RESURFACING, CRATER DEGRADATION, AND CRATER STATISTICS. C. I. Fassett[1] and B. J. Thomson[2], [1]Dept. of Astronomy, Mount Holyoke College, South Hadley, MA (cfassett@mtholyoke.edu), [2]Center for Remote Sensing, Boston University, Boston MA (bjt@bu.edu).

Introduction: When properly applied, crater statistics are a valuable analytical tool for assessing and determining the chronology of planetary surfaces and geologic units. If the impact flux is independently constrained or modeled, as most prominently exemplified by Apollo samples [e.g., 1, 2], then crater size-frequency distribution (CSFD) can also be used to estimate the absolute age of units.

Recently, we have been examining how to use independent measurements of crater characteristics to derive additional age constraints that complement crater statistics. In particular, new data from Kaguya Terrain Camera and LOLA allowed us to complete a detailed survey of how the topography of ~km-scale craters on the Moon evolve with time [3].

The Evolution of Crater Characteristics and Crater Age: Both theory [4] and our observations [3] are consistent with the idea that crater topography undergoes a diffusion-like evolutionary process (much like hillslopes on Earth). Older craters have less distinct rims, less relief, and lower depth-diameter ratios. The likely process controlling this diffusion is micrometeorite bombardment [4], although whether micrometeorite impact is the sole or even dominant process of importance remains an open question. Other processes such as thermal expansion and contraction [5] or seismic shaking [6] may also contribute to the observed terrain's diffusive behavior. For a given crater's topography, we can determine its best fit degradation state, which is a function of the diffusivity calibrated for the Moon as a whole as a function of time, and the crater's age.

Besides topography, the roughness or rockiness of craters' ejecta using thermal inertia [e.g., 7] or radar [e.g., 8] has been demonstrated to provide information about how individual craters evolve with time. These measured crater characteristics can then be used to infer information about the age and evolution of a surface, independent from, or in addition to, crater statistical approaches.

However, the methodology for linking crater degradation characteristics to age requires a set of assumptions that link crater degradation state to age that we wish to discuss and explore at the workshop. In particular, we typically assume that: (1) craters start with the same initial topographic form (this is equivalent to saying that at least the vast majority of craters in the size range we consider are primaries); (2) craters fall in a monotonic sequence of age, from least degraded (youngest) to most degraded (oldest); and (3) the crater in the median degradation state has an age equivalent to 50% of the frequency of the terrain on which it sits (for a sufficiently large number of craters; we use n=100).

Crater Retention, Resurfacing and Resurfacing Corrections: It has long been understood that the observed number of craters in a given range is a function of both crater production, and, potentially, of how many craters have been removed due to erosion or burial in that size range. The age determined from crater statistics can thus be either a formation age for the surface (where removal is unimportant) or a retention age (where removal or erasure is important).

CraterStats [9] is a widely applied, easy-to-use, and highly valuable IDL software tool for analyzing crater statistics measurements to interpret age. Because it rigorously fits isochrons to CSFDs and incorporates a wide variety of up-to-date chronology and production functions for different planetary bodies, it allows the user to avoid a variety of common errors when doing crater analysis. *CraterStats also* includes functionality that allows for computation of resurfacing ages (see also [10] for extensive applications to Mars). This resurfacing correction is based on considering discrete events that destroy craters below some size; for example, where a lava flow has buried and erased all preexisting craters smaller than ~500 m but craters larger than 5 km on the same terrain remain unmodified. This creates an obvious kink in a cumulative CSFD. By fitting the data, the resurfacing tool in *CraterStats* allows correct simultaneous determination of both the model age for forming the local surface, and the model age of the resurfacing unit.

However, planetary surfaces are seldom so simple. Discrete resurfacing events that dramatically affect a narrow portion of the CSFD are probably the exception rather than the rule, and a wide variety of different types of erosion and gradation mechanisms can alter the observed CSFD [e.g., 11-13]. Numerous studies have shown that many or most terrains on Mars are depleted of small craters D<~500-1 km relative to what would expect from the population of craters D~2-4 km or larger on the same unit. The effect is clearly apparent in the data in [10]; see also observations by [14] where all Noachian units are found to converge in crater frequency at craters smaller than 2-4 km even if they differ dramatically at larger sizes.

The geologic mechanism for this resurfacing is often not apparent, and assuming that it happened in discrete episodes based on the CSFD alone is problematic. The essential issue is that it is always possible mathematically to calculate a resurfacing age on a portion of the CSFD, but such an age does not necessarily have any physical meaning. The same is true with retention ages – these do not necessarily have any inherent chronological implications, but reflect a convolution of formation age with the intensity of resurfacing. When examining small areas or areas with poor counting statistics, it is easy to be fooled into thinking that the observed CSFD can be interpreted in terms of the age of geologic unit (a formation age), or the age of specific resurfacing event (a resurfacing age), when in fact the observed population is dominated by how well the surface can retain craters against long-term continuous resurfacing mechanisms.

An example of such a continuous resurfacing mechanism at work is the diffusive crater degradation process (probably from smaller impacts) described above. Calculations suggest that diffusive evolution is sufficiently fast to completely erase the oldest craters smaller than ~100 m on surfaces with the average age of the lunar maria (~3 Gyr) [3]. The characteristic timescale for topographic diffusion goes as D^2, so at small scales, it becomes efficient as an erasure mechanism. In fact, we hypothesize that this effect largely controls the “equilibrium frequency” of craters at small sizes on the Moon [e.g., 15-16]. In equilibrium, the age equivalent to the observed frequency is a convolution of crater production and the intensity of crater removal and has no other independent meaning.

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