DEFORMATION AND MELTING OF IRON-RICH PROJECTILES IN HYPERVELOCITY MEMIN CRATERING EXPERIMENTS

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To investigate structural and geochemical changes that occur upon impact in projectiles we conducted hypervelocity cratering experiments using projectiles composed of steel or the iron meteorite Campo del Cielo, and sandstone targets [1, 2]. The masses of coherent projectile relics that were recovered in different MEMIN experiments [3] range between 58 and 92 % of the initial projectile mass. No clear trend was observed between impact energy, the presence of pore water in the target and the mass of projectile relics. However, projectile fragmentation seems to be enhanced if the target contains substantial amounts of water. Their deformation inventory was investigated for two experiments with 1 cm-sized steel projectiles (3.4 kms^{-1} / 23.7 kJ and 5.3 kms^{-1} / 58.4 kJ). The recovered pieces of the projectiles are intensely plastically deformed and display a bowl-shape with a serrated, sometimes fragmented brim and a knobby region in the center of the inner side. Deformation mechanisms inferred from EBSD measurements include dislocation glide and dislocation creep. The latter led to the formation of sub-grains and micrometer-sized dynamically recrystallized grains. In case of the 5.3 kms^{-1} experiment this deformation is followed by grain annealing. In addition, brittle fracturing and friction-controlled melting at the surface along with melting and boiling of iron and silica was observed in both experiments. We demonstrate that shock and post-shock heating of the projectile is insufficient to explain the melting phenomena. Heating is largely the result of plastic deformation. We estimated that heating and melting of the projectile impacting at 5.3 kms^{-1} consumed 4.4 % of the total impact energy that was converted to thermal energy and heat of fusion. Beside the formation of cm-sized projectile relics, projectile matter is distributed in the ejecta as spherules, unmelted fragments, and intermingled iron-silica aggregates down to the sub-µm scale [2].

In an experiment with a 1 cm-sized sphere of Campo del Cielo as projectile (4.56 kms^{-1}, 43 kJ), melted projectile material is mixed mechanically and chemically with the sandstone melt. During mixing of projectile and target melts, Fe of the projectile is preferentially partitioned into target melt over Ni and Co yielding a Fe/Ni that is generally higher than this ratio in the projectile. This fractionation results from differing siderophile properties, specifically from the different reactivity of Fe, Ni, and Co with oxygen during projectile-target interaction.

References: [1] Kenkmann, T. et al. (2013). Met. Planet. Sci. 48, 150-164, [2] Ebert M. et al. (2013). Met. Planet. Sci. 48, 134-149. [3] Poelchau, M.H. et al. (2013). Met. Planet. Sci. 48, 8-22.