THE GOLDSCHIMDT REGION AS VIEWED FROM MOON MINERALOGY MAPPER (M^3) DATA.

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Introduction: Recent findings from the Deep Impact-EPOXI, Cassini and Chandraayn-1 missions have identified absorption features near 3 µm attributed to water/hydroxyl on the lunar surface [1, 2, 3]. High spatial resolution data from the Moon Mineralogy Mapper (M^3) onboard Chandraayan-1 show that these absorptions exhibit marked variability in their local distribution. One area with a particularly strong hydrous signature is the region near Goldschmidt crater on the northern lunar nearside. Here we present a preliminary overview of the geologic character of this area using (M^3) data.

Background: Goldschmidt crater is a highly-degraded 113-km diameter crater located in the northern highlands (73.0°N, 3.8°W), directly north of Mare Frigoris. Much of the plains material in and around Goldschmidt consists of ejecta from the smaller (51-km) Copernican crater Anaxagoras on its eastern rim (73.4°N, 10.1°W). Based on Galileo multispectral SSI data, Hawke et al. [4] noted that the plains in this region are spectrally distinct from local small highland craters. Telescopic analyses have suggested that pure anorthosite has been excavated by the Anaxagoras impact and deposited in the floor of Goldschmidt [5]. Similarly, recent analyses of Clementine 5-band UVVIS spectra have indicated that the highlands soils in this region north of Imbrium are anomalously noritic and are underlain by more feldspathic material [6]. The Moon Mineralogy Mapper (M^3) is an imaging spectrometer onboard Chanraayan-1 that collects reflectance spectra in 85 spectral bands from ~430 nm to 3000 nm at 20-40 nm spectral resolution (in its reduced resolution mode), at a spatial resolution of ~140 m/pixel, and allows detailed investigations of the mineralogical variations across the lunar surface. Various band parameters derived from M^3 spectra provide a preliminary look at the compositional variation of this region near Goldschmidt and Anaxagoras.

Methods and Data: We have used a north polar mosaic of individual M^3 strips to examine the northern highland region around Goldschmidt crater. Figure 1 shows this mosaic with the locations of Goldschmidt, Anaxagoras, and Mare Frigoris indicated. The spectra presented here have not been corrected for thermal emission effects. A correction factor has been applied to suppress residual band-to-band artifacts in the spectra. At these northerly latitudes, thermal emission is weak and has only a minor effect on 3000nm band depths.

Three parameters have been used in this analysis to describe key spectral variations across the region: 1) the 1000 nm integrated band depth (sum of band depths between 789 and 1308 nm relative to a local continuum, 'IBD'); 2) the 2000 nm IBD (sum of band depths between 1658 and 2498 nm relative to a local continuum); 3) and the band depth at 3000 nm (2626 nm /2856 nm).

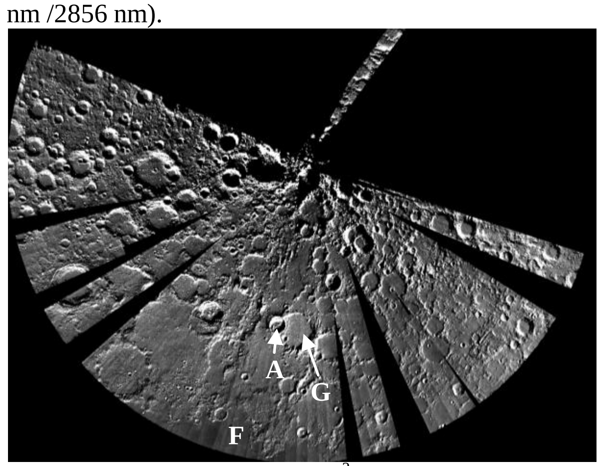

Figure 1. North Polar mosaic of M^3 data. Reflectance at 2900 nm, which measures thermal emission and thus is sensitive to topography. G = Goldschmidt crater, A = Anaxagoras crater, F = Mare Frigoris. Bottom is the nearside.

Results: North of Mare Frigoris, at least two distinct materials are observed: a mature highland soil and a fresh feldspathic unit that has been excavated by several large craters. A color composite shown in Figure 2 highlights the distribution of this underlying unit. In this image, red and green represent the strengths of ferrous absorptions at 1000 and 2000 nm, respectively. Blue represents the depth of the absorption near 3000 nm attributed to OH/H_2O by [3]. Therefore, green, yellow and orange colors in Figure 2 reflect variations in mafic mineral abundance. Blues and purples reflect more feldspathic lithologies. Figure 3 is a grayscale image showing the distribution of the 3 µm feature.

By this characterization, Anaxagoras ejecta in the floor of Goldschmidt crater appears similar to the material excavated by the large crater to its west, having relatively weak ferrous absorptions but a relatively strong hydrous absorption. There is notable heterogeneity in the highland soil, with the area north of Goldschmidt (indicated by yellow arrow) having somewhat stronger mafic absorptions and/or weaker 3000nm absorptions (Figure 2). At this time it is unclear whether this heterogeneity is the result of mixing with ejecta from large craters, reflects a latitudinal variation, or both.

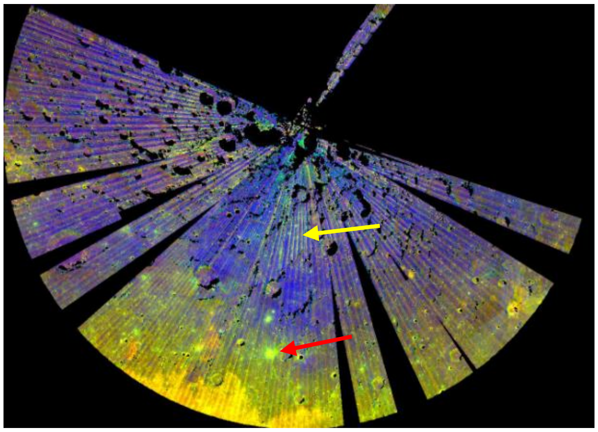

Figure 2. Color composite image showing variations in the strengths of mafic and hydrous absorptions. R: IBD at 1000 nm, G: IBD at 2000 nm, B: 3000 nm BD. Greens, yellows, and oranges reflect variations in composition and maturity in mafic lithologies, while blue and purples represent more feldspathic materials. The distinct north polar highland soil region is indicated by a yellow arrow. Epigenes F (67.3, 7.5ºW) corresponding to the spectrum in Figure 4 is indicated by a red arrow.

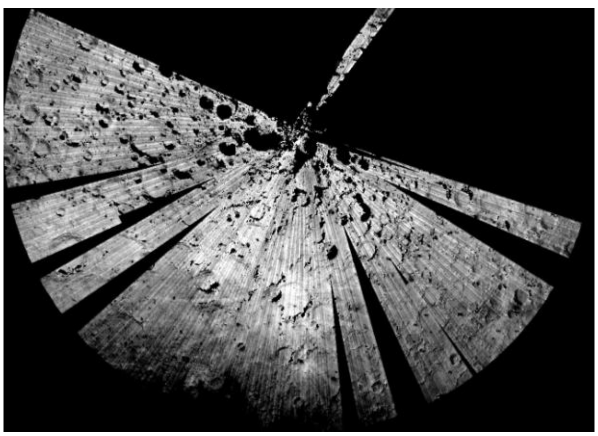

Figure 3. Depth of the 3000 nm band (2626 nm /2856 nm).

Spectra representative of the distinct materials in this region are given in Figure 4. The Goldschmidt spectrum is an average of four 5X5 pixel spectra from the floor of the crater that are within Anaxagoras ejecta. The highland soil spectrum is an average of four 5X5 pixel spectra south of Goldschmidt, between the crater and Mare Frigoris. The red arrow in Figure 2 indicates the location of the fresh crater Epigenes F [7].

The background soil is characterized by weak ferrous absorptions and red continuum slope. Anaxagoras ejecta in the floor of Goldschmidt crater has similarly weak features, but has a stronger absorption near 3000 nm. From this preliminary analysis, it is unclear whether maturity or compositional differences are the principal source of distinction between the highlands soils and excavated material. We have not identified crystalline (unshocked) anorthosite [8] in Goldschmidt. Several small fresh craters throughout the scene are distinctly noritic, showing very strong and short-wavelength 1000 and 2000 nm absorptions [e.g., 9].

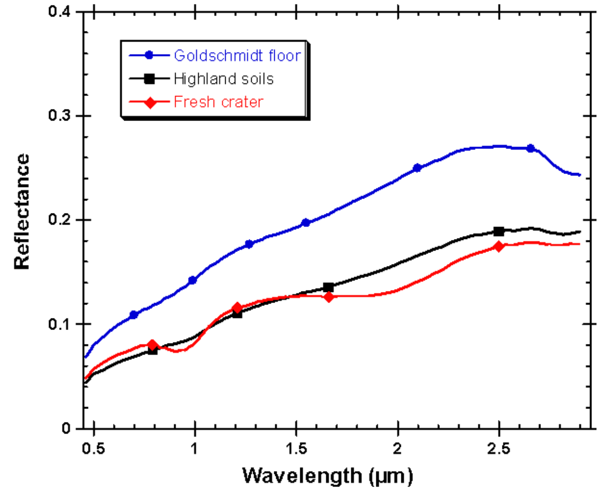

Figure 4. Representative M^3 spectra for the Goldschmidt interior, highland soils north of Mare Frigoris and a fresh noritic crater south of Goldschmidt. These spectra have been thermally corrected.

Conclusions and Future Work: A preliminary examination of M^3 data indicates that the region near Goldschmidt crater is largely feldspathic and has been affected by ejecta from several large nearby impacts. The materials excavated by these various events are spectrally similar, and show the most prominent 3000 nm absorptions in the region. To further characterize the nature of the highlands material north of Mare Frigoris, we will incorporate M^3 data collected later in the Chandrayaan-1 mission that covers much of the farside north polar region and includes some repeat coverage of the nearside regions discussed here.

References: [1] Sunshine et al. (2009) *Science 326*, 565-568, [2] Clark et al. (2009) *Science 326*, 562-564, [3] Pieters et al. (2009) *Science 326*, 562-564, [4] Pieters et al. (1993) *LPSC XXIV*, 1141, [5] Hawke et al. (2003) *JGR Planets 108(E6)*, 5050-5066, [6] Isaacson et al. (2009) *JGR 114*, 9007-9021. [7] Klima et al., (2009) *these abstracts* 1485. [8] Pieters et al. (2009) *LPSC XL* 2052, [9] Cloutis and Gaffey (1991) JGR Planets *96(E5)*, 22,809–22,826.

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