THE EFFECTS OF PLANETESIMAL COLLISIONS.

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Introduction: As planetesimals are expected to form via gentle aggregation of smaller bodies, the first generation of large solid bodies likely possessed significant (>50%) porosity [1-3]. The compaction of a substantial volume of pore space can dramatically decrease the peak shock pressure and increase the post-shock temperature of impact-processed materials [4,5].

Critical to understanding the consequences of planetesimal collisions in the early solar system is quantification of (a) the disruption threshold for weak, porous first-generation planetesimals; (b) the evolution of planetesimal porosity with time through impact-induced compaction; and (c) the redistribution, retention and cooling of heated material in sub-catastrophic collisions. Here we simulate sub-catastrophic planetesimal collisions to late times, quantifying momentum transfer and compaction as well as the ejection and redistribution of impact heated material.

Method: We used the 2D iSALE hydrocode [6,7] to simulate sub-catastrophic head-on collisions between planetesimals. ANEOS-derived equation of state tables for dunite were used to represent the non-porous planetesimal material. Pore-space compaction was modeled using the improved epsilon-alpha porosity model [6,8]. Material strength was modeled according to [7] with parameters for weak rock. Target planetesimals 100 km and 500 km in diameter with a uniform initial temperature (300K) and initial porosities of 0-50%, were modeled. Impacting planetesimals with diameters 0.1-0.3 times target planetesimal diameter, and with identical material properties, collided with the target at 0.1-7 km/s. The gravity field was updated periodically during the calculation using a self-gravity algorithm, inspired by [9].

Results: The compaction of pore space during a planetesimal collision increases shock heating and reduces ejection velocities relative to the non-porous case. Hence, if planesimals are sufficiently porous, collisions can cause localized heating and, even in large sub-catastrophic collisions, the vast majority of the heated material is retained on the target planetesimal. As the energy of the collision approaches the disruption threshold, the fate of the heated material changes considerably, with important implications for post-collision thermal evolution. In small collisions, the small volume of heated material is buried beneath an insulating lens of breccia in the crater. In larger collisions, the heated material is localized within the impacted hemisphere, forming a deep plug beneath the impact site. Close to the disruption threshold, the heated material is distributed in a thin layer over the entire surface of the planetesimal. Secondary compaction occurs across the surface of the rear-side, which may reduce the potential for subsequent impacts to further heat the planetesimal.

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