IMPACT CRATERS AS PROBES OF THE LUNAR CRUST. B. J. Thomson[1], P. D. Spudis[2] and D. B. J. Bussey[2], [1]Harvey Mudd College, 340 E Foothill Blvd., Claremont CA, [2]Lunar and Planetary Institute, 3600 Bay Area Blvd., Houston TX.

The volumes of lunar lava flows provide important information about the thermal evolution and resurfacing history of the Moon. In the absence of an abundance of direct surface measurements of flow thicknesses, indirect techniques must be employed to further constrain the dimensions of mare units. Methods that have been developed for estimating the thickness and volume of mare basalts include geophysical techniques such as gravity mapping [1,2], active siesmometry, and the use of stratigraphy and topography [3], although these techniques yield relatively coarse, imprecise estimates. More precise point estimates of thickness are provided by partially flooded craters [4-6], but the point density of these data points decreases as the thickness of superposed material increases [7]. This makes thick lenses of material located deep within basins difficult to resolve. Our ability to now obtain precise thickness estimates using craters which have penetrated the mare [8,9] allows us to analyze a new class of unflooded craters, thus increasing the point density of thickness data in sparse regions.

We have estimated the thickness of mare units by using craters to probe the Moon at depth, based upon compositional data from the Clementine mission. We focused on craters with diameters in the 15-35 km range which have impacted upon mare or upon mare/highland boundaries. Craters in this size range have depth to diameter (*d*/*D*) ratios of about 1/10, indicating that the apparent crater volume approximately equals the volume of the excavation cavity [10].

The Clementine spacecraft obtained images at eleven wavelengths from the ultraviolet to the near infrared [11]. Initial ratio images aid analysis by emphasizing differences in composition and maturity [12,13]. Using the UVVIS wavelengths of 415 nm, 750 nm, and 950 nm, we produced co-registered ratio image mosaics images where red = 750/415 nm, green = 750/950 nm and blue = 415/750 nm. The spatial resolution in these images varies between 100-200 m per pixel. We then used the three original bands of these mosaics to construct compositional maps of iron and titanium according to the Lucey et al. method [14]. When applied on a pixel-by-pixel basis, this method determines the abundance and distribution of iron and titanium by weight in surface crustal material to a high precision. Our analysis concentrated primarily on iron maps because iron dominates the reflectance properties of the lunar surface, and thus the iron weight percentages have smaller relative uncertainties than those for titanium.

Typical highland material contains about 3-10 wt% Fe, while typical mare basalts contain roughly 14-20 wt% Fe [14]. For selected craters, we determined the mean abundance of iron in the ejecta blanket by averaging the pixel values in the area from the rim crest out to a distance of about one crater diameter. For this first-order analysis, we assumed that the ejecta of the crater was a simple linear mix of the basement and overlying material, according to the equation:

$$e = (m \cdot F_{mare}) + (h \cdot F_{highland}) \qquad (1)$$

In this equation, e is the average iron wt% in the ejecta, m is a representative local mare iron wt%, h is a representative local highland iron wt%, and F_{mare} and $F_{highland}$ are the fractional percentages of mare and highland material, respectively. With the additional constraint that $F_{mare} + F_{highland} = 1$, the relative proportions of mare and highland material in the ejecta can be calculated.

Without detailed topographic data, the numbers obtained above only represent relative measurements of the amounts of mare and highland material. Several Lunar Topographic Orthophotomaps (LTOs), which were constructed from stereo pairs of Apollo metric and panoramic photographs [15], were digitized to produce digital elevation models for each of the craters. We took a series of 36 profiles radiating from the center of the crater outward and averaged them to produce a mean profile for each crater. From these profiles we can precisely determine the apparent crater depth, d (the difference in elevation from the rim crest to the crater floor). The thickness, t, of the pre-impact mare basalt is reconstructed by taking Fmare, the observed fraction of basalt in the crater ejecta, and restoring an excavation cavity of depth d based on the measured profile, in which basalt overlies highland material.

The results for four impact craters are summarized in the following table:

Crater	*lat/ lon*	*D, diameter (km)*	*d, Appar. Crater Depth (m)*	*t, Mare Thickness (m)*
Euler	23°N 29°W	28	2261	1350
Timocharis	27°N 13°W	34	2870	1430
Picard	15°N 55°E	23	2140	>2140
Dionysius	3°N 17°E	18	2481	400

Results from this preliminary analysis indicate that this technique provides reasonable values of mare thicknesses. Dionysius, for example, lies on the southwestern boundary of Mare Tranquillitatis. From the iron map, it appears to be almost perfectly bisected by the mare/highland boundary. The low iron signature of highland material on the left half on the interior of the crater contrasts the high iron signature of the right. The large ejecta blanket of Dionysius also follows the same pattern. The value for the mare thickness at Dionysius is quite thin (~400), which is what one would expect near the edges of maria. All of the thickness estimation techniques mentioned previously yield lesser thicknesses near the edge of basins. Conversely, thicknesses increase as one moves towards the center of the mare. This observation is supported in our data as evidenced by the much greater basalt thicknesses in the targets of craters Euler and Timocharis, which are located closer to the center of Mare Imbrium. The iron map of Picard indicates a paucity of highland material in the ejecta blanket, suggesting that this crater did not excavate to a depth greater than the basaltic thickness. Andre et al. [8] also concluded that the basaltic thickness at Picard exceeds the apparent crater depth.

These results are encouraging, and this method needs to be applied to a larger population of craters (N>100) to map how the thickness varies laterally. This additional suite of data points should allow the overall precision of current basalt isopach maps to be greatly increased. A larger sample of craters might also lead to a better understanding of the effects of such complicating factors such as slumping in the crater, discontinuous ejecta blankets, and inhomogeneous ejecta mixing process.

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