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Hypervelocity impact into dry and wet sandstone

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The influence of pore space water on impact cratering in sandstone is studied experimentally (see also companion abstract by *Thoma et al.*, this volume). The effect of intergranular water during a shock event is that of a fluid cushioning the high energy grain–to-grain impacts [1]. Water reduces the compressibility of porous materials, so that the shock states attained during compression are less dense than those of dry material shocked to the same pressure [2]. A second effect is the mechanical disruption of the target material by expanding steam after the passage of the shock wave. For Hugoniot pressures between 5 and 70 GPa, partial vaporization of water will occur upon pressure release [3]. The formation of steam is accompanied by a large increase in volume and enhances the crater cavity growth in comparison to that in dry rocks. Moreover, fluids are likely to change the mode and yield of impact-induced failure in rocks [4].

Two pilot shots [5] with a two-stage light gas gun have been conducted with 1.0 x 1.0 x 0.5-m-sized blocks of quartz sandstone ("Seeberger Sandstein", Seeberg, Germany), set into a steel frame. This fine-grained sandstone (0.17 +/- 0.01 mm grain size, about 97 wt.% SiO_2) displays a layering with a porosity of 12-20 vol.%. One of the blocks was placed in a water basin for four month and reached a water saturation of 44 vol.% of the pore space, on average, the other block remained untreated. Steel spheres with a diameter of 10 mm and a mass of 4.1 g were launched against these blocks. The impact velocity for both experiments was $\sim$5.3 km/s.

The resulting craters had a diameter of 24.3 and 28.7 cm, with a depth of 5.6 and 4.5 cm, for the dry and wet experiments, respectively. The crater in dry rock has a shape of an inverted spherical cone, the crater in the wet rock is much broader and has a flat floor. Volumetric analyses of the craters based on 3D-scans yielded 715 and 1099 cm^3 for the dry and wet case, respectively. Ejecta cone angles recorded with high speed cameras are 69.8° and 58° after 1.2 msec for the dry and wet experiments. Parabolas fitted to these angles and to the maximum crater depth provided a crater diameter of 8.2 and 11.3 cm for the dry and wet experiment, respectively. The crater enlargement is caused by spallation and fragmentation.

The experiments demonstrate the strong influence of pore fluids on cratering mechanics. Pore space collapse and successive compaction were probably more effective in the dry sandstone experiment. Target water also affected the ejection angles and the ejecta flow. Different ejecta angles can be attributed to differences in the bulk mechanical properties. The effect of pore space water to reduce the effective mean stress may increase the size of the zone in which tensile failure occurs.

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