SMALL CRATER DENSITIES NEAR APOLLO 17: CLUES TO PROPERTIES OF LUNAR PYROCLASTIC DEPOSITS.

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Overview: We determined crater density distributions of ~3.5 to 300 m diam. impact craters on mantled and unmantled mare units located west of the Apollo 17 landing site using data from the Narrow Angle Camera (NAC frame M117304864R; 0.67 m/pixel) of the Lunar Reconnaissance Orbiter (LRO) Camera [1]. These data indicate a deficiency of small craters on the mantled surface and confirm previous results [e.g., 2]. The deficiency is thought to be due to the presence of an unconsolidated, 'dark mantle' deposit of pyroclastic origin on a mature mare surface. New high-resolution data and an automated crater-counting method allow us to examine the viability of using small crater populations to improve identification and characterization of lunar pyroclastic deposits.

Lunar Pyroclastic Deposits: The presence of a very dark, possibly young volcanic deposit at Taurus-Littrow was a major motivation for its selection as the Apollo 17 landing site [e.g., 3]. Pyroclastic deposits at this site and elsewhere are high-priority targets for exploration [e.g., 4], in part because they are thought to be volatile- and metallic-element (e.g., S, Fe, Ti) enriched remnants of ancient lunar volcanic eruptions. Their compositions and distributions provide information on the early lunar interior [e.g., 5-7] and the location of possible resource materials [8, 9]. Studies of pyroclastic deposits with telescopic and Clementine (ultraviolet and visible) spectral data demonstrate their compositional heterogeneity and expanded our knowledge of deposit types [e.g., 10-16]. Gaddis et al. [13] discussed the moderate albedoes of some pyroclastic deposits (for example the Apollo 15 green glasses [e.g., 6]) and indicated that low albedo alone is not a reliable diagnostic tool for identification of pyroclastic units [e.g., 17]. A new method is needed to identify and characterize these deposits.

The pyroclastic deposit near Taurus-Littrow is very dark and covers portions of the ancient (~3.8 Ga, [18]) mare deposits in the highlands near southeastern Mare Serenitatis (MS; ***Figure 1***). Dated at ~3.7 Ga [19], the pyroclastic materials are comprised of iron- and titanium-rich orange glass and quenched black beads [e.g., 10]. Younger maria within and southeast of MS were not mantled. This analysis focuses on mantled and unmantled mare units in an area west of Taurus-Littrow Valley.

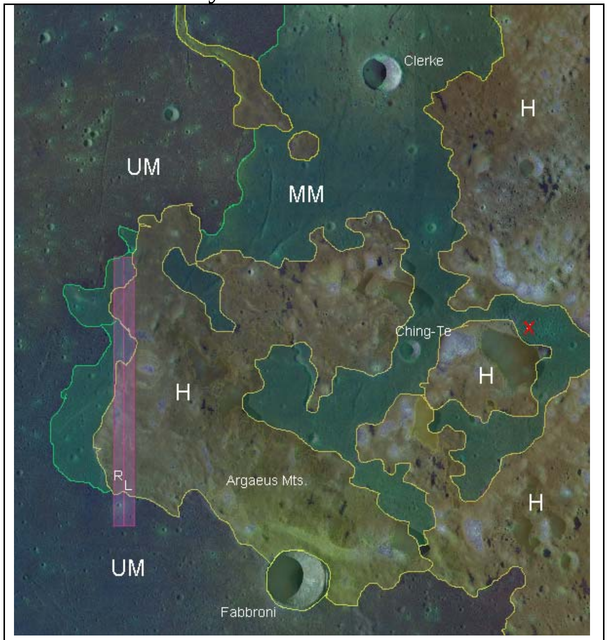

Figure 1. The Apollo 17 landing site (red X) region of SE Serenitatis basin as viewed by the Kaguya Terrain Camera (~10 m/p) and in Clementine color-ratio (UVVIS bands, red=2/1, green=2/4, blue=1/2) data. The location of the LROC NAC study frame (M117304864R, 87° inc.) is marked in pink at left. Mantled mare (MM) units are shown in green, and highlands and low hills are shown in yellow. Fabbroni crater is 11 km across.

Method: ***Crater Counting.*** An automated impact crater detection algorithm, developed at the Jet Propulsion Laboratory (JPL) for use in navigation and landing [20-22], was used to measure craters. The method identifies fresh and degraded impact craters and can detect and characterize craters as small as 5 pixels in diameter (~2.5 m for typical LROC NAC data). The algorithm searches an image at multiple scales and makes identification using models of 'typical' crater appearance. For each identified crater, a measure of crater freshness is derived from the image intensity gradients. For fresh craters, the rim contour is often very precise, but for eroded craters the rim placement is a best estimate. Such measures of crater sharpness are used as an indication of crater hazardousness to help assess landing risk [22]. The output is a crater list including the location, semi-axes lengths, ellipse orientation, rim sharpness, and a measure of confidence for each crater detected. Performance tests [23] show that the crater detector compares well with human-counted results up to the limit of detection (~2.5 m), with an estimated accuracy of ~85%.

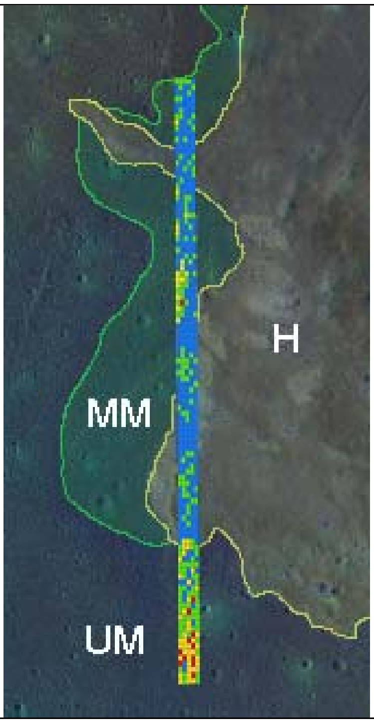

Figure 2. Binned crater density (20 to 300 m) for 2.5-km wide NAC frame M117304864R (blue=low, red=high counts/500m^2) of area of west of Taurus-Littrow. Note that densities are lower in the mantled maria (MM, green) and higher in the unmantled mare unit (UM).

Method: ***Density Calculation.*** Crater detections from a single NAC frame (M117304864R), totaling 210,186 craters ranging in size from 3.5 to 300 m, were mapped as point data in pixel-space using ArcMap. Average crater sizes were calculated from major and minor axes and bins of 500 m^2 were used to calculate crater density in the size range of 20 to 300 m (n=4816). The resulting map (***Figure 2***) shows that crater density is lower for mantled mare units (average density ~38 craters/km^2) than for unmantled mare units (average density ~73 craters/km^2).

Analysis: Crater chronologic data [24] for larger craters (D>1 km) show that the unmantled mare unit of NE Mare Tranquillitatis (A7) has an absolute model age of ~3.7 BY. The pyroclastic and mare deposits west of Taurus-Littrow are inferred to be older because of their similarity to materials sampled at Apollo 17, with samples dated at ~3.75 Ga [18]. These age relationships are at odds with our results because lower crater densities typically correlate with lower absolute model ages. However, these model ages were derived for larger crater diameters than analyzed in our data. We will perform manual crater counts of small crater populations on the mantled and unmantled mare units to test our automated results. One goal is to determine the size threshold below which crater counts are most useful for mantle detection.

Lucchitta and Sanchez [2] also observed an unusually low density of small craters on the mantled mare units west of Apollo 17. They noted that the unconsolidated pyroclastic material in southeast MS likely experienced abnormally rapid degradation of small craters. Thus, a low crater density may provide clues to the presence and properties of lunar pyroclastic deposits. Further analyses of the NAC data will help to assess the nature of the mantling materials, including estimates of their strength properties and thickness. These preliminary results suggest that crater densities calculated from automated crater counting using LROC data may be useful for identifying and characterizing pyroclastic deposits. We will compare our results to those from analyses of LRO Mini-RF RADAR data for mapping the extent of pyroclastic deposits [e.g., 25].

References: [1] Robinson et al., 2010, Space Sci. Rev, 150, 81-124. [2] Lucchitta and Sanchez, 1975, PLPSC 6th, 2427-2441. [3] Greeley and Gault, 1973, EPSL 18, 102-108. [4] Gaddis et al., 2009, LRO Sci. Targ. Mtg., #6025. [5] Heiken et al. 1974, GCA 38, 1703. [6] Delano, 1986, JGR 91, D201. [7] Shearer et al., 2006, RMG 60, 365. [8] Hawke et al., 1990, PLPSC 20th, 249. [9] Duke et al., 2006, RMG 60, 597. [10] Pieters et al., 1973, JGR 78, 5867. [11] Gaddis et al., 1985, Icarus 61, 461. [12] Hawke et al., 1989, PLPSC 19th, 255. [13] Gaddis et al., 2003, Icarus 161, 262. [14] Lucey et al., 2006, RMG 60, 83. [15] Wilcox et al., 2006, JGR 111, E09001. [16] Hawke et al., 1989, PLPSC 19th, 255. [17] Gustafson et al., this volume. [18] Kirsten et al., 1973, EPSL 20, 125-130. [19] Taylor, 1982, LPI Press, 481 pp. [20] Cheng & Ansar, 2005, IEEE Int. Conf. Robotics & Automation, p. 5. [21] Ansar and Cheng, 2005, PE&RS 71, 10. [22] Cheng and Huertas, this volume. [23] Cheng and Huertas, 2010, Plan. Crat. Consort., abs. #1013. [24] Hiesinger et al., 2000, JGR 105, 29239. [25] Carter et al., 2010, LPSC 41, abs. #1563.