TOWARD AN IMPACT BASIN FORMATION SCALING LAW. S. T. Stewart, Department of Earth and Planetary Sciences, Harvard University, 20 Oxford Street, Cambridge, MA 02138 (sstewart@eps.harvard.edu).

Introduction: Impact basins are the largest geologic structures on planetary surfaces. Basin-sized craters (e.g., larger than about 300 km diameter on the moon) typically exhibit multiple ring-shaped scarps or arcuate chains of massifs [1]. Impact basins also possess central mass anomalies related to removal of a portion of the crust and uplift of the mantle.

The presence of multiple rings has complicated identification of the primary rim diameter that is analagous to the rim around smaller craters. The formation of multiple rings must involve a physical process that is not active during the formation of smaller craters, and several hypotheses have been proposed (see summary in [1]).

Around smaller impact craters, the diameter of the single rim scarp is calculated via a two step process: (i) a scaling law that relates the impact conditions (projectile size, velocity and composition) to the transient cavity diameter and (ii) a modification law that describes the collapse and widening of the transient cavity to the observed final crater diameter. The extension of transient crater scaling from smaller craters into the basin regime has been questioned [2]. Because of the large uncertainty in the size of the transient cavities of impact basins, a modification law has not been developed to relate the observed ring structures to the transient cavity.

To date, the impact energies required to form the largest impact scars on planets remains an unsolved problem. In this work, I outline a method of constraining the size of the transient cavity for impact basins.

Method: The general approach is to model the formation of impact basins using a shock physics code and compare to geophysical observations of mantle uplift [3-5] and shock demagnetization [6]. In this work, we focus on the deformation of the mantle because it is a more robust calculation than determining a crater rim as the calculations are not able to form multiple rings. In companion work [see abstracts by R. Lillis et al. at this meeting and [6]], the shock pressure field is compared to forward modeling of shock-induced demagnetization of the crust around impact basins.

Using the CTH shock physics code, I simulate the complete formation of impact basins in 3D with self-gravity. Note that 3D simulations are required to capture the shock pressure distribution in the planetary crust [7]. For 45° impacts at the typical velocity for the body (moon or Mars), the projectile size, crustal thickness, thermal gradient, and rheological (strength) parameters are varied. Here, I consider the end member cases of a hydrodynamic material and quasi-static strength. In between, the planet is modeled with a transient strain-weakening model appropriate for large impact events [8].

Ultimately, two independent observations (mantle deformation and shock demagnetization) that are spatially separated, one within and one exterior to the basin, can be used to constrain the impact energy.

Results: For a range of impactor sizes (20-40 km radius) onto the moon, the transient crater size at the scaled formation time is in good agreement with scaling laws developed for small craters [9] (see Figure 1). Note that the floor of the transient cavity begins to uplift before the scaled size is reached for the simulations with strength (green and red lines). In the example shown in Figure 1, the final crater size is about 750 km using the strain-weakening model. This particular result is in general agreement with the transient crater estimates developed by [3, 4]. However, the results should diverge for larger craters where more material is horiztonally translated during crater collapse and some of the mantle is excavated.

The excavated volume and ejecta distribution are also calculated and can address resurfacing by basin-forming events. I will present comparisons between calculations and the geophysically inferred mantle perturbations beneath impact basins on the moon and Mars.

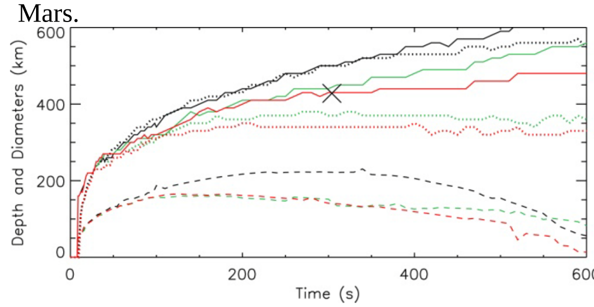

Figure 1. Transient cavity growth for a 45° impact by a 80 km diameter rocky body at 15 km/s onto the moon with a 40 km thick crust. Black – hydrodynamic; green – strain-weakening; red – quasi-static strength models. Solid – apparent crater diameter; dashed – apparent crater depth; dotted – diameter of mantle perturbation. × denotes the predicted transient crater diameter at the scaled time using pi-scaling [9]. The final basin main rim diameter is about 750 km and the width of the mantle perturbation is about 600 km using the strain-weakening model.

Summary: Knowledge of the impact energy associated with basin-sized events is required to understand the influence of these energetic events on planet formation and evolution. The preliminary results from this work show a promising path toward the development of a scaling law for the formation of impact basins.

Formation of multiple rings could be addressed in future work once the impact energies associated with basins are better constrained. Direct modeling cannot address ring formation at this time because of computational limitations and possibly missing physics.

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