BRIDGING THE GAP BETWEEN LABORATORY AND NATURE: GEOCHEMICAL CLUES FROM EXPERIMENTAL APPROACHES. M. Ebert[1], C. Hamann[1,2], L. Hecht[1,2], A. Deutsch[3] and T. Kenkmann[4]. [1] Museum für Naturkunde, Leibniz-Institut für Evolutions- und Biodiversitätsforschung, Invalidenstraße 43, D-10115 Berlin, (matthias.ebert@mfn-berlin.de); [2]Freie Universität, Department of Earth Sciences, Malteserstr. 74-100, D-12249 Berlin; [3] Westfälische Wilhelms-Universität Münster, Institute for Planetolgy, Wilhelm-Klemm-Str. 10, D-48149 Münster; [4] Albert-Ludwigs-Universität Freiburg, Institute for Earth and Environmental Sciences, Albertstr. 23B, D-79104 Freiburg.

Introduction: Along with petrological and mineralogical investigations of natural impactites, laboratory experiments [e.g., 1–3, and references therein] are an important, yet highly challenging tool to study shock metamorphism, formation of impact melts, and possible chemical modifications of projectile and target during impact. Experimental limitations mainly result from extreme and strongly heterogeneous *P*–*T* conditions (several tens to hundreds of GPa and several hundreds to thousands K), high impact velocities (>10 km/s), and, from an experimental perspective, long shock durations (fractions of a second to several seconds) of natural impact events.

Here, we show that — despite these experimental limitations — hypervelocity impact experiments and laser-induced melting experiments within the frame of the **M**ultidisciplinary **E**xperimental and **M**odeling **I**mpact Research **N**etwork (MEMIN) were able to produce a wide range of features very similar or even identical to those of well-described impactites from terrestrial meteorite craters.

Experimental Rationale: Various MEMIN hypervelocity impact experiments (HIE) have been performed using two-stage light-gas accelerators at Fraunhofer Ernst-Mach-Institut, Freiburg, Germany [4]. Along with the HIE, laser-induced melting experiments (LE), performed with Nd:YAG lasers at Technische Universität, Berlin, Germany, involved rapid melting and subsequent quenching of the contact zone between a “target” block and a “projectile” block, simulating impact melt formation during decompression phase and allowing us to better constrain properties of melts from the starting materials and mixtures of them.

Above all, the usage of predominantly natural geologic projectiles (iron meteorite, basalt, or doped steel) *and* targets (sandstone, quartzite, tuff, marble, or porous limestone) distinguishes the MEMIN experiments from previous studies, which mainly involved artificial projectile and/or target “analogue” materials (e.g., impacts of plastic projectiles into loose sand [2]). For a detailed description of the experiments, we refer to [4–6].

Analytical Techniques: Samples (highly shocked ejecta particles from the HIE and melt tracks from the LE) were mounted in epoxy and/or thin-sectioned and subsequently analyzed with a field-emission electron microprobe, a scanning electron microscope, and a transmission electron microscope.

Results: The MEMIN experiments yielded impact melt particles [5–6] and laser-melted materials [7] that closely resemble natural impact melt rocks and glasses [8–13]. If not mentioned separately, the observations below are valid for HIE and LE.

Melting and Mixing: Both HIE and LE yielded materials that feature, amongst others, incipient to complete transformation of quartz to silica glass (lechatelierite), partially to completely molten targets and projectiles, and injection of metallic projectile droplets into siliceous target melts. As apparent from HIE [5–6], melting is concentrated in the phyllosilicate-bearing matrix of the sandstone and quartzite, but involves quartz grains, too. Furthermore, the LE produced thermal gradients ranging from no thermal modification to intense melting [7], corresponding — in simplified form — to hemispherically decreasing post-shock temperatures around the point of impact. In comparison, impactites from the Kamil, Egypt, Wabar, Saudi Arabia, and Barringer, Arizona, impact structures show similar features, such as mixing of molten projectile spheres or schlieren of iron meteorite matter with shocked sedimentary target rocks [8–12]. Furthermore, incipient melting of quartz, starting at grain margins and propagating inwards, is known, e.g., from the Wabar impact glass as well [12], which is in good agreement with the results of our LE [7].

Chemical Modification of Projectile and Target: The materials produced in HIE and LE reveal several geochemical similarities with natural impactites from small terrestrial craters formed by iron meteorites. For example, it has been showed that impact melts from the Wabar [12] and Kamil [11] impact structures are generally enriched in Fe over Ni compared to Fe/Ni of the iron meteorite projectiles. Identical chemical processes were observed in the highly shocked ejecta fragments from HIE using iron meteorite (and steel) as projectile and sandstone and quartzite as target [5–6]. Furthermore, significant inter-element fractionation occurs during mixing of projectile and target materials in both types of experiments; e.g., the silica-rich target melts are strongly enriched in projectile tracer elements (not to be confused with *trace elements*; e.g., Ni is a major element in an iron meteorite). The degree of enrichment is mainly controlled by the lithophile or siderophile character of the respective tracer element. Moreover, the fractionation results from differences in reactivity of the respective elements with oxygen during interaction of metal melt with silicate melt [5–6, 12–13]. The different geochemical affinities of the tracer elements lead to element ratios in the target melts differing strongly from the respective element ratios of the projectile. Brett et al. [13] suggested that this combined oxidation–fractionation process occurred in very short time intervals during atmospheric flight of molten metallic projectile residues, i.e., prior to the injection of the projectile melt into the target melt. However, contrary to this assumption, our HIE unequivocally show that the projectile melt was directly separated from the projectile, injected into the target melt, and oxidized *in-situ* [5–6]. This is in agreement with recent observations by Hamann et al. [12], who described similar processes in the Wabar impact glasses.

In both HIE and LE, silicate emulsion textures, observed within projectile-contaminated target melts, indicate phase separation of Fe-rich, Si-poor silicate melts from Fe-poor, Si-rich silicate host melts. Silicate emulsions were also observed adjacent to iron meteorite (or steel) melt droplets and siliceous target melts in several HIE, texturally documenting the oxidation–fractionation process described above. Similar silicate emulsion textures occur in impact glasses of, e.g., the Wabar [12] and Kamil [14] impact structures.

Shock Metamorphism: The performed HIE yielded ejecta particles that show several indicators of shock metamorphism. For example, ejecta particles recovered from the sandstone and quartzite HIE show multiple sets of PDF in quartz, incipient to complete transformation of quartz to lechatelierite, and partial melting of the targets. Usually, these shock features occur at distances of ~20 μm next to each other, substantiating an utterly heterogeneous *P*–*T* distribution and history. Moreover, shocked calcite grains recovered from HIE with marble targets show a variety of shock effects that are known from previous experiments [15]. Specifically, the majority of calcite grains show low- to medium-grade shock effects, i.e., pronounced twinning in form of three sets of cross-cutting, mechanical twins per grain (most likely *e*, *r*, and *f* twins). In addition, melting of calcite is recognized by loss of calcite grain boundaries and *in-situ* appearance of vesicles, isotropisation of the material, CaO, MgO, and CO_2 contents akin to those of the pre-impact calcite, and Raman spectra characterized by disappearance of the characteristic calcite bands (cf. the companion abstract by [16]). Although calcite melts are known from previous experiments as well [15], the record of carbonate melting *vs.* decomposition in natural impactites remains controversially discussed among those that study terrestrial impact structures and associated impactites (e.g., see the recent discussions by [17] and [18]).

Conclusions: We demonstrate that HIE and LE are capable of simulating typical post-shock high-temperature effects that govern the formation of impact melts. Although it has to be stressed that the LE cannot exert the high pressures commensurate with natural hypervelocity impacts, they are capable of simulating typical conditions of rapid melting and subsequent quenching during post-shock decompression and, hence, impact melt formation. The HIE and LE, thus, provide a broad applicability for studying geochemical impact-processes, which typically seem to occur in small- to mid-sized impact craters [8–13].

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