Enhancement of the degree of impact heating in pressure-strengthened rocks

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Introduction: Hypervelocity mutual collisions between small bodies occur throughout the solar-system hostory. A strong compression and thermal pulse caused by an impact can produce various unique features, such as a change in spectral properties, mosaicism, planer deformation features, high-pressure minerals, atomic diffusion, volatile loss, shock veins, impact melt, and so on. We can obtain these features in meteorites [e.g., 1–3]. Given that we have a reliable model connecting the degree of shock metamorphism with the impactor/target conditions, the impact histories of the parent bodies of meteorites is reproduced more correctly. Frequently, the table from Stöffler et al. [1, 2] is used to deduce the shock stage of meteorites using observed shock features, which are subsequently used to infer impact velocities on target bodies. Recently, [4] reported that the degree of heating in low-velocity impacts (<10 km/s) is expected to be much higher than previously expected. In this abstract, we introduce the significance of the strength effects on the degree of impact heating based on the results by [4].

Numerical model: We used the two-dimensional model of the iSALE shock physics code [5-9], combined with a simple well-established constitutive model. The strength model for rocks [8, 10] and ANEOS [11] for dunite [12] were applied for both projectile and target. The detail of the numerical simulation is described in [4]

Results: We confirmed that the results in the case without strength, i.e., purely hydrodynamic, are consistent with the thermodynamic prediction (Fig.1ac). In contrast, we found that the post-shock temperature in strength-supported media could be much higher than previously expected. For example, if we consider a spherical impactor colliding onto a flat target at 3 km/s, the post-shock temperature of the target materials experiencing 10 GPa-compression exceeds 1,000 K (Fig.1bd). Low-velocity impacts do not produce large-scale impact melting, but trigger a comminution of both impactor and target materials. Although the materials experiencing compression do not have a tensile strength, they still have a compressive one. Plastic deformation of the pressure-strengthend comminuted rocks dissipates the energy, and converts from the kinetic energy of the flow field to the internal energy. Thus, the required impact velocities for producing the unique features produced mainly by the rise in temperature is greatly lowered.

Discussion and Conclusions: Our results imply that the experienced peak temperatures in shocked meteorites would be much higher than the prediction by the Stöffler's table at a given shock stage. We are planning to revisit the accuracy of the Stöffler's table by using both labolatory and numerical approaches.

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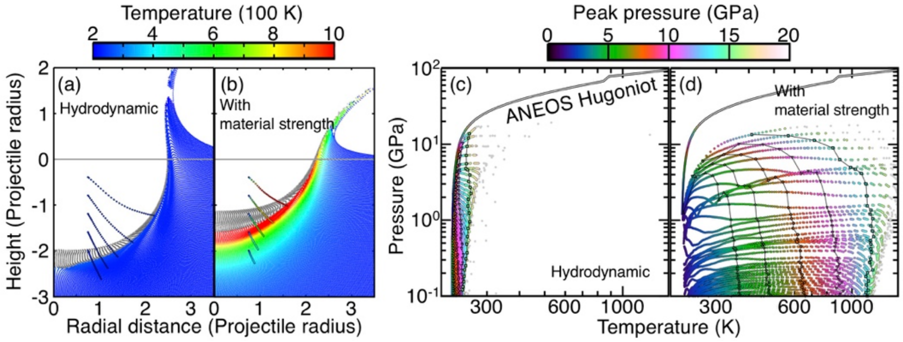

Figure 1. Snapshots of the simulation (a and b). The pressure -temperature pathes of the selected tracers (c and d). The results in the pure hydrodynamic case are shown in Panels a and c. The roles of material strength on impact heating are shown in Panels b and d.