Mapping Low-Calcium Pyroxene Using LOLA. M A. Riner[1*], P. G. Lucey[1], G.A. Neumann[2], and E. Mazarico[2]
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Introduction: The Lunar Orbiter Laser Altimeter (LOLA) on the Lunar Reconnaissance Orbiter spacecraft will provide a precise lunar topographic model. It also provides a high spatial resolution measurement of surface reflectance at the single laser wavelength of 1.064 microns. LOLA is not commonly thought to be a mineralogic sensor, but its data can be used to map the relative abundance of magnesian low-calcium pyroxene through detection of changes in spectral reflectance with temperature.

Many minerals change color with temperature, and pyroxene is among them. Both pyroxene and olivine have been demonstrated to exhibit strong temperature-dependent spectral changes in the near-infrared beyond 700 nm [1-5]. This effect explains the anomalous shape of the olivine bands in the main belt A-asteroids [6] and helped constrain the mineral chemistry of those asteroids. The effect was observed on the asteroid Eros using data from NEAR, and the variation in reflectance with temperature and wavelength was used to constrain the composition of that body [7]. Meteorites and lunar samples also show temperature-dependent variations in reflectance, all due to the spectral effect on the mafic silicates olivine and pyroxene [5].

In the olivine and pyroxene common on the Moon, the near-IR temperature effect occurs very strongly on the long-wavelength side of each crystal field absorption; little or no variation is seen in the band center or on the short-wavelength edge of the absorption. This shift leads the common mineral with the shortest NIR absorption feature (magnesian low-Ca pyroxene) to have its maximum reflectance-temperature effect at the wavelength of the LOLA laser. At the LOLA wavelength, the reflectance of the pyroxene changes by a factor of two from lunar nightside to equatorial noontime temperatures (100 to 400K). The result is that if we can compare the reflectance of pyroxene bearing locations at different times of the lunar day, we should be able to detect the signature of their temperatures variations, and regions with more magnesian, calcic pyroxene will show stronger effects.

Method: In ideal temperature-reflectance experiment a sample is observed under identical conditions at different temperatures. Using data from LOLA we can only approximate that condition, but the positive result from observations of Eros using NEAR [6] suggest these approximations may be acceptable.

We plan two types of experiments. In both experiments we rely upon the fact that temperature varies with lunar time of day, and that LOLA data contains either actual repeat locations—especially the orbit track cross-overs that are used to help form a closed solution for lunar topography—or orbit tracks occur within compositional units that share similar pyroxene abundances. The first type of experiment is to bin the data at various scales to attempt a global map. This method suffers from the fact that our arbitrary grid will contain a range of compositions in many cases, introducing noise and invalid solutions. The second experiment is to use the cross-over observations. This method suffers from low counts of data points.

Preliminary Results: We expect detections of temperature sensitivity to be in very restricted locations. Prettyman et al. [8] did not find strong evidence of highly magnesian terrains (in terms of Mg-number) detectable at the approximately 100 km resolution of the Lunar Prospector Gamma-ray Spectrometer. Because this technique has strong selective sensitivity to the abundance of magnesian pyroxene, the Prettyman et al. [8] result suggests temperature sensitivity will be localized. Further, the influence of the pyroxene will be attenuated by space weathering, so immature locations, by definition also localized, are the most likely locations for detections. On the other hand, the increase in measurement sensitivity by averaging will be most effective in extensive, relatively uniform locations.

So far, we have focused on the first two months of data obtained after insertion into the mapping orbit. Our first experiment was to bin the LOLA tracks from detector 1 into 1 degree increments. Most of the bins contain tracks obtained during separate months, with different solar incidence angles, hence surface temperature. We fit the reflectances versus incidence angle as a proxy for temperature per Lucey and Hinrichs [5]. The average reflectance (Figure 1) shows a clear image of the Moon with few artifacts. Figure 2 shows the slope of the fits to reflectance versus incidence angle. Black areas did not contain points from two months with well-separated incidence angles. The slope image is a measure of temperature sensitivity, and is centered at a mean near zero. No clear detection of temperature sensitivity is apparent, though there is some high latitude striping that probably indicates a subtle calibration artifact or variation in LOLA sensitivity with latitude. We have not yet compared results from the other four detectors.

Future Work: As data accumulates we will produce more binned fits, and begin to analyze LOLA track crossovers where the reflectances are obtained from the same, or approximately the same, locations. Particularly at high latitudes where crossovers are abundant, some of these crossovers (on the order of 5%) will be in immature locations.

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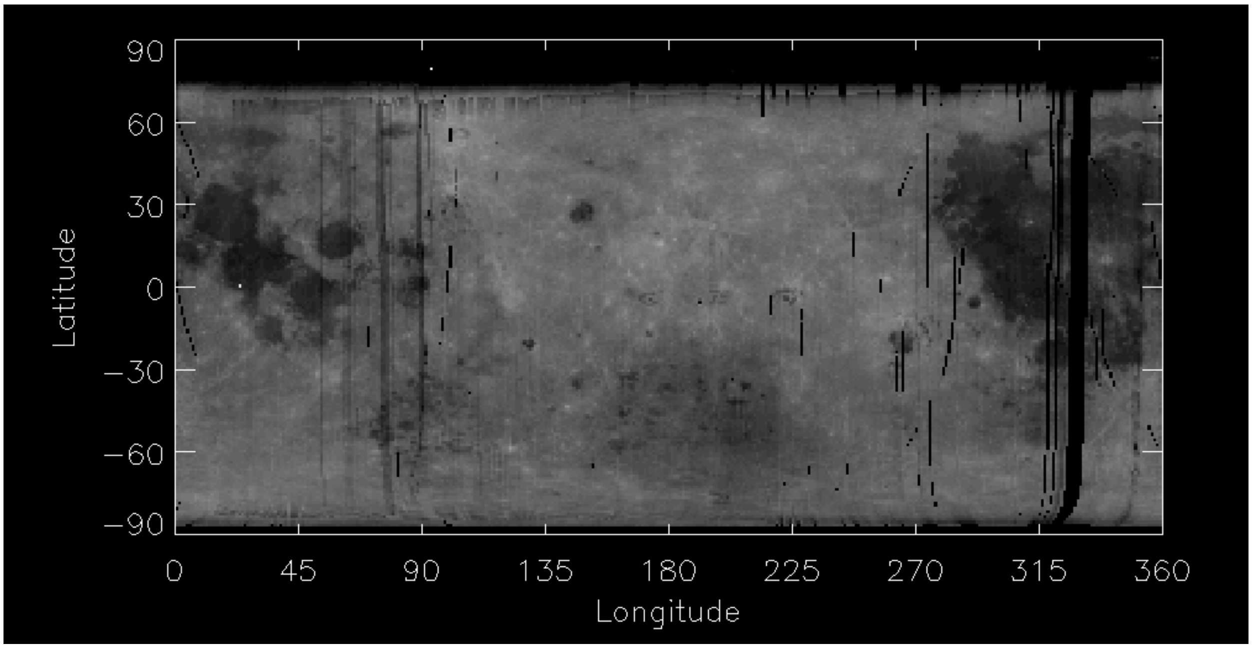

Figure 1 - Global mosaic of LOLA reflectance used in this analysis.

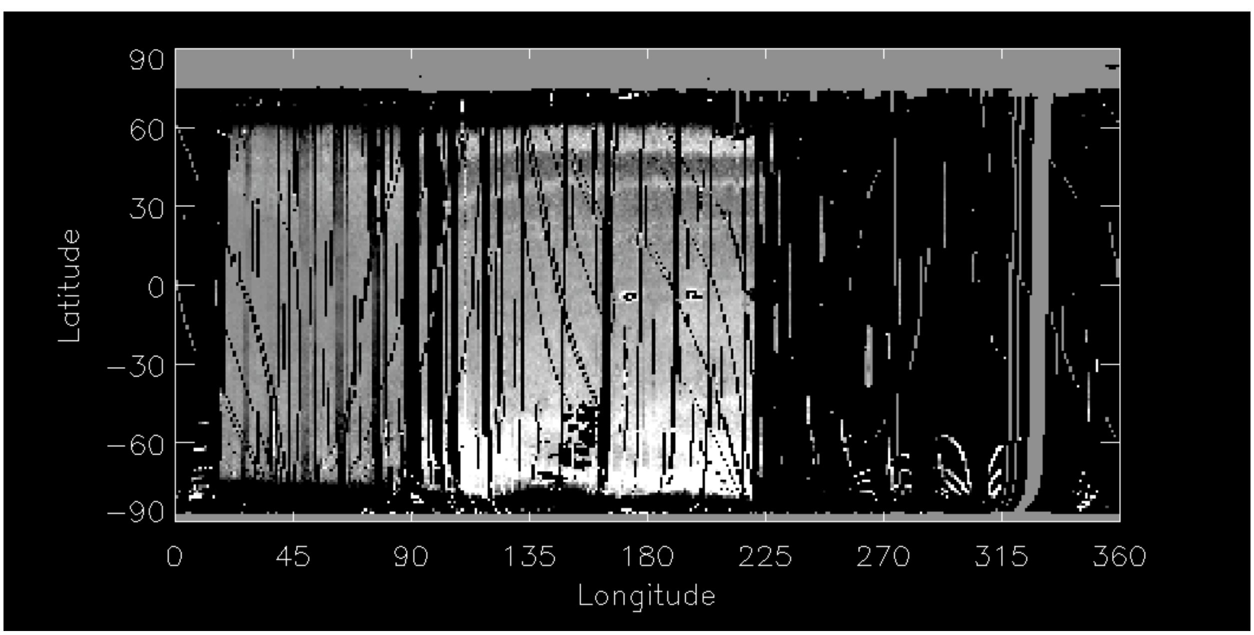

Figure 2 - Map of the slope of the temperature-incidence curve for all areas with data points from both months. Stretch is from -0.005 to 0.005 units of delta R / delta incidence angle. Data confined to dayside returns only.