From microns to kilometres: Linking meteorite observations to asteroid impact processes

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Primitive solar system solids were bimodal mixtures of mm-sized, non-porous igneous inclusions (chondrules) and a porous matrix of sub-µm dusty particles. Depending on their position in the protoplanetary disk, early solid bodies would have also contained varying quantities of water/ice.

The most ubiquitous surface process for all solid objects in the solar system is impact. The response of these bimodal mixtures to shock processing has only recently been understood [1–3], using both numerical simulations and laboratory experiments. Extra shock heating of the matrix material due to its high porosity leads to strong dichotomies in the temperature in the matrix and the chondrules (differences in temperature of 100's K, over a length scale of ~ 100 µm, which will equilibrate over 1–100 s). Porosity can be maintained in the matrix in the interstitial spaces between chondrules or in the area protected from the shock on the lee side of the chondrule.

The initial (pre-shock) composition of the material has a large effect on its pressure-temperature history. For impacts at 2 km/s, material analogous to carbonaceous chondrites (high matrix volume fraction) experienced pressures of ~ 5 GPa, while material analogous to ordinary chondrites (high chondrule volume fraction) experienced pressures of ~ 12 GPa, and non-porous dunite (an approximation of equilibrated ordinary chondrites) saw pressures of ~ 24 GPa. Thus, the shock stage recorded in a meteorite is not only an indicator of the intensity of the shock, but is also controlled by the composition of the precursor material; this is evidenced by the difference in shock stages between different meteorite groups. Similarly, the volume fraction of ice inside void space between matrix grains changes the shock processing: in simulations with constant porosity, as the ice-to-rock volume ratio decreases, a lower velocity is required to reach the same shock pressure, but this results in higher temperatures in the olivine grains.

[1] Bland et al. (2014), *Nat. Comms.* 5, 5451. [2] Davison et al. (2016), *The Astrophys. J.* 821, 68. [3] Davison et al. (2017), *Proceedia Eng.* 204, 405–412.