GEOCHEMICAL EXCHANGE PROCESSES BETWEEN PROJECTILE AND TARGET IN HYPERVELOCITY CRATERING EXPERIMENTS.
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Introduction: The detection and identification of meteoritic components in impact-derived materials are of great value for confirming an impact origin and for reconstructing the type of extraterrestrial material that penetrated the Earth in the past [1]. However, little is known about processes that control (i) projectile dissemination into the various impactites that originate during cratering and excavation, and (ii) inter-element fractionation between "meteoritic" tracer elements during impact cratering. The aim of this work is to investigate how impact energy (variation of projectile mass and/or velocity), water-saturation of the target, and target porosity influence (i) and (ii).

Experimental setup: In the context of the MEMIN program [2], cratering experiments have been performed using spherical projectiles of the Cr-V-Co-Mo-W steel D290-1, and target blocks of quartz-rich sandstone and quartzite. Some of the sandstone blocks have been saturated with water. The experiments investigated in this study (A6-5126, E6-3452, E1-3382) were performed at an impact velocity about 5 $km*s^{-1}$. The projectile masses of 0.067 g and 4.14 g result in impact energies of ~0.8 kJ and 70 kJ, respectively. The experiments were carried out at the two-stage acceleration facilities of the Fraunhofer Ernst-Mach-Institute (Freiburg, Germany [3]). Impact ejecta was collected with an ejecta catcher [4], which allows the determination of ejection angles of certain ejecta materials.

Results: Our study is focused on target-projectile interaction occurring in the recovered highly shocked and projectile-rich fragments (ejecta type 3 in [5]). In all of the investigated impact experiments, whether sandstone or quartzite targets, the highly shocked ejecta fragments show significant mechanical (and chemical) mixing of the target rock with projectile material. Most prominent is the injection of projectile melt droplets into the partially molten targets (Fig. 1). Thus, two coexisting but largely immiscible melts exist in the highly shocked ejecta fragments. The ejecta contain various shock features including multiple sets of planar deformations features (PDF) in quartz (Qtz), onset to complete transformation of Qtz to silica glass, and partial melting of the targets. This melting is concentrated in the phyllosilicate matrix of the sandstone and quartzite, but involves quartz grains, too.

Chemical fractionation processes: The silica-rich target melts are enriched in elements that are used to trace the projectile, like Cr, V, and Fe (but have no or just minor traces of Co, W, and Mo). Inter-element ratios of these meteoritic tracer elements within the contaminated target melts may be strongly modified from the original ratios in the D290-1 steel. The fractionation most likely results from differences in their lithophile or siderophile character of these elements, or more precisely, from differences in their reactivity with oxygen [5, 6] during interaction of metal melt with silicate melt. The element map in Fig. 1 shows that Cr and V of the projectile droplets nearly totally partition into the sandstone melt, whereas the siderophiles Co, Mo, and W, almost entirely remain in the projectile droplets. The element ratios in the original D290-1 steel are completely changed within the projectile melt droplets.

Effects of experimental conditions: Recent MEMIN cratering experiments (E6-3452) were carried out with a quartzite target with almost no <u>porosity</u>. Electron microprobe and microscope (SEM) investigations of highly shocked ejecta from these experiments suggest in some cases enhanced inter-element fractionation processes during the impact compared to the experiments with sandstone targets (0% vs. ~23 % porosity). Partitioning of projectile tracer elements (Cr, V, Fe) into the silicate target melt is much more enhanced, especially for Fe in experiments with a quartzite target compared to those with sandstone (cf. Fig. 2). Some projectile droplets are mainly surrounded by a Fe-rich silicate melt as well as small Cr-V-rich minerals (probably spinels forming partially dentritic domains; Fig. 3). These Fe-rich silicate melt rims and the Cr-V-rich minerals, however, are completely absent in experiments with sandstone targets at similar impact velocities. Furthermore, the highly shocked ejecta of the quartzite target has a higher amount of silica glasses, a lower content of projectile droplets, and shows very often melt textures suggesting liquid immiscibility between Fe-rich and Si-rich melts (Fig. 3). Comparable liquid immiscibility textures were recently described for Wabar crater impact melt [7].

A systematic relation between <u>impact energy</u> and the relative proportion of projectile relicts could not be found. At higher velocities, a stronger fragmentation of the projectile can be assumed [8] but we did not observe any influence of the impact energy on inter-element fractionation processes. Projectile fragmentation seems to be enhanced in experiments with water-saturated targets [8] but geochemical processes between projectile and target are obviously not affected by the degree of water-saturation.

Projectile distribution in the ejecta: During the cratering process the highly shocked projectile-rich ejecta fragments are ejected in a steep angle (71° - 81°). The rest of the projectile is represented as mm-sized, irregularly formed fragments or as a bowl shaped fragment of almost pure projectile material [8].

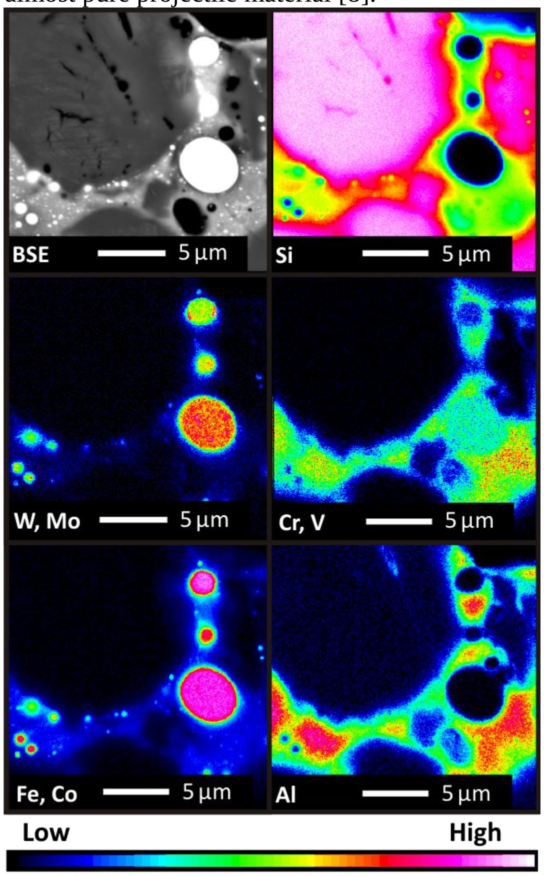

Fig. 1 Electron microprobe (JEOL JXA-8550F, MfN) element maps of a highly shocked ejecta fragment (A6-5126) with shocked Qtz with PDF (BSE - dark grey), sandstone melt (light grey) and projectile droplets (light spheres of D290-1 steel). Note diffuse distribution of Cr and V near projectile droplets.

Conclusions: The mesoscale MEMIN laboratory experiments yield results very similar to observations in nature, e.g., at Meteor Crater and the Wabar craters [7, 9, 10]. The strong alteration of the ratios of meteoritic tracer elements in impact melts from the respective ratios in the projectile causes a problem for identification of the projectile type, as noted by e.g. [9]. In accordance with these authors we recommend caution in assigning projectile types without detailed knowledge of projectile-target mixing and inter-element fractionation involved.

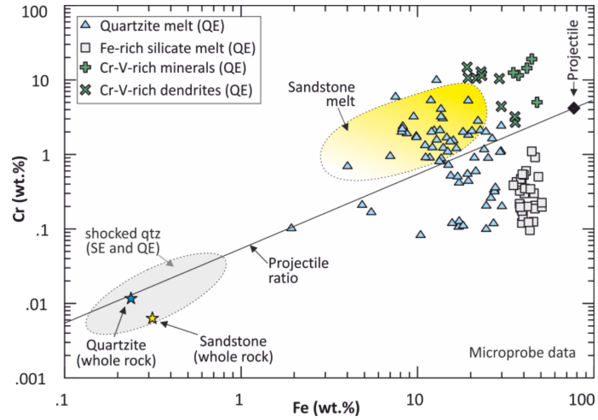

Fig. 2 Fe vs. Cr for various phases in highly shocked ejecta fragments from exp. with sandstone and quartzite targets. The diagram shows the significant enrichment of Fe and Cr, derived from the steel projectile, within target melts. The yellow field represents data of the sandstone melt. SE = exp. with sandstone target; QE = exp. with quartzite target.

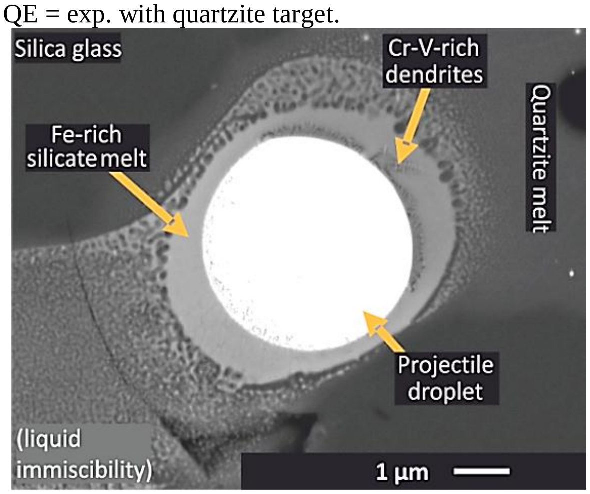

Fig. 3 BSE image of typical projectile-target mixing and unmixing textures in a highly shocked ejecta fragment of exp. E6-3452 with a quartzite target.

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