PAST AND PRESENT USE OF THE OPTICAL MATURITY PARAMETER (OMAT) ON THE MOON – THE RELATIVE AGE OF CRATERS AND CRATERED SURFACES

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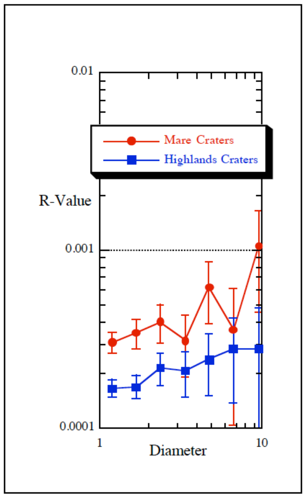
Maturity and OMAT: Impact cratering is the dominant weathering process on the Moon. Larger impacts deform and redistribute material across the lunar surface while smaller and micro-meteorite impacts act to weather the lunar material; the physical evolution of the lunar surface with exposure to the space environment is termed “maturation”. Maturation of lunar soils has strong effects on their optical properties [1]. Young, fresh material has high albedo and easily identifiable absorption bands in spectra. Mature material, on the other hand, tends to be lower in albedo, has smaller particle sizes and exhibits redder spectra without strong absorption bands [1, 2, 3, 4]. Using ratios of Clementine color data [1] developed an optical maturity parameter (OMAT) for lunar materials. Since its development, OMAT has been used as a metric for the overall maturation of particular surface types, and for their relative ages on the Moon and elsewhere, i.e. [5, 6]).

Crater Ejecta: One of the lunar surface types that can be investigated with the OMAT parameter are areas blanketed with crater ejecta, or that have been disturbed by ejecta emplacement. [7] Used radial profiles sensitive to optical changes in reflectance spectra of soils and ejecta with age, classifying craters through the optical maturity parameter of [1]. OMAT values for crater ejecta systematically with distance from the crater rim [7]. The youngest and freshest craters tend to have high OMAT values at the crater rim, which will then decrease over distances from the rim. More mature craters have lower OMAT values at the rim, and old and very mature craters have OMAT values that are nearly indistinguishable from the lunar background values.

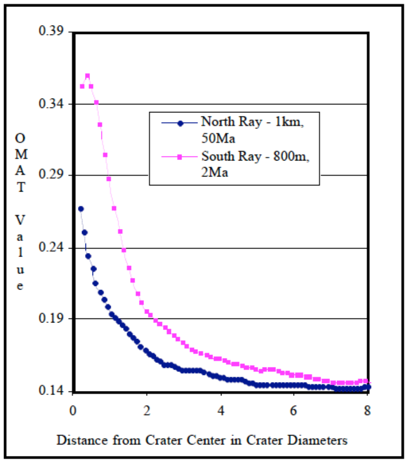
Small Craters: Issues with counting populations of small craters have been well documented [i.e. 8]. The statistics of these populations have been called into question due to difficulties in determining which impact craters (among those =/< 1km) are primary impacts, and which may be well-formed secondaries. Use of the OMAT parameter has been used on small craters to examine relative age, and to begin to unravel issues related to this key population. Work by [9] surveyed the interior OMAT values of 327 small craters, along with profiles for specific small craters of note. They found (a) a bias between the populations in the mare and highlands, (b) potential use of absolute ages for some small craters to be used as ‘calibrations’ for comparing others of the same size range on similar terrain.

Mare and Highlands. The figure below from [9] shows the size-frequency distribution (R-plot) for the mare and highlands craters surveyed. While the curves are similar the densities are notably different. The highlands distribution is significantly less dense than the mare distribution. Several mechanisms were postulated for this difference, including downslope movement in the highlands or potentially a thinner regolith in the mare.



It is possible that regional mineralogy differences can affect the absolute values of the OMAT index [10, 11, 12]. For example, [12] showed that the composition of mare soils, particularly the abundance of pyroxene and the opaque phases (ilmenite and iron spinel) could affect the absolute value of the OMAT index. This was confirmed by [13], and the authors provided a procedure to deal with this complication for mare basalts. This procedure may help to mitigate this bias, but has not been applied to these data.

Absolute Ages for Small Craters. The figure below from [9] shows radially averaged OMAT profiles for North and South Ray craters. Note that the optical maturity values for the younger South Ray crater (2 Ma) are much higher than for the larger and older North ray crater (50 Ma) (inferred ages from [14, 15]. The profile for South Ray drops off more steeply, and maintains higher OMAT values out to the more distal ejecta, as well. The shapes of the profiles are therefore consistent with the ages inferred for the craters. South and North Ray craters may therefore provide age benchmarks to assist in calibrating the relative ages of the small craters, similar to what was done for the large craters.

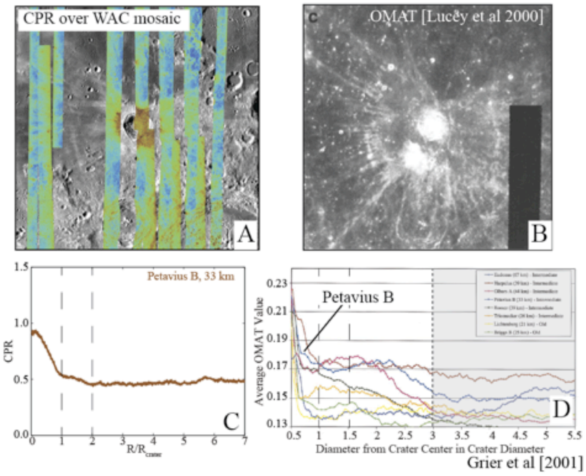


Comparing Data Sets: The exact mechanisms for change with time for the OMAT values of crater ejecta are not completely understood. Several factors, such as those already noted (downslope movement, boulders within ejecta, differences in weathering based on background terrain) may compete. Comparing data sets is a key approach to unraveling the processes that determine how crater rays and ejecta change over time, and how this in turn relates to the optical properties [16]

We can compare the CPR behavior for the Copernican crater Petavius B with published results for OMAT [1, 7] (Figure below.) Note that areas of high CPR (red in HHA) correlate with higher OMAT values. The CPR profile also returns to the linear background level around 1 crater radius outward from the rim, which is consistent with the distance for the leveling off of the OMAT parameter as well. Based on the OMAT value, Petavius B is classified as an "Intermediate" crater [1, 7], and falls into the "Type 1" category based on the m-χ profiles of its ejecta blanket.

Though OMAT has been considered as a sort of "standard" in lunar relative age dating, each of the data sets described above provide unique and important information about the maturity of lunar materials. Integrating the results from the variety of data sets and wavelengths available in recent lunar data is an important task. We will present preliminary results where we first determine relative ages with each data set., then following this, we will compare across the data sets described above (Mini-RF, Diviner CF, WAC UV, M^3). Ultimately, we will compare the calculated ages with those determined from the analysis of Clementine OMAT data.

From [7] and others, we know that steep slopes and sharp peaks allow for soil to be continually refreshed. Boulders and other radar rough features may then correspond to areas of optical immaturity, but the scale at which this becomes an important factor is not understood. This may be an important factor in the size bias of how crater ejecta ages with time. [7] noted how larger craters have ejecta that appears immature longer than that of smaller craters. Comparison of the data sets is therefore a logical approach for further investigation.



Grier et al [2001]

Conclusion: The OMAT parameter remains a powerful method of investigating the relative age of craters and cratered surfaces. Further development and refinement of the method, as well as research in small crater populations and multiple data sets will allow for more insight into crater ages, and how craters and cratered surfaces change over time.

References: [1] Lucey et al. (2000) *JGR 105*, 20,377-20,386. [2] Fischer and Pieters (1994) *Icarus 111*, 2, 475-488. [3] Fischer and Pieters (1996) *JGR 101*, E1, 2225-2234. [4] Noble et al. (2007) *Icarus* 192, 2, 629-642. [5] Blewett et al. (2014) LPS XXXXV, Abst. #1777, 1131. [6] Braden and Robsinson (2013) JGR Planets 118, 9, 1903-1914 [7] Grier et al. (2001) *JGR 106* (E12), 32847-32862. [8] Strom (2015) *Research in Astronomy and Astrophysics 15*, 3, id. 407. [9] Grier et al. (2000) *LPS XXXI*, Abst. #1950. [10] Clark and McFadden 2000, [11] Elphic et al. 2000, [12]Staid and Pieters 2000 [13] Wilcox et al. [2005], [14] Eugster, O. (1999) *MAPS*, 34. [15] Arvidson et al. (1975) The Moon, 259. [16] Neish et al. (2013) JGR Planets 118, 10, 2247-2261.