MEMIN: CHEMICAL MODIFICATION OF PROJECTILE SPHERES, TARGET MELTS AND SHOCKED QUARTZ IN HYPERVELOCITY IMPACT EXPERIMENTS. M. Ebert[1], L. Hecht[1], A. Deutsch[2], T. Kenkmann[3] [1]Museum für Naturkunde (MfN), Leibniz Institut an der Humboldt Universität Berlin, Invalidenstrasse 43, D-10115 Berlin, (Matthias.Ebert@mfn-berlin.de), [2]Institut f. Planetologie, Whilhelm-Klemm-Str. 10, Univ. Münster, D-48149 Münster, [3]Institut für Geowissenschaften, Univ. Freiburg, Albertstr. 23b, D-79104 Freiburg.

Introduction: The detection of meteoritic components in impact-derived rocks (e.g. in the crater floor or ejecta) is of great diagnostic value for confirming an impact origin and for projectile identification [1]. However little is known about processes that control the projectile distribution and inter-element fractionation between siderophile elements during impact cratering. Here, we present first results of hypervelocity cratering experiments using iron meteorite matter as a projectile and a natural sandstone target.

Experiment: The experiments were carried out at the EMI-Freiburg with a two-stage light gas gun under various conditions [2,3]. For an overview of all experiments see [4]. Our results are based on experiment #3298 using a Campo del Cielo meteorite sphere projectile (Ø 10 mm, weight 4.12 g) [5,6] accelerated to ~4.56 km*s-1 and as target material a 50x50x50 cm block of Seeberger Sandstone [6]. The impact energy amounted to about 43 kJ. Ejecta material was captured with a catcher system consisting of Vaseline and phenolic foam plates [7].

Samples and Analysis: The ejecta recovered from the catcher system was characterized by optical and electron microscopy. We collected dark grey, partly fused fragments in mm-size. Major and minor element concentrations of polished ejecta fragments were analyzed by the JEOL JXA-8550F electron microprobe (15kV, 30 nA; host institution MfN) using pure element standards for Fe, Ni, and Co, and mineral standards for quartz (Qz) and silicate melt.

Results: The ejecta fragments show various shock features including multiple sets of PDFs in Qz, onset to complete transformation of Qz to lechatelierite, and partial melting of the sandstone (Fig. 1). This melting is concentrated in the clay-bearing matrix but involves quartz too. Projectile material is mixed physically and/or chemically into the sandstone melt to various amounts. Droplets of projectile have entered the low-viscosity sandstone melt but not lechatelierite.

Sandstone melt (SM) consists of SiO_2 (51-94 wt.%), Al_2O_3 (1.9-17 wt.%), FeO (4.5-32 wt.%), and NiO (0.01-0.9 wt.%). Components of this mixture are Qz (SiO_2=99.8 wt.%, FeO<0.05 wt.%), clay (SiO_2=45 wt.%, Al_2O_3=28 wt.%, FeO=3.2 wt.%) and up to ~20% projectile (Fe=93 wt.%, Ni=6 wt.%, Fig. 2). The Fe/Ni of SM is generally below the projectile ratio. The projectile component increases with the Al content of the SM.

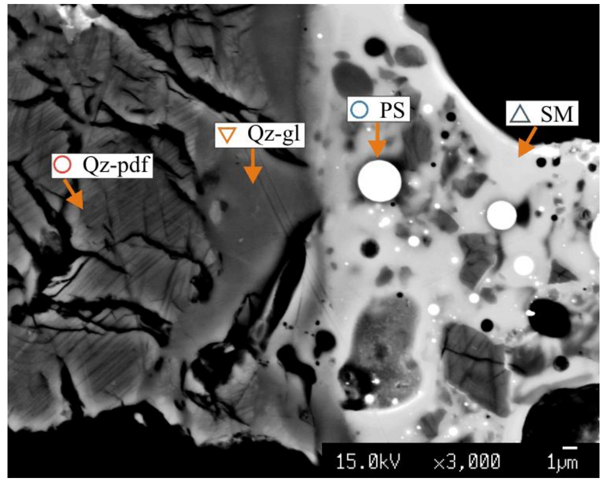

Fig. 1. BSE-image of an ejecta sample; for explanation see Fig. 2 and text.

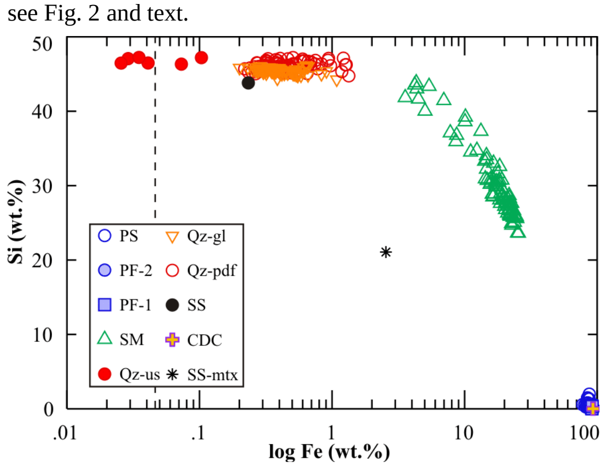

Fig. 2. Fe vs. Si for various materials of Exp. # 3298.; PS: projectile sphere; PF-1: partly fused projectile fragment; PF-2: projectile fragment; SM: sandstone melt; Qz-un: unshocked quartz; Qz-gl: quartz glass; PDF: PDFs in quartz; SS: Seeberger sandstone; CDC: Campo del Cielo projectile; SS-mtx: mean of the sandstone matrix. Dashed line corresponds to the average detection limit for Fe.

Shocked quartz: Transformation of Qz to glass along multiple sets of PDFs or complete transformation to lechatelierite is visualized in the backscatter mode due to density contrast of Qz and Qz glass (Fig. 1, 3). Occasionally vesicles within the Qz glass indicate melting (Fig. 3). Qz with PDFs and lechatelierite contain minor FeO (<1.7 wt.%) and NiO (< 0.08 wt.%) components (Fig. 2). The average FeO content of shocked Qz is 0.58 wt.%, Al-enrichment relative to unshocked Qz was not observed. The data indicate incorporation of <1 % projectile material into the Qz.

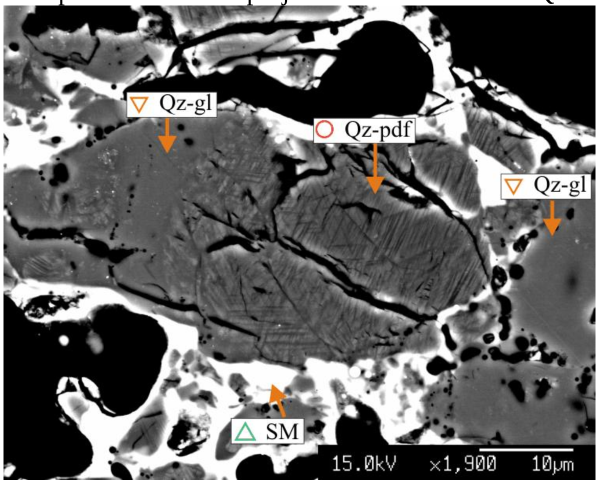

Fig. 3. BSE-image of highly shocked Qz; for explanation see Fig. 2 and text.

Projectile residues occur as spheres in the sandstone melt and as spheroids or partly molten fragments attached to ejecta fragments. Spheres, spheroids and the molten sections of projectile fragments are slightly enriched in Ni and Co and depleted in Fe compared to the unshocked Campo del Cielo meteorite. Fractionation of Ni and Co from Fe is most extensive for those spheres that have entered the sandstone melt. The spheres vary in composition from Ni=5.6 to 17.3 wt.%, Co=0.4 to 1.3 wt.%, and Fe=77.7 to 94.0 wt.%. In addition, Ni is on average more enriched than Co resulting in a higher Ni/Co ratio in spheres compared to the unshocked meteorite (Fig. 4). The sizes of metallic particles in the sandstone melt ranges from a few nanometers to hundreds of micrometers. Enrichment of Ni and Co versus Fe correlates negatively with the size of the projectile spheres, and is most prominent in spheres smaller than 3 µm (Fig. 5).

Discussion: Our experiment indicates that chemical and physical mixing between projectile and target occurs in different stages that most likely involve inter-element fractionation. 1) After shock compression with formation of PDFs in Qz and Qz transformation to diaplectic glass or lechatelierite and during early unloading, <1 % of projectile matter is added to the glass phases without detectable element fractionation. More sensitive micro-analytical tools such as LA-ICP-MS, however, are needed to substantiate this result.
2) Later, when waste heat triggers (partial) melting of the sandstone, molten projectile material is mixed physically as well as chemically with the sandstone melt. Significant inter-element fractionation occurs at this stage. Fe is selectively enriched in the silicate melt, Ni and Co are enriched over Fe in coexisting projectile spherules. Similar fractionation processes have been observed in natural impactites [8-10]. The increase of fractionation with decreasing size of the spherules indicates that the fractionation of Fe, Ni, and Co occurs during solution of the metal spherules in the silicate melt due to differences in reactivity [9].

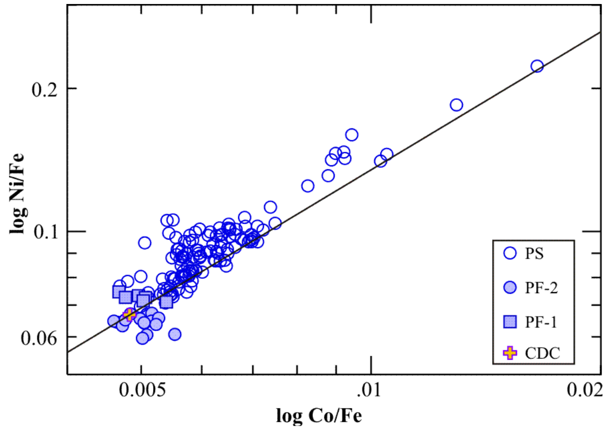

Fig. 4. Log Ni/Fe vs. log Co/Fe plot for projectile residues; the line represents the initial meteoric element ratio; for legend see Fig. 2

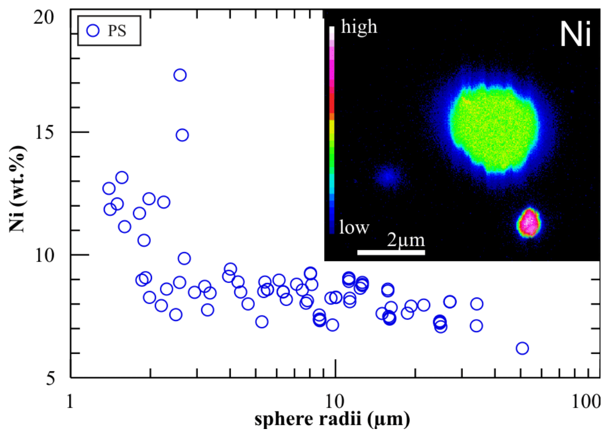

Fig. 5. Ni-content vs. sphere radii; insert shows a Ni element map.; for legend see Fig. 2.

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