NEW CONSTRAINTS ON MULTI-RING BASIN FORMATION. P. H. Schultz[1], D. A. Crawford[2], and K. L. Donaldson[1], [1]Brown University, Providence, RI, USA. [2]Sandia National Laboratories, Albuquerque, NM, USA.

Introduction: A new survey of the composition of central uplifts within craters and basins on the Moon reveals that most did not expose mantle material [1, 2]. This result places a new constraint on the formation and interior ring formation of large impact basins.

Background: Near-infrared studies using the Moon Mineralogy Mapper (M^3) on Chandrayaan-1 [1,2,3] reveal that relatively un-shocked, pure (≥ 99% plagioclase) anorthosite characterizes many central peaks and uplifted massif rings within basins. Even the inner rings of large basins such as Orientale, Crisium, Humorum, Hertzsprung, and Nectaris exhibit pure anorthosite, not exposed deep mantle materials, particularly where the crustal thickness ranges from 30 to 63km (from the GRAIL crustal thickness model [4]). Exposures of pure anorthosite mixed with mafic lithologies, however, generally occur where the crust is estimated to be between 22 and 32km, thereby leading to the conclusion that the pure anorthositic portion of the primary crustal thickness (likely derived from the early magma ocean) must have been at least 30km thick. Consequently, the inner rings of large basins are not derived from great depths. In models depicting a collapsed, deep transient crater, the uplifted interior rings of the large basins (>300km) on the Moon should come from below the anorthositic crust (into the mantle). This observation places new constraints on basin-formation models.

Discussion: Traditional views of crater and basin excavation depict a deep transient crater resembling a simple crater before undergoing collapse (and oscillations), thereby leading to a central peak or interior rings [e.g., 5]. This view has several implications. First, there should be a progression in compositions of the uplifted interior. Central peaks from smaller craters should sample the anorthositic crust, whereas the inner rings of large basins should expose deep mantle materials. Moreover, the final crater should not retain any expression of the initial conditions of coupling between the projectile and target. For convenience, the former model is termed here the "*oscillation model*" (*OM*).

A second view argues that the central structures within craters and basins retain signatures of the initial stage of cratering, best expressed by oblique impacts [6,7,8]. In this model, the interior ring of a large multi-ring basin marks the transition between the initial downward displacement and an annulus of lateral excavation. Consequently, the interior ring correlates with early-stage initial conditions (momentum controlled), whereas the transient excavation diameter relates to excavation of surrounding shocked and comminuted crust (energy controlled) limited in growth by gravity [7]. As a result, the interior ring should not sample the deep mantle; rather it should expose shallower depths, i.e., the anorthositic crust. This second model is termed here the "*lateral excavation model*" (*LEM*).

These two views have very different predictions for exposure depths and retention of initial conditions. For a collapsing transient crater (*OM*), the central peak or peak ring should contain materials derived from about 1/2 the transient crater depth. As a result, larger basins should expose greater depths and traces of initial conditions should be erased. For example, the central uplift of a 200km rim-rim diameter basin (~130 km transient diameter) could have exposed depths of greater than 60km. But the inner rings of large multi-ring basins (such as Orientale, Crisium, Nectaris) should have exposed mantle materials from greater depths (>100km). For the lateral excavation model, the central uplift delineates the edge of downward displacement from much shallower depths (~1/4 the transient crater diameter, i.e., the anorthositic crust).

In the *LEM*, the central uplift preserves evidence for first-contact conditions, including the impactor trajectory and size. As scale increases (or impact angle decreases), initial conditions comprise a greater fraction of crater growth, thereby becoming more obvious in expression, e.g., the elliptical or downrange-breached interior ring along with an uprange offset of the interior mascon within basins (e.g., Moscoviense, Orientale, Crisium, and Imbrium). The breached downrange ring results from retained momentum in the early-stage flow field [8], including shallow downrange scouring by the failed projectile.

Implications: Observations of pure anorthosite in the M^3 near-infrared data suggest a new approach for modeling of multi-ring basin formation [e.g., 9] is warranted. Multiple mechanisms with differing regimes of efficacy such as deep vs. shallow, or radially inward vs. outward may need to be combined to fully explain the observations. We will be using numerical simulation compared to experimental and remote sensing data to investigate combined mechanisms [e.g. 4, 9] to see if they can better explain the observations than a single mechanism alone.

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