DIFFERENTIAL SCALING: IMPLICATIONS FOR CENTRAL STRUCTURES IN LARGE LUNAR CRATERS. M.J. Cintala* and R.A.F. Grieve*. *Code SN4, NASA Johnson Space Center, Houston, TX 77058; *Geophysics Div., Geological Survey of Canada, Ottawa, Ontario K1A 0Y3

The change in morphology of central structures with crater size on the terrestrial planets has been studied by many investigators.1-4 While the progression of morphological change essentially follows the same basic pattern, the appearance of central peaks, and the transitions from single to multiple peaks and peaks to peak rings occur at crater diameters that appear to be dependent on parameters associated with the target planet.5-7 Statistical data, morphological information, and model results exist for central structures in large craters, but the amount of "ground truth" is comparatively meager. What, for instance, is the amount of stratigraphic uplift in craters? Answers to questions such as this will provide useful constraints on models of origin for central structures, and would help in interpretation of remote-sensing data. This contribution uses terrestrial information and model calculations to estimate the amount of stratigraphic uplift for central-peak craters on the Moon — the only planet other than Earth for which sufficient topographic data are available.

Sources of Information: Morphometric data for the terrestrial craters used below were obtained from a literature search. Morphometric information for the lunar craters was taken from 8 and supplemented with our own measurements from the Lunar Topographic Orthophotomap and Lunar Topophotomap series. Depths of impact melting on the Moon were calculated with a model of impact heating described elsewhere.9 Chondritic projectiles impacting anorthosite normal to the planetary surface at a nominal velocity of 15 km s\(^{-1}\) were used in all cases. Transient-cavity dimensions were calculated with relationships given by Schmidt and Housen,10 and extrapolation to final crater diameters was made using the "modification-scaling" relationship of Croft.11

Approach and Results: The amount of stratigraphic uplift for terrestrial craters has been addressed previously13,14 and, on the straightforward basis of geometry, was equated to the depth of excavation during the formation of the crater.14 At impact velocities characteristic of planetary encounters, however, considerable volumes of target material are melted by the shock.15,16 This forms the basis of the hypothesis for the remainder of this contribution; that is, the minimum depth of origin of central-peak material for any crater formed by impact normal to the surface is equal to the maximum depth of impact melting (Fig. 1). In principle, the actual depth of origin can be somewhat deeper, if the ejection process removes additional material in the center of the crater, below the zone of melting.14 Figure 2 presents this minimum depth of origin of the central peak for impacts at 7.5, 15, and 30 km s\(^{-1}\). Note the very weak dependence on impact velocity, and the break in slope corresponding to the assigned diameter of transition from simple to complex morphology (18.7 km).17 Additional data not shown here indicate that the dependence on projectile type is as weak as that on impact velocity. Assuming that the calculated depth of melting is reasonable, and having available topographic data to provide the depth from the preexisting target surface to the top of the central peak, the stratigraphic uplift for a set of lunar craters can then be estimated (see Fig. 1). (Because highland topography complicates estimation of the preexisting target surface, only topographic data for craters located in mare terrain are used here.) The results of this derivation are plotted in Figure 3, which also

![Figure 1. Schematic illustration of the relationship between the stratigraphic uplift, maximum depth of melting, and depth to the top of the central peak. The region labeled "Excavated" was estimated from a Z-model calculation (z=2.71);12 material below that region is displaced, but not ejected, during formation of the transient cavity. The three dashed and dotted lines below the original target surface represent idealized strata before and after uplift.](image-url)
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includes the available data for terrestrial craters. Most of the terrestrial data points represent craters in sedimentary or mixed sedimentary and crystalline targets; this must be noted, since there is evidence that the cratering process in such targets will differ somewhat from that in crystalline rock,\(^{18}\) as is essentially the case for the lunar craters. Even given this, the lunar and terrestrial estimates are in very good agreement, particularly since much of the scatter in the terrestrial data is undoubtedly due to erosion.

**Discussion:** Assuming that excavation in large craters is similar to that described by the Z-model,\(^{12}\) the most deeply excavated material is derived from a relative position somewhere between the central peak and the cavity wall (Fig. 1). Nevertheless, it is apparent from Fig. 2 that even the minimum depth of origin of central peaks can be substantial. The top of the central peak for a crater the size of Copemicus, for example, would come from a minimum depth of 10 km, irrespective of impact velocity or impactor type. This value supports the interpretations of Pieters,\(^{19}\) but also suggests caution, due to the pervasive presence of impact melt. Finally, the values of stratigraphic uplift presented here for the Moon were derived from the same principles used in other applications of differential scaling,\(^{20-22}\) The degree of agreement between the lunar and terrestrial estimates of stratigraphic uplift lend additional support to the potential validity of this approach.

**References:**