ANALYSIS OF *CHANG'E-3* ROVER COLOR IMAGES. Tiffanie X. Choi[1], David T. Blewett[2], Yong-Chun Zheng[3], Edward A. Cloutis[4]. [1]Long Reach High School, Columbia, Md., USA. [2]Planetary Exploration Group, Johns Hopkins University Applied Physics Laboratory, Laurel, Md., USA. [3]National Astronomical Observatories of Chinese Academy of Sciences, Beijing, China. [4]Dept. of Geography, University of Winnipeg, Canada.

Introduction: On December 14, 2013, the *Chang'E-3* (CE-3) mission placed a lander and rover on the lunar surface in Mare Imbrium [1, 2]. The rover carried a pair of mast-mounted Panoramic Cameras (PCAM [3]), used to collect monochrome and color (red-green-blue, RGB) images of the surface during the rover's traverse. We are exploring the usefulness of these broadband color images for studies of rocks and soils at the landing site.

Lunar Sample Context: A better understanding of variations in the RBG color space is needed as a framework for more detailed interpretation of the PCAM color data, and would also be useful for analysis of data from future lunar rovers or landers that may carry a Bayer-filter camera similar to PCAM. To help establish this framework, we consider low- and medium-Ti *Apollo* mare soils, with Ti contents ranging from ~2–6 wt.% TiO_2 (the basalts at the CE-3 landing site contain ~5 wt.% TiO_2 [2]). We took RELAB laboratory reflectance spectra [4] for the soils and convolved them to the PCAM RBG responsivities. Plots of color ratios (Figs. 1 and 2) illustrate trends related to space weathering in these samples of known soil maturity index (I_s/FeO). In general, for each sample, fresher material (lower I_s/FeO) has higher values of the color ratios. Next, we convolved spectra of lunar mineral separates to the PCAM responsivities, and plotted the color ratios (Fig. 3 and 4). The plagioclase is distinguishable from the other minerals by having high values in all three ratios. Olivine has intermediate values in all three ratios.

Processing PCAM images: We obtained Level 2B images archived at the National Astronomical Observatories of the Chinese Academy of Sciences website. Image reduction to radiance for each pixel includes correction for dark current, flat field, gain, and exposure time [6, 7]. Geometric information for each image includes the solar zenith and azimuth angles, and the platform and camera orientation. We performed demosaicking [8] and converted the R, G, and B image planes to radiance using calibration coefficients contained in the image headers [9]. The radiance images were divided by the solar spectrum [10] convolved to the PCAM responsivities in order to produce images in units of reflectance factor (*I/F*), following the method of Jin et al. (2015) [9]. We then form the three ratios B/R, B/G, and G/R. To first order, spectral ratios normalize photometric differences caused by the widely varying incidence and emergence angles that are typically present within a scene.

Discussion: Distinctive bright spots are seen on the large boulder visited by the rover. Some authors have described the bright spots as micrometeoroid impact "zap pits" [11], while others [1, 2, 12] refer to the bright spots as phenocrysts, i.e., large mineral grains. We sought to determine if the PCAM color data can help to distinguish between zap pits and large mineral crystals. We defined regions of interest (ROIs) in the PCAM image of the boulder (Fig. 5), and plotted the pixels from each ROI on color-ratio plots (Figs. 6). The scatter plots show that the fresher pixels on the boulder have higher ratios than the more mature soil in the foreground, consistent with our findings for the *Apollo* soils (Figs. 1 and 2).

The pixels in the ROI for the boulder front (red points) extend to the highest values in the three ratios. This suggests that the most extreme (high ratio) pixels could represent plagioclase grains (compare Figs. 3 and 4). However, examination of ratio values for the brightest pixels reveals that the bright pixels have intermediate ratio values. Hence, it might be that the bright pixels correspond to large olivine crystals (Figs. 3 and 4). This is consistent with the analysis of data from the CE-3 Visible and Near-infrared Spectrometer and Active Particle X-ray Spectrometer by Zhang et al. [13], who concluded that the regolith at the landing site contains a high abundance of olivine. Alternatively, the ratio values of the bright pixels could result from mixtures of the major minerals, which would tend to produce intermediate ratios. If this is the case, the bright spots potentially represent micro-crater zap pits. Thus, it may not be possible to distinguish between phenocrysts and micro-craters with the PCAM color data.

References: 1] L. Xiao (2014), *Nature Geosci. 7*, 391. [2] L. Xiao et al. (2015), *Science 347*, 1226. [3] J.-F. Yang et al. (2015), *Res. Astron. Astrophys. 15*, 1867. [4]. L. Taylor et al. (2001), *J. Geophys. Res. 106*, 27985. [5] X. Ren et al. (2014), *Res. Astron. Astrophys. 14*, 1557. [6] C. Li et al. (2015), *Space Sci. Rev. 190*, 85. [7] X. Tan (2014), *Res. Astron. Astrophys. 14*, 1682. [8] X. Li (2005), *IEEE T.I.P. 14*, 370. [9] W. Jin, et al. (2015), *Geophys. Res. Lett. 42*. [10] C. Gueymard (2004), *Solar Energy 76*, 423. [11] A. Basilevsky et al. (2015), *Planet. Space Sci. 117*, 385. [12] Z. Ling et al. (2015), *Nature Comm. 6*, doi: 10.1038/ncomms9880. [13] H. Zhang et al. (2015), *Geophys. Res. Lett. 42*, doi:10.1002/2015GL065273

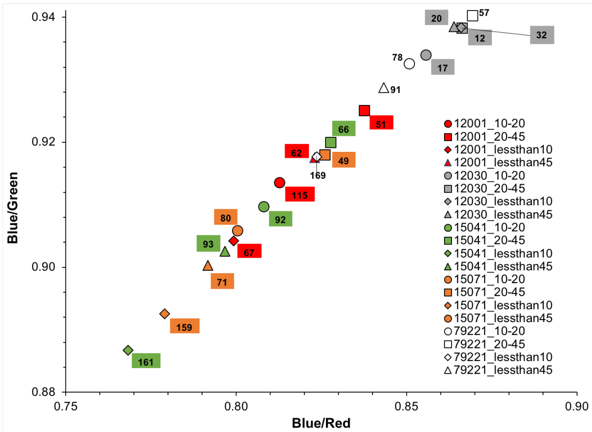

Fig. 1.
Plot of the B/G ratio vs. B/R ratio for low- and medium-Ti mare soils. Labels on the data points give the sample's I_s/FeO value.

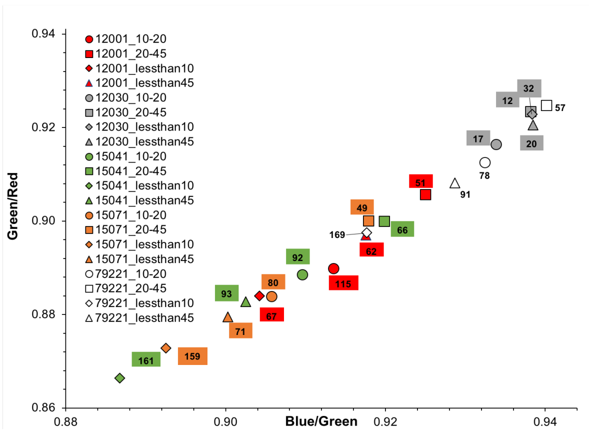

Fig. 2.
Plot of the G/R ratio vs. B/G ratio for the Apollo soils of Fig. 1.

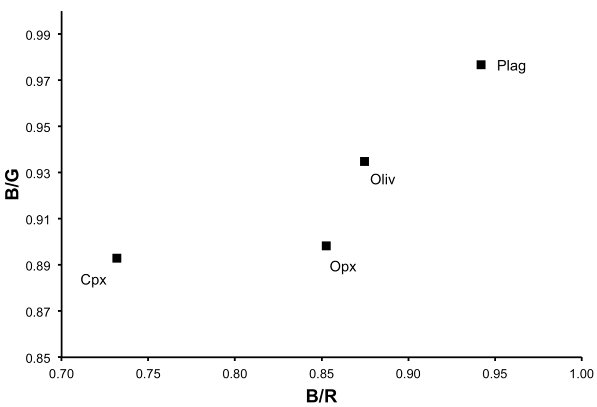

Fig. 3.
RELAB spectra for four lunar mineral separates, convolved to the PCAM responsivities, and plotted as the color ratios.

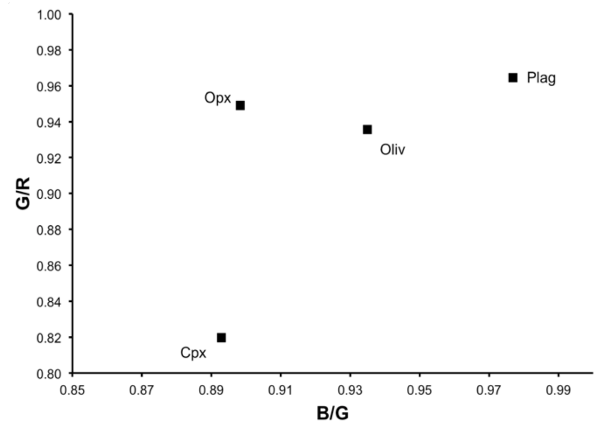

Fig. 4.
G/R ratio vs. B/R ratio plot for the minerals of Fig. 3.

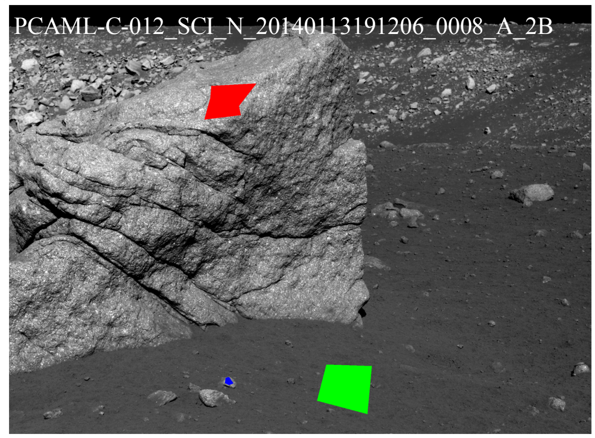

Fig. 5.
Image ROIs were defined for a large boulder front (red), foreground soil and small rock (green), and bright foreground rock (blue).

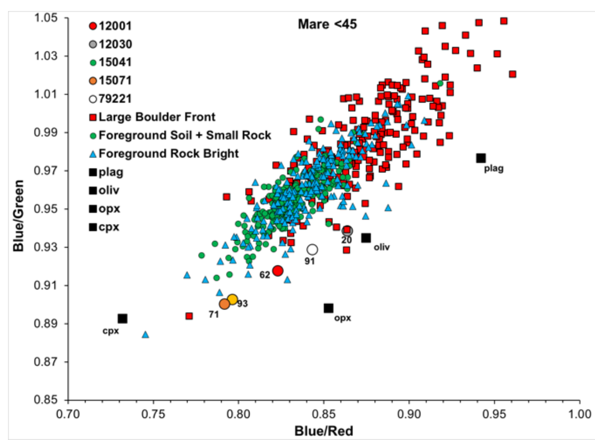

Fig. 6.

Plot of B/G ratio vs. B/R ratio for 200 random points for each ROI from Fig. 5, with *Apollo* soils from Fig. 1, and mineral separates from Fig. 3.