THE EFFECTS OF TERRAIN PROPERTIES ON DETERMINING CRATER MODEL AGES OF LUNAR SURFACES.

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Introduction: Analyzing crater size-frequency distributions (SFDs) and using them to determine model ages of surfaces is an important technique in understanding the Moon's geologic history and evolution. The use of small craters with diameters (D) < 1 km is becoming particularly prolific, especially for analyses utilizing the very high resolution imaging available from Lunar Reconnaissance Orbiter Narrow and Wide Angle Cameras (LROC-NAC/WAC) and the Selene Terrain Camera [e.g, 1, 2]. However, in this diameter range, crater SFDs can change shape depending on the properties of the terrains on which they are recorded [e.g., 3–6]. Both the strength of the terrains and how that strength changes with depth are important in determining how the crater SFD will be affected (Fig. 1; [7]). If these influences are ignored crater model ages may not be computed correctly. In this work, we use the Model Production Function (MPF; [3]), which includes terrain properties in computing the crater production functions, to explore how incorporating terrain properties affects the calculation of crater model ages. We also demonstrate how using the MPF can improve estimations of lunar terrain ages.

Methods: As an example, we analyze a region in Mare Imbrium containing the Apollo 15 landing site. We first compile a crater SFD for D=0.01-2 km utilizing LROC-WAC/NAC images (Fig. 2). We use a nested technique to obtain this wide diameter range. Craters D=0.5-2 km are measured in the largest area (2200 km^2). The large white box in Fig. 2b indicates the first nested region where D=0.09-0.5 km are measured (95 km^2). The smaller white box in Fig. 2b indicates the second nested region where D=0.01-0.1 km craters are measured (1.6 km^2; Fig. 2c).

Then, we quantitatively fit the crater SFD with distinct MPFs that use broadly different terrain properties. Terrain properties are varied through coarsely altering the parameters in the crater scaling law [7] that represent material type (consolidated, unconsolidated, porous), material tensile strength, and material density (for further details see [3]).

Finally, the fits are used to compute the D=1 km crater model ages for the region. These ages are compared to radiometric age for Mare Imbrium basalts returned by Apollo 15 (3.25-3.62 Ga; [8]).

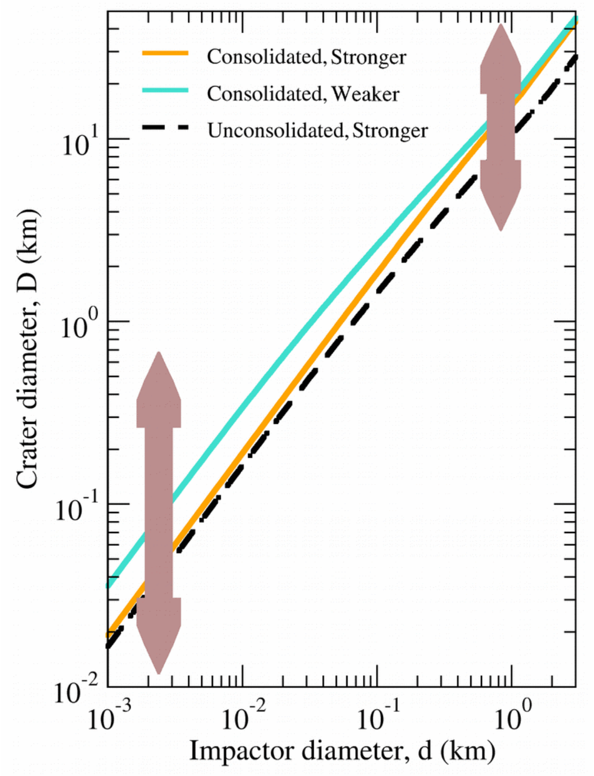

Figure 1. Crater scaling law for different materials [7]. Comparing two consolidated materials with different strengths (orange vs. blue line) indicates that smaller craters will form for similar impact conditions in a stronger consolidated material and the difference is greater for smaller impactors (arrows). Comparing consolidated (solid line) to unconsolidated (dashed line) materials indicates a crater forming in the unconsolidated material will be smaller.

Results and Discussion: Table 1 shows the crater model ages computed using the MPF for a variety of terrain properties. We also indicate whether those properties are likely appropriate for the Mare Imbrium basalts (while we do not have the data to determine the exact terrain type, tensile strength, and density, there are broad values that most likely represent the terrain based upon its geology).

We first find the model ages can be quite variable indicating that considering strength for these diameters is important. Second, we find the model age that best

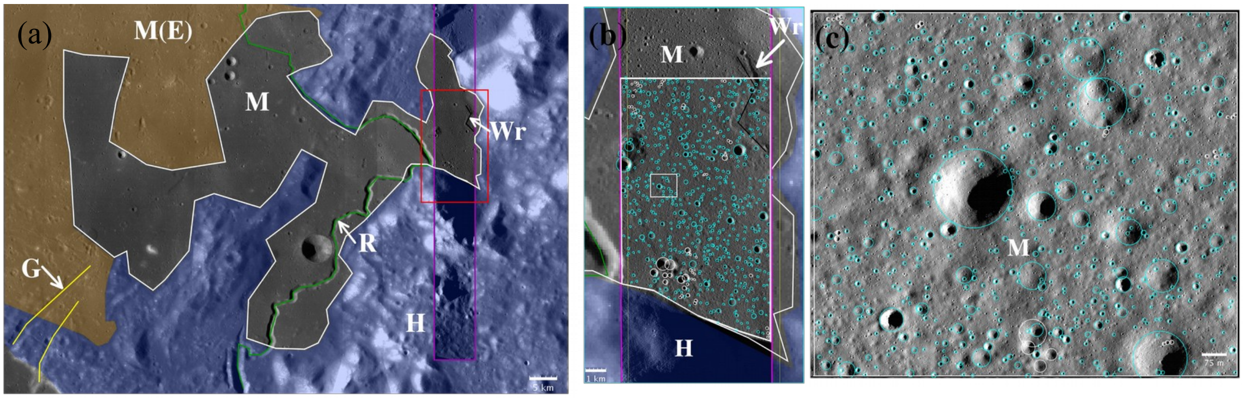

Figure 2. (a) White outline indicates region selected within Mare Imbrium. Terrains and features we mapped in this region are: M = mare, M(E) = mare region with lighter albedo (mantled with ejecta from Copernicus), H = hilly terrain, Wr = wrinkle ridge, G = graben, R = rille. Background is LROC-WAC mosaic and selected NAC image is indicated by the purple box. The red box indicates the close-up area shown in (b). (b, c) Crater measurements in nested regions. Blue circles designate measured primary craters. White circles designate secondary craters in clusters/chains. Counting area for D=0.09-0.5 km craters is outlined by the larger white box. Smaller white box is the nested region for smaller craters (D=0.01-0.1 km) shown in (c). North is up and scale is indicated.

agrees with the radiometric age is computed with an MPF using parameters for a consolidated material with a tensile strength of 2 x 10^7 dyne/cm^2, reasonable for basalt [e.g., 7]. Model ages not incorporating strength or using larger or smaller tensile strengths are well outside the radiometric age range (they also have poorer fits to the crater SFDs, not shown). The ability of the MPF to incorporate terrain properties into calculations of model ages makes it a valuable tool in more accurately estimating ages of lunar terrains.

Future Work: We will continue to use this approach to constrain the influence of terrain properties on crater model ages by extending the variety of lunar terrains examined. Furthermore, we will explore the effect of changing terrain properties with depth (i.e., layering) on the computation of model ages. The MPF can currently incorporate a change in terrain properties with depth as a step function. We will use hydrocode simulations to improve on a layered terrain crater scaling law [9] and incorporate results into the MPF.

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Table 1. Computed MPF Model Ages of Mare Imbrium Region for Various Terrain Properties

Terrain Properties	**Age ± 1σ (Ga)**	**Terrain Properties Likely Appropriate**
Terrain properties not incorporated (i.e., gravity scaling only)	2.0 ± 0.2	N/A
Consolidated, Tensile strength = 2x10^6 dyne/cm^2 (highly fractured rock)	2.5 ± 0.2	No
Consolidated, Tensile strength = 2x10^7 dyne/cm^2 (fractured rock)	3.5 ± 0.2	Yes
Consolidated, Tensile strength = 2x10^8 dyne/cm^2 (intact rock)	3.7 ± 0.2	No