Subsurface deformation in hypervelocity cratering experiments into high-porosity tuffs

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Introduction: Most planetary surfaces contain porosity to varying degrees in the form of sedimentary rocks or regolith [1]. Additionally, observations of asteroids made by spacecraft missions suggest that many asteroids have remarkably low densities [2]. Understanding cratering mechanics in highly porous media is thus essential for interpreting the impact phenomenon in the solar system [3] and with regard to deflection strategies of asteroids. In order to understand the momentum transfer on a potentially very porous asteroid detailed knowledge about possible material responses to a hypervelocity impact is significant [4]. We investigated the crater shapes and processes in the subsurface of hypervelocity impacts into a highly porous, but solid and naturally occurring material.

Methods: We analyzed three hypervelocity impact experiments into 43 % porosity Weibern Tuff, which were performed as part of the MEMIN research network [5]. Two experiments used a 2.5 mm, one a 12 mm steel projectile and impact velocities lay between 4.8 and 5.6 km/s. The experiments were investigated regarding the influence of target porosity on crater shape and crater sub-surface deformation mechanisms. Thin section scans and stiched mosaics of SEM micrographs (SE mode) of the crater floor were taken and mapped in detail. Orientations of several groups of deformation features were analysed.

Results: Porosity determination revealed a strongly compacted region underneath the crater into a depth of ~ two projectile diameters. Microscopic mapping distinguished three different types of deformation features, namely intragranular cracks, tensile fractures in the matrix and deformation bands. Crack density constantly decreases with distance to the crater floor, tensile failure occurs in two zones, one directly beneath the crater floor and another one in ~two projectile diameters depth. Deformation bands form in the proximal crater floor as shear bands. The crater shapes and the orientations of aligned clasts point to a depth of app. 17 mm, where the projectile came to a halt. Transgranular crack orientations point towards the calculated depth of burst at 6 mm depth.

Conclusions: Compaction is a dominant crater forming process. Within the compacted material shearing is an important deformation process. The high porosity of the tuff leads to a strong dampening of the shockwave compared to experiments in less porous materials [6]. The orientations of intragranular cracks indicate that although the projectile penetrated deeper into the target, energy coupling took place at the calculated impact point source.

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