

SUB-KILOMETER LUNAR CRATERS: ORIGINS, AGES, PROCESSES OF DEGRADATION, AND IMPLICATIONS FOR MARE BASALT PETROGENESIS. Clark R. Chapman¹, Jayne C. Aubele^{1,2}, Wm. James Roberts³, and James A. Cutts³; (¹Planetary Science Institute, 2030 E. Speedway, Tucson, AZ 85719; ²Dept. Planetary Science, Univ. of Arizona, Tucson AZ 85721; ³Planetary Science Institute, 283 S. Lake Ave., Pasadena, CA 91101)

The size distributions of sub-kilometer lunar craters generally have been interpreted during the past decade to be the product of impact cratering and gardening in the regolith. One important application of this interpretation has been the assignment of relative ages to lunar mare units using a crater morphological parameter called D_L (1). Correlations of such D_L ages with mare basalt compositions inferred from spectrophotometry have been used as constraints for petrogenetic and thermal models for the evolution of mare basalt source regions with time. Such interpretations based on D_L ages would be wrong, however, if many sub-km lunar craters were of endogenic rather than impact origin, as has been proposed by a minority of workers (2-7).

Motivated by this important problem in basaltic volcanism, we embarked on a new project to study small crater populations in several carefully selected lunar mare regions, representative of both red and blue basalt types with both "young" and "old" D_L ages. The methodology employed is the same as applied to a variety of other lunar regions by Chapman *et al* (4). Craters of diameter 20m to 2km were counted and classified into 4 morphological classes. In order to correct for systematic classification and measurement biases between the present study and earlier ones (4 and 7), regions common to those earlier studies were also measured again.

The new crater size distributions show many of the same anomalous features previously reported that have seemed incompatible with a simple model of impact cratering and equilibrium degradation and obliteration by the cratering process. In particular our "young blue" units show an excess of ~100m diameter (largely degraded) craters compared with both the "old red" and "old blue" provinces studied; the excesses approach factors of 2 to 5 respectively and violate our intuitive expectation that younger units should always have the same number or fewer craters than older units. Most of the regions we have measured share most of the characteristics previously ascribed to the "Imbrium" or "Alphonsus" population types described by Chapman *et al* (4) (called Types I and III by Schultz *et al* 7).

Preliminary examination of our size-frequency plots show few cases where even small segments of the distributions approach the -2 cumulative distribution slope characteristic of classical equilibrium. There are numerous bumps and dips in the distributions that do not always seem to be compatible with the two-layer differential erosion process described by Schultz *et al* (7). But an elaboration of that model permits us to explain most of the major features of these distributions without requiring an ad hoc endogenic component to the population. Schultz *et al* pointed out that differential erosion and degradation of larger craters formed in bedrock and smaller craters formed wholly in regolith would yield offset equilibrium populations approximately as observed. We point out that, in addition, differences in energy/diameter scaling relations in the regolith and bedrock substantially modify the production function (see Fig. 9 left in Ref. 4), which is manifested in the equilibrium population of craters

SUB-KILOMETER LUNAR CRATERS

Chapman, C. R. et al

in a manner not envisioned by Schultz et al. Together, the two scaling effects produce a complicated pattern of frequency relations for craters of different morphological classes (and for all classes together) similar to those observed. In particular, our two-layer impact model yields the steep distribution slope observed for some populations at sizes ~300m, ascribed by Schultz et al. to a superposed population of non-impact craters.

Included in our interpretation are expectations that craters with dimensions comparable to the regolith depth may be formed with initially "degraded" morphology. Furthermore, we expect the equilibrium percentages of craters in the several classes (and the percentage of geometric saturation for total craters) to vary with size due to different degradation processes that operate at different scales. Preliminary examination suggests our data are compatible with these expectations.

While we believe our results diminish the requirements for a substantial endogenic crater population, there remain some puzzling features of our data and other previously published distributions. In addition, we believe that it remains difficult to understand the preservation of the small primary flow features (ring moats, etc.) described by Schultz et al (6) if crater degradation is proceeding at the rates implied by our present model. And there is clear evidence that endogenic craters do, in fact, exist in at least some lunar localities (e.g. those craters arranged in chains).

But on balance we believe that the case for predominant impact cratering as the origin of the small lunar crater populations is strengthened by these considerations. In view of these results, we believe it likely that a crater morphological parameter such as D_L may reflect relative ages of lunar provinces and thus ultimately be useful for establishing the chronology of basalt emplacement. On the otherhand, it remains to be evaluated to what degree modifications of the application of the D_L criterion will be required to take account of the more complicated, target-dependent cratering and erosive processes implied by our interpretation and the associated work of Schultz, Greeley, and Gault.

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