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Meso-scale hypervelocity cratering experiments (MEMIN project): Characterization of projectile material

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The DFG-funded "MEMIN" (multidisciplinary experimental and modelling impact crater research network) research group is aimed at a better understanding of the impact cratering process by combining (i) numerical modelling of crater formation, (ii) investigation of terrestrial craters and (iii) meso-scale hypervelocity impact experiments using the large two-stage light gas gun at the Ernst-Mach-Institute (EMI; Efringen-Kirchen, Germany). In the framework of MEMIN, 1 cm-sized projectiles of the steel SAE 4130 (mass of 4.1 g) have been fired with a velocity of $\sim$ 5.3 km s-1 onto blocks of Seeberger sandstone (size 100 x 100 x 50 cm, grain size 169+/-8 µm; porosity 12-20 vol.%). One goal of MEMIN is to document, analyze, and understand the fate of the projectile and its distribution between crater and ejecta; hence, the use of well-analyzed projectile material is mandatory. For this purpose, we use optical, and electron microscopy, electron microprobe (WWU, and MfN), and LA-ICP-MS microanalysis (WWU). Currently we evaluate which steel or iron meteorite is adequate for the intended use. Important properties of a projectile are (i) textural and chemical homogeneity, (ii) clear chemical distinction to the target sandstone, (iii) presence of elements such as Co, Ni, Cr, PGE that as "meteoritic component" are used in terrestrial craters to trace projectile matter, and characterize the type of the projectile (i.e., meteorite group), and finally (iv) mechanical properties that guarantee stability during sphere production, launch and flight. Strong chemical differences to the target material and geochemical homogeneity of the projectile will allow detection of small volumes of projectile matter by high spatial resolution in-situ analysis with the LA-ICP-MS. Steel SAE 4130 is heterogeneous at the 100-μm scale and has low trace element contents. In future, we plan the use of the alloyed heat treatable steel D290-1 as projectile as its texture is quite homogenous at the scale of <10 µm. Moreover, the steel has only 0.09 wt% silica in the matrix, but significant concentrations of Cr (4.2 wt%), Co (5.3 wt%), W 6.0 wt%), and Mo (4.3 wt%) that will facilitate detection of projectile matter within the crater floor or ejecta using SEM and EMPA. In addition, mechanical properties of D290-1 allow production of even small spheres on the lathe – at a size which is used in calibration experiments. Furthermore, we have investigated the two iron meteorites Arispe (group IC) and Campo del Cielo (IAB) for their suitability as projectile in the MEMIN experiments. Arispe is rather coarse-grained (2.9 mm) and shows many micro-fractures, but has an extraordinary high PGE content that would allow tracing interelement fractionation in the ejecta material. Campo del Cielo with a Widmannstatten bandwidth of 3.0 $\pm$ 0.6 mm, has a rather homogeneous kamacite matrix, in which schreibersite and taenite are distributed rather irregularly. Conspicuous are also the up to cm-sized silicate inclusions, which carefully have to be avoided during projectile assembly. With use of steel D290-1 and iron meteorites as projectile material, we expect to get a better understanding of the chemical and physical processes during projectile dissemination into the target, the ejecta, and the vapour phase. These data will serve as input parameter for the numerical modelling of crater formation.