resulting in high thermal gradients), the CF has significantly enhanced spectral contrast compared to other mid-infrared spectral features [e.g. 3,5].

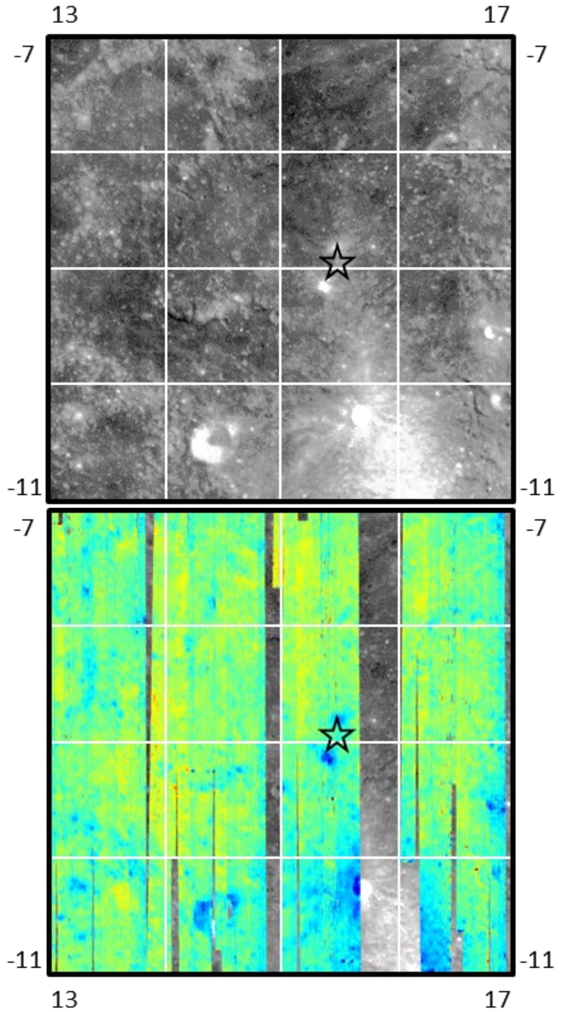

Figure 1: Clementine Albedo (top) and CF Value (bottom) Maps of Apollo 16, Descartes. The Apollo 16 landing site is indicated by the black star. The CF value color stretch is 7.95 (blue) to 8.4 μm (red). The CF map is overlain on the Clementine v2 basemap.

Therefore, only laboratory experiments conducted in SLE are directly comparable to Diviner data. The Lunar Thermal Environment Simulator at University of Oxford's Atmospheric, Oceanic, and Planetary Physics Laboratory is uniquely capable of measuring high spectral resolution thermal emission of samples in SLE [8]. In the lunar environment, large thermal gradients develop in the top few hundred microns of the surface, driven by the difference in the solar and thermal skin depths (i.e. the surface is heated to greater depth than the infrared emitting layer). The thermal gradients generally result in a shift and significant enhancement of Christiansen feature spectral contrast and significant decreases in Reststrahlen Bands spectral contrast.

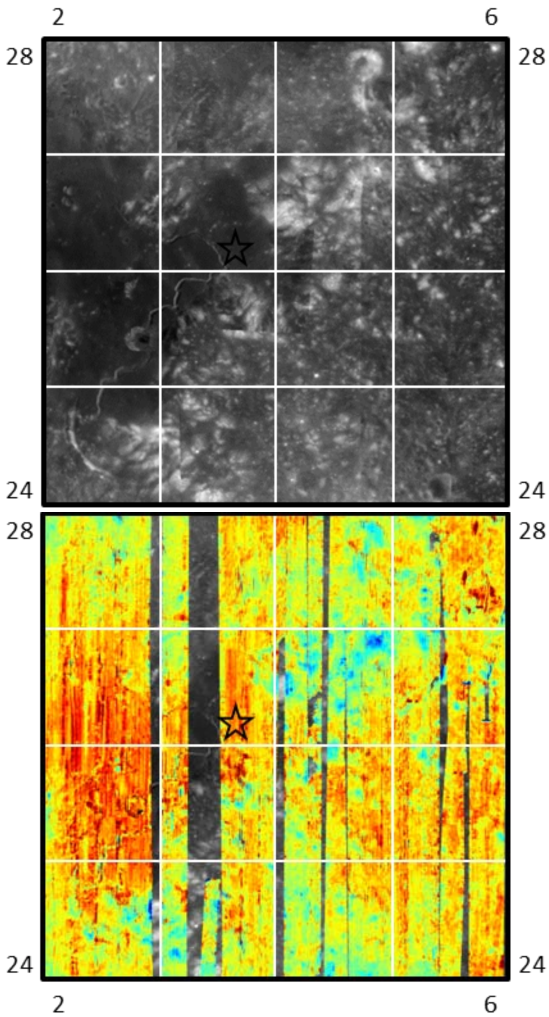

Figure 2: Clementine Albedo (top) and CF Value (bottom) Maps of Apollo 15, Hadley-Apennines. Color stretch and annotations are the same as Fig. 1

Apollo as Ground Truth: Since their compositions are known, the Apollo soils and sites are important calibration points for the Diviner dataset. Diviner observations include all six Apollo sites at approximately 200 m spatial resolution. Spectral differences between the Apollo sites caused by composition and space weathering are apparent in Diviner data [1]. For example, Apollo 16 (Figure 1) is dominated by highland compositions and has shorter wavelength CF values than Apollo 15 (Figure 2), which is dominated by mare compositions. However, even individual Apollo sites are compositionally complex within the distances that were sampled. It is therefore critical to choose the best pixels to represent each Apollo sampling station.

In this study, we measured a range of lunar soils measured in SLE from 5 of the 6 Apollo missions. The soils include typical low-albedo mare (Apollo 11), high-albedo highlands (Apollo 16), low-titanium basalt (Apollo 12), and high concentrations of volcanic glass (Apollo 15 and 17). We also included data from early SLE experiments measured during the Apollo Era [5].

Initial analyses of Diviner observations and SLE measurements show good agreement with each other and with previous geochemical measurements of Apollo soils from the Lunar Sample Compendium [9]. The corrolation between CF value and FeO is very strong (Figure 3). Other geochemical species, including SiO_2 and Al_2O_3, are also well correlated with Diviner observations. This presentation will highlight experiments and observations to date and implications for Diviner compositional studies.

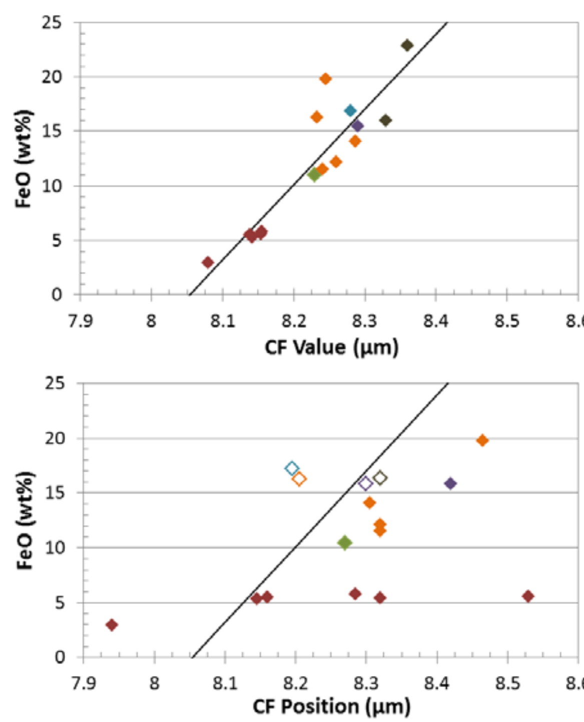

Figure 3: Correlation Between Sample Geochemistry and CF Value/Position. Top is the correlation for Diviner observations. Bottom is the correlation for laboratory measurements in SLE, where empty diamonds are from this study and filled diamonds are from literature [e.g. 5].

References: [1] Greenhagen B.T. *et al.* (2010) *Science, 329*, 1510. [2] Paige D.A. *et al.* (2010) *SSR*, *150*, 125. [3] Logan L.M. *et al*. (1973) *JGR*, *78*, 4983. [4] Salisbury J.W. and Walter L.S. (1989) *JGR*, *94*, 9192. [5] Salisbury J.W. *et al*. (1973) *LPS IV*, 3191. [6] Bandfield J.L. *et al*. (2011) *LPS XLII*, 2468. [7] Greenhagen B.T. *et al*. (2011) *LPS XLII*, 2679. [8] Thomas I.R. *et al*. (2010) *LPS XLI*, 1364.
[9] http://curator.jsc.nasa.gov/lunar/compendium.cfm