DEVELOPMENT OF GUIDELINES FOR RECOMMENDED LUNAR CSFD COUNT AREA SIZES VIA ANALYSIS OF RANDOM CSFDS. C. H. van der Bogert[1], G. Michael[2], T. Kneissl[2], H. Hiesinger[1], and J. H. Pasckert[1], [1]Institut für Planetologie, Westfälische Wilhelms-Universität, Wilhelm-Klemm-Str. 10, 48149 Münster, Germany (vanderbogert@uni-muenster.de), [2]Freie Universität Berlin, Malteserstr. 74-100, 12249 Berlin, Germany.

Introduction and Background: The accuracy and precision of absolute model ages (AMAs) derived from crater size-frequency distributions (CSFDs) are important for our ability to interpret the geological evolution of planetary surfaces. Factors that affect the quality of model ages include the careful selection of appropriate counting areas, consistent and accurate measurement of crater diameters, as well as the statistical significance of the dataset [1-3].

As higher resolution imagery becomes available, such as LROC NAC imagery of the Moon [4], smaller regions can be investigated. However, these areas contain fewer craters for CSFD analysis. For example, a study of irregular mare patches (IMPs) [5] was only able to measure craters large enough for derivation of AMAs at three locations, using the current lunar chronology and production functions (valid for craters 10m<D<100km [6]). In addition, a few farside basalt units also have small areas (down to ~4 km^2) [7]. The questions are whether the AMAs derived for such small areas provide robust results, and what minimum count area sizes are required for reliable ages on differently aged surfaces?

To investigate the effects of small count areas on AMAs for farside basalts, Pasckert et al. [7] checked the ability of 4 km^2 count areas to reproduce the age of a 100 km^2 count area on a mare basalt in Tsiolkovsky crater. The 100 km² area is 3.19+0.08-0.12 Ga, while the ages of the 25 4 km² areas show AMAs between 2.22+0.55-0.57 and 3.69+0.10-0.44 Ga, with an average of 3.2 Ga and standard deviation of 0.33 Ga [7]. While 19 of the ages are within the error bars, six of the ages fall outside of the error: four higher and two lower. However, it is unknown whether the variability can be ascribed to statistical effects or if the younger ages could reflect subsequent resurfacing events [7].

To eliminate the possible influence of subsequent resurfacing on the lunar surface, we generated random CSFDs for theoretical lunar surfaces with ages of 0.1-4 Ga, and analyzed the effects of decreasing count area size on the precision and accuracy of the resulting AMAs [8]. We found that the precision of the model age (error bars) decreases with decreasing count area size, primarily because each CSFD contains fewer craters. Moreover, we observed that the accuracy also decreases for smaller count areas. The percent errors for younger surfaces are significantly greater than for older surfaces. Young (100 Ma) surfaces may have 50-100 percent errors, while old (4 Ga) surfaces have percent errors typically <5% [8]. The variablility in accuracy means that it may be possible to select a count area that does not give a representative age, even when

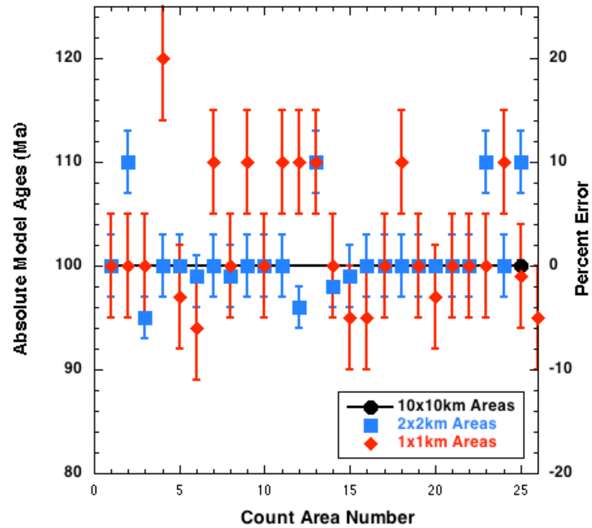
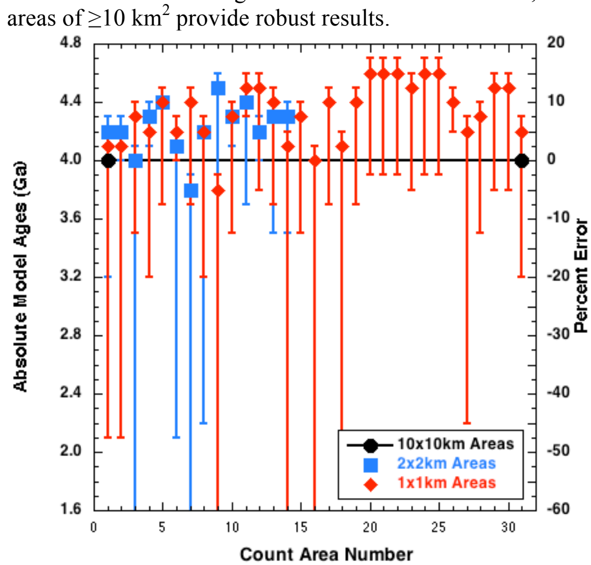


Figure 1. Absolute model ages (AMAs) for differently sized areas on a theoretical lunar surface, derived from a random CSFD based on the chronology and production functions of [6], for a surface age of 100 Ma with D_{min}=10 m.

Figure 2. AMAs derived for a theoretical lunar surface of 4 Ga for D_{min}=1 km, as limited by the effect of saturation equilibrium. D_{eq} limits the number of craters available for age fitting to such an extent that count area sizes of ≤4 km^2 are not useful for dating 4 Ga old surfaces. However, count areas of ≥10 km^2 provide robust results.



the distribution of craters is random. This effect cannot be mitigated by the usual approaches for selecting ideal count areas, except to increase the size of the area, which may be impossible for small features [8].

Our initial models did not, however, consider the effects of saturation equilibrium on the populations of craters available for AMA fits. The so-called equilibrium diameter (D_{eq}), for which craters with $D \leq D_{eq}$ are in equilibrium rather than production, increases with increasing surface age [9]. For craters to be useful for AMA dating, they must be in production, rather than equilibrium [e.g., 1,6]. Thus, D_{eq} serves as a minimum diameter (D_{min}) for valid derivation of AMAs – e.g., 4 Ga old surfaces require craters >~1 km for derivation of AMAs, whereas 100 Ma old surfaces require craters >~10 m. These D_{min} have consequences for the minimum useful count area size. Here, we analyze the effects of nominal saturation equilibrium on AMAs derived for theoretical lunar surfaces of 0.1-4 Ga in age, as well as the effects of decreasing count area size on their precision and accuracy.

Methods: CSFDs were generated for theoretical lunar surfaces with differing ages based on the production and chronology functions (PF, CF) of [6] using a Monte Carlo method. For each aged surface, we used the corresponding D_{eq} as the D_{min} for which Poisson event intervals were generated from the CF until the required cumulative time was achieved. Crater diameters were drawn from the PF, with the craters being emplaced homogeneously and randomly within the areas. These were converted into shapefiles for analysis with ArcGIS, where count areas of differing sizes were defined and resulting CSFDs (using fractional craters) exported using CraterTools [10]. The CSFDs were plotted and fit with CraterStats [2], using the techniques described in [1, 2]. The derived AMAs are based on the CF and PF of [6], valid for lunar craters with 10m<D<100km.

Results: *0.1 Ga Surface.* D_{eq} for a 100 Ma surface occurs at <10 m. However, because the CF/PF of [6] is only valid for craters larger than 10 m, we used this as D_{min}. For a 100 km^2 area, we derived an age of 100±0.5 Ma (*Fig. 1*, black circles/line). For 25 4 km^2 areas, the ages range from 95±2 to 110±3 Ma with an average of 101 Ma and a standard deviation of 4 Ma (*Fig. 1*, blue squares). Only 6 of the 25 areas give ages that do not exhibit the expected 100 Ma age even within their error bars. We derived ages for 100 1 km^2 areas, and plotted 25 representative values in *Fig. 1* (red diamonds). The ages range from 86±5 to 120±6 Ma, with an average of 102 Ma and standard deviation of 6.7 Ma. Nine of the 25 representative 1 km^2 areas do not exhibit ages within error of the expected 100 Ma.

4.0 Ga Surface. D_{eq} for a 4.0 Ga lunar surface occurs at ~1 km, which we used as D_{min}. For a 100 km^2 area, we derived an age of 4.0±0.01 Ga (*Fig. 2*, black circles/line). For 25 4 km^2 areas, we were only able to derive ages for 14 areas, because some areas did not contain any craters. The ages range from 3.8+0.1-4.0 to 4.5+0.1-0.7 Ga with an average of 4.23 Ga and a standard deviation of 0.18 Ga (*Fig. 2*, blue squares). We were only able to derive ages for 31 1 km^2 areas due to the paucity of craters (*Fig. 2*, red diamonds). The ages range from 3.8 to 4.6 Ga, with an average of 4.33 Ga and a standard deviation of 0.20 Ga. Most of the fittable areas contained only fractions of craters, thus giving very poor precision.

Discussion: Our preliminary results show that count areas as small as 1 km^2 on young lunar surfaces (ca. 100 Ma), such as IMPs, can give results with percent errors of up to ~10%. Thus, the ages derived for IMPs are even more robust than we reported in [8], barring effects of target properties [e.g., 11].

For old surfaces (ca. 4 Ga), count areas of 10 km^2 give excellent precision and accuracy, such that typical area sizes for basalt units measured by [12 and references therein] give reliable ages. However, count areas on 4 Ga old surfaces with sizes of ≤4 km^2 have percent errors of up to 20% and even larger error bars (*Fig. 2*).

The results of the current study show that the ability to date small, very young areas using CSFDs is not greatly affected by D_{min}, as constrained by saturation equilibrium. However, equilibrium places significant minimum count area size limits on old features. For 4 Ga old features, the minimum best count area size lies between 4 and 100 km^2.

Ongoing Work: We are investigating count area sizes between 4 and 100 km^2 to more specifically define size limits for 4 Ga surfaces. We will also define size limits for other aged surfaces, and extend the analysis for young surfaces to smaller areas and younger ages. Finally, we will present an evaluation of the potential improvement of the statistics for small areas using buffered crater counting [13].

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