
The importance of the preservation of ring-moat structures on the lunar mare as related to existing crater degradation models [in particular, that of Soderblom (1)] has been discussed by Schultz et al. (2). Schultz et al. (2) indicate that, if ring-moats are formed at the same time as the surface then, according to the Soderblom model the moats should be eroded beyond recognition. They suggest that this is evidence that the model fails to predict the observed degree of erosion of the moats. Schultz et al. (2) point out that in areas that contain small ring-moats (< 50 m), larger craters (~ 200 m diameter) occur that have slopes of only a few degrees. They suggest that these craters must be original endogenic features because if they were degraded impact craters their presence would be inconsistent with the degradation state of the ring-moats. Additionally, Trask (3) and Schultz et al. (2) have interpreted ring-moats as remnants of flow topography that lapped up on volcanic vents associated with mare emplacement. Schultz et al. (2) have suggested that the terrestrial analog of these features are volcanic ring-moat structures described by Greeley and King (4).

However, the weight of the evidence suggests to us that ring-moats are predominantly the surface expression of impact craters buried by lava flows and that these features are probably formed by subsequent collapse and compaction at a later time. Hence, the preservation of ring-moat may be irrelevant as a test of the Soderblom erosion model (1).

The evidence for ring-moats being buried impact craters is that they exhibit (A) a size-frequency distribution that has the same form as that of impact craters (N = KD^N) (Figure 1); (B) a random map pattern (non-alignment with structure common to primary volcanic forms); (C) consistently circular outlines; and (D) decreasing numbers of larger diameter ring-moats with decreasing age of surface (suggesting they require substantial time to form). Additionally, in mare regions where these features occur, ring-depressions are absent where the lavas lap up against pre-flow highland terrain and older large craters. If the ring-depression structures were indeed caused by lap up of volcanic flows (2) then they would be expected around all pre-flow features.

New data from Mare Tranquillitatis and data from Schultz et al. (2) indicate that, if ring-moats are as old as the mare then, the preservation of the smallest of these features are also inconsistent with the cratering record and that they should be unobservable as complete structures. That is, these structures have widths equal to or less than the 100% saturation diameter (5). In the Flamsteed area, which has a crater saturation diameter of 10 m, moat widths are as small as 10 m. The southeast Mare Tranquillitatis region has a crater saturation diameter of 19 m, but moat widths are as small as 10 m to 15 m.

Additionally, if ring-moats are as old as the mare surface then, the smaller ones should be proportionally more degraded than the larger ones. This is not the case. Figure 3 of Schultz et al. (2) shows this clearly; two ring-moats shown of different size but with nearly the same slopes and
morphologic freshness. One ring-moat is 100 m across (moat width ~ 40 m) and the other is 300 m across (moat width ~ 120 m). This is clearly inconsistent with the fundamental premise that small features degrade faster than large ones.

There is a population of craters of about 200 m diameter with slopes < 2° that are found in the Letronne area (2), an area that also contains ring-moats. The presence of these craters is predicted by the Soderblom model. Additionally, the presence of these craters is consistent with the observations of Soderblom (6) who used Apollo terminator photography to show that even young mare is saturated with 50 m to 100 m diameter craters with slopes ~ 1°. These observations coupled with suggestions of Schultz et al. (2) that the highly subdued 200 m craters in Letronne must be volcanic leads to the unreasonable conclusion that the mare must be saturated with craters of 50 m to 100 m.

Therefore, we conclude that ring-moats are impact craters that have been buried by lava flows. They are erosional anomalies whose preservation is inconsistent with the cratering record, crater degradation models, and established principles of erosion of topography; which indicate small features eroded more rapidly than large ones. This anomaly could be reconciled if these features developed at a much later time than the original surface. A possible model for the origin of these features could be by burial by thin lava flows of fresh impact craters with extremely blocky and, hence, cavernous rim deposits. The ring-depression would subsequently form by collapse of the cavities in the rim deposits due to weight of the overlying lava and impact-related compaction. If the collapse has a time constant larger than the age of the surface, some of these features would be very young. Central depressions can be caused by compression and collapse of the flooded craters central breccia zone by the bulk of overlying lava. This model is supported by the many rings that contain rimless depressions with diameters about that of the ring-depression width, some of which form chains along the ring. Hence, this model provides for development of the ring structures at a later time than the mare surface. Evidence that other features are continuing to collapse can be seen in the only partial development of some sinuous rilles (collapse lava tubes).

Alternatively, Soderblom (7) suggests that ring-moats may be the result of "barriers to erosion" which could be caused by the emplacement of volcanic necks (at the same time as the latest flows) which are composed of rock that is significantly more competent than the surrounding flows (possibly caused by layering in the flows). He suggests that the erosion model (1) might predict that in this situation the net result of erosion and transport would be the formation of a depression around the neck. However, items (A), (B), (C), and (D) listed above do not support his model.

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References

Figure 1. Size-frequency distribution of ring-moats in Flamsteed (constructed from the data of Schultz et al., 1976).