EJECTA DISTRIBUTION AND CRATER FORMATION OF LARGE IMPACT BASINS ON THE MOON: INSIGHTS FROM NUMERICAL MODELING.

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Introduction: Large-scale impact basins are the most prominent structures on the Moon. Although only a relatively small number of roughly ~ 50-60 basin structures have been identified, basin-forming impactors clearly dominate the mass and energy delivery to the Moon. These impactors penetrate deep into the Moon and produce large volumes of impact melt and ejecta, which may cover an area with a radius several times larger than the actual basin. A few such events may have completely resurfaced the Moon by inverting the crustal stratigraphy, and by emplacing impact melt and originally deep seated crustal or mantel material into the near surface strata. Several attempts have been made to model the formation of impact basins using so-called hydrocodes [e.g. 1-5] using morphology and gravity signature as constraints. However, the ejecta distribution has not been considered due to the relatively poor preservation of the ejecta deposits of the old basins that have been modified by subsequent impact gardening. In this work, we present a systamtic study of ejecta distribution for large impact basins as a function of impactor properties (size and velocity) and target properties (crustal thickness and thermal gradient). The goal is to predict the thickness, composition (crustal or mantle material), and melt content of the ejecta blanket as a function of distance.

Modeling: We used the shock physics code iSALE 2D [6-8] to simulate basin formation. We carried out a suite of vertical impact models: impact velocity: v=10-20 km s^{-1}; impactor diameter L=50-100 km; crustal thickness h=30, 60 km. The crust and mantle material is assumed to be gabbroic and dunitic composition, respectively. The material behavior is modeled with an ANEOS for gabbro and dunite, combined with a strength and damage model [8] using parameters according to [1, 9]. We do not consider any effects caused by porosity in this work. For all simulations, we assumed a planar target covering an area of 1200 km in lateral and vertical direction with a cell size of 1 km x 1 km in the high-resolution zone. The surface gravitational acceleration is 1.62 m s^{-2}. All simulations were stopped at 2.5 hours after impact. As the thermal gradient of the target has a strong effect on the final structure of the basin, we considered two extreme cases (warm and cold) according to [2] in our simulations. These temperature profiles represent a range of possible thermal conditions for the Moon during the formation of most basin structures.

We use tracer particles to record the launch angle and velocity at the time of ejection. Assuming pure ballistic flight of the ejecta, we reconstructed the parabolic trajectory of each tracer to calculate its landing velocity and deposition distance. We assume that each tracer represents the mass of the cell it was initially located in. The surrounding surface of the crater was subdivided into discrete concentric rings. The ejecta thickness was then calculated from the number of tracers that land in each ring. Note, we do not account for the formation of an ejecta plume in our models and assume that the effect of vaporized material on the ejecta distribution is negligible.

Results: Our results show that the ejecta thickness for cold and warm impact scenario decreases proportionally to a power-law with an exponent $e \cong -3$, similar to that derived from the laboratory experiments [10] and observations [11]. However, the decay exponent e differs depending on the thermal gradient. The ejecta deposit is thicker close to the basin rim and decreases more rapidly in the case of warm target than the cold target. This is because the launch angle of most ejecta is > 45^o for the warm target but approximately 45^o for the cold target. For the same velocity ejecta with a launch angle close to 45^o are deposited the furthest whilst shallower or stepper ejection angles results in shorter deposition distances.

The melt volume is also determined by using tracer particles to record the peak shock pressures the material experienced. If the peak shock pressure is in excess of the material's critical shock pressure for melting (gabbro: P_c = 56 GPa; dunite: P_c = 156 GPa) [*e.g.*, 12] the material is considered to be molten. Our results indicate that the impact-generated melt increases with the size of the impactor, in agreement with previous estimates and scaling laws [13]. However, for same impact condition, the ejecta deposits for warm targets contain a higher fraction of molten material than in case of a cold target.

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