# Multiscale modeling of compaction of primitive solar system materials

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Impact is a fundamental and ubiquitous process in the solar system. Material within every object orbiting the Sun has been processed in some form of collision. A record of these collisions is preserved in meteorites; but decoding the messages in these rocks is not trivial. Chondritic meteorites, like their precursor solids, are heterogeneous porous aggregates with components—highly porous matrix and dense chondrules—that witness different conditions during the same impact. Moreover, meteorites are tiny samples from multi-kilometre mini-worlds as complex and diverse as the recently imaged surfaces of asteroid Vesta and comet 67P.

Figure 1: (a) A numerical simulation of an oblique collision between planetesimals. This slice through the centre of the planetesimal shows the bulk shock pressure at one instant during impact. To relate these large-scale conditions to meteorite samples (e.g., (e)) mesoscale simulations of shock compaction examine spatial heterogeneity in: (b) shock pressure; (c) temperature; (d) and porosity. Observe the strong temperature dichotomy between chondrules and matrix owing to the high compaction of matrix porosity, which is incomplete only in the lee of chondrules. (e) An example meteorite sample, showing the heterogeneous nature of a typical meteorite, with abundant chondrules and matrix.
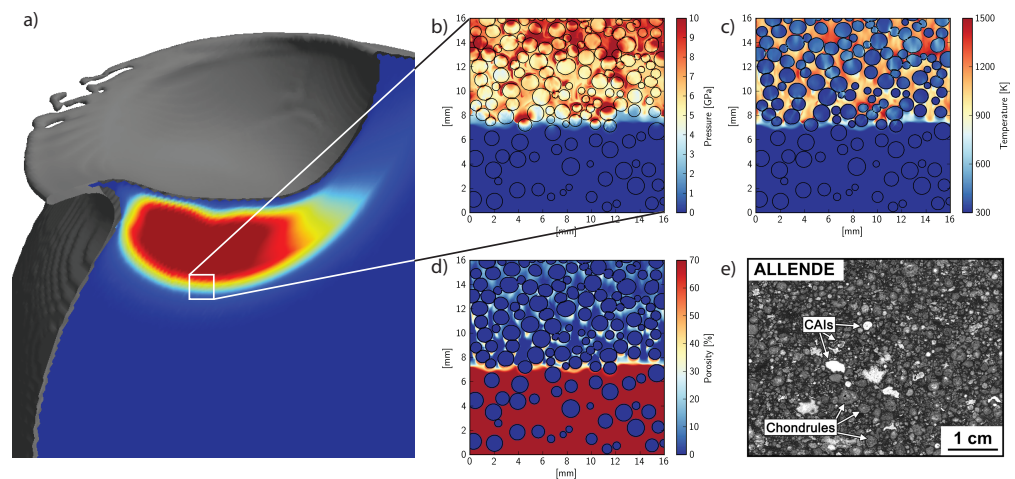
To connect evidence recorded in submillimetre grains to impact processes that affected cubic kilometres of their parent body we have developed a novel multiscale numerical framework [1]. Using this approach we have shown that low-velocity collisions can produce large temperature excursions in the highly compacted matrix, while the hard, solid chondrules are relatively unscathed. The dramatic but brief heating of the matrix during its compaction suggests that impact-induced compaction was a vital step in the evolution of chondritic meteorites. The aim of this project is to use this approach to establish: how primordial dust became solid rock; how the internal structure of meteorite parent bodies evolved; how shock indicators are affected by porosity and matrix abundance; and how evidence in meteorites and asteroid samples can constrain dynamic models of solar system formation. This insight will directly inform interpretation of data from current missions to comets and asteroids (i.e., Dawn, Rosetta, Hayabusa 2 and OSIRIS-Rex).

The project The goal of the proposed research is to investigate the role of impacts in the compaction of primitive meteoritic material through a programme of numerical simulations across different length-scales. Our mesoscale modelling approach will be developed to consider more complex precursor materials, including fragmental breccias (e.g. lunar regolith), and meteorite precursors containing metal inclusions and/or ice. Our macroscale shock physics calculations of pair-wise planetesimal collisions will be extended to consider objects with cores, mantles and crusts, and with realistic internal temperature and porosity gradients. And our Monte-Carlo synthesis framework will be extended to account for the physical and thermal evolution of the planetesimal during, and in response to, impact bombardment.

The successful candidate will join, and be supported by, a vibrant and dynamic research group with world-class expertise modelling impacts. They will be trained in state-of-the-art numerical methods for simulating hypervelocity impact, impact physics and high-performance computing. The candidate will have the opportunity to develop their career and profile by presenting at international conferences and publishing in high impact journals. Candidates for PhD positions should have a good mathematical background and a good degree in an appropriate field, such as earth science, physics, mathematics or computer science.

[1] Bland PA, Collins GS, Davison TM, *et al.* (2014) Nature Communications. 5:5451.