SILICATE LIQUID IMMISCIBILITY IN NATURAL AND EXPERIMENTAL IMPACT MELTS. C. Hamann[1,2], A. Fazio[3], D. Schultze[4], M. Ebert[1,2], L. Hecht[1,2], W. U. Reimold[1,5], and R. Wirth[6]. [1]Museum für Naturkunde, Leibniz-Institut für Evolutions- und Biodiversitätsforschung, Invalidenstraße 43, 10115 Berlin, Germany (christopher.hamann@mfn-berlin.de), [2]Freie Universität Berlin, Malteserstraße 74–100, 12249 Berlin, Germany, [3]Università di Pisa, Via Santa Maria 53, 56126 Pisa, Italy, [4]Technische Universität Berlin, Ackerstraße 76, 13355 Berlin, Germany, [5]Humboldt-Universität zu Berlin, Unter den Linden 6, 10099 Berlin, Germany, [6]Deutsches GeoForschungsZentrum, Telegrafenberg, 14473 Potsdam, Germany.

Introduction: The importance of silicate liquid immiscibility for petrogenetic processes has remained an often controversially debated topic; recently attempts have been made to reevaluate its petrogenetic and geochemical aspects [*e.g.*, 1]. Although several studies exist on melt unmixing in terrestrial [2] and lunar rocks [3], emulsion textures have rarely been described from impact glasses. For example, [4] reported silicate emulsions in Zhamanshin impact glasses (Kazakhstan), whereas [5] described carbonate–silicate emulsions in Haughton impact glasses (Canada). Recently, we have shown that phase separation of impact melt into coexisting silicate liquids may occur when an iron meteorite is mixed with a highly siliceous target [6], or when rapid crystallization of impact melt shifts the composition of a residual melt into a two-liquid field [7]. Driven by these results, we extended our search for melt unmixing to impact melt rocks from three other young impact structures: Barringer (USA), Kamil (Egypt), and Tenoumer (Mauritania), as well as to experimentally produced impact glasses from a recently performed hypervelocity impact experiment (MEMIN experiment A20-5339; [8]). Here, we report preliminary results of an ongoing micro-analytical study and show that silicate liquid immiscibility is readily encountered in impact melts.

Results: Silicate emulsions showing a dispersed phase in a continuous matrix were observed in all studied specimens using a combination of field-emission EMPA, SEM, and TEM. Typical emulsions, which are the result of liquid–liquid phase-separation upon cooling, comprise micrometer-sized droplets of one glass disseminated in a chemically distinct matrix glass.

Barringer impact melt rocks. The Barringer specimens are hypocrystalline, clast-poor impact melt rocks, which were formed by an IAB iron meteorite impact into a complex sequence of sandstone, siltstone, and dolomite. In these melt rocks, genuine glasses appear in three varieties: (i) homogeneous, non-phase-separated, presumably pristine, holohyaline areas up to several hundred micrometers in size, (ii) homogeneous, non-phase-separated, slightly Mg-depleted matrices around acicular olivine (Ol) and dendritic pyroxene (Px) quench crystals, and (iii) phase-separated mesostasis trapped between a granular assemblage of olivine, pyroxene, and magnetite (Mag). Due to crystallization of the ferromagnesian minerals this mesostasis is substantially depleted in Mg and distinctly enriched in Al and K (compared to the pristine impact glass). Compositionally and texturally, the immiscible liquids in the Barringer mesostasis resemble immiscible liquids in the mesostasis of tholeiitic basalts [2]. Silica, Al, and K are concentrated in a highly polymerized, felsic, Si-rich liquid (*Lsi*), yielding distribution coefficients $D_i^{Lfe/Lsi} < 1$, whereas the remaining major elements are concentrated in a poorly polymerized, ultrabasic, Fe-rich liquid (*Lfe*) with $D_i^{Lfe/Lsi} > 1$. Typical textures comprise ~200-nm-diameter droplets of *Lsi* disseminated in a matrix *Lfe*, which, in some cases, is replaced by dendritic magnetite crystallites (Fig. 1a).

Wabar and Kamil impact glasses. The holohyaline, clast-poor impact glasses from Wabar and Kamil were both formed by iron meteorites (Wabar: IIIAB iron, Kamil: ungrouped iron) that impacted sand/sandstone targets. Thus, the impact glasses found at these sites resemble each other both petrologically and chemically [*cf.* 6 and 9]—they are glassy melt bombs containing inclusions of shocked sandstone and/or quartz, diaplectic quartz glass, schlieren and patches of lechatelierite (Lech), as well as metallic projectile remnants. Silicate emulsions dominate the bulk of the black glasses from both sites. In the black Wabar glasses, droplets and patches of *Lfe* of variable diameter are disseminated in a matrix *Lsi* (Fig. 1d), whereas in the black Kamil glasses, droplets of *Lsi* of ~0.2–1 µm diameter are disseminated in a matrix *Lfe* (Fig. 1b). Occasionally, coalescence of *Lfe* to coherent patches and rims around silica phases (Wabar: ballen α-cristobalite, Kamil: lechatelierite) is indicated in the impact glasses of both structures. In the black Wabar glasses, conspicuous rims of *Lfe* are located around metallic projectile droplets (Fig. 1d).

Tenoumer impact melt rocks. The Tenoumer specimens are hypocrystalline, clast-poor impact melt rocks that were formed by an unknown projectile that impacted a complex sequence of granite, orthogneiss, mica shist, amphibolite, and cherty limestone. Silicate emulsions comprising droplets of *Lfe* of up to 2 µm diameter disseminated in a partially crystallized matrix *Lsi* are present in a mesostasis trapped between pyroxene, plagioclase, and olivine quench crystals (Fig. 1c). Crystallization of plagioclase in the mesostasis is often accompanied by deformation of the *Lfe* droplets, which adhere to plagioclase phase boundaries. In some cases, *Lfe* droplets are partly replaced by dendritic, Fe-rich crystallites (magnetite?).

Experimental impact glass. The recently performed MEMIN hypervelocity impact cratering experiment A20-5339 was carried out with a two-stage light-gas gun at the Fraunhofer Ernst-Mach-Institute in Freiburg, Germany. The experiment involved the impact of a 2.5-mm-diameter steel projectile onto a 20 × 20 × 20 cm block of quartzite at ~5.0 km s^{-1}, which resulted in a peak pressure of ~81 GPa. The experiment yielded highly shocked ejecta particles, which were extensively studied by [8]. Here, we focus on frequently occurring silicate emulsions (Fig. 1e), which seem similar in texture to the Wabar emulsions (*cf.* Fig. 1d). However, since manufactured steel was used instead of an iron meteorite, the *Lfe* contains WO_3 (<9.9 wt.%), as well as traces of CoO (<3.1 wt.%), MoO_3 (<1.9 wt.%), Cr_2O_3 (<1.4 wt.%), and V_2O_3 (<1.0 wt.%).

Discussion and Conclusion: This ongoing study suggests that silicate liquid immiscibility is a common process encountered in impact melts. As they combine diverse and sometimes "exotic" compositions with rapid cooling, it seems likely that a two-liquid field is (i) directly encountered upon quenching of a compositionally appropriate mixture (*e.g.*, iron meteorite and highly siliceous target, as in the case of Wabar, Kamil, and the MEMIN experiment), or (ii) by shifting the residual melt composition into a two-liquid field during crystallization (as in the case of Barringer and Tenoumer). We conclude that silicate liquid immiscibility is a much more common petrogenetic process in impact melt development than previously recognized.

Acknowledgments: G. Pösges for the Wabar and Barringer specimens, L. Folco/M. D'Orazio for the Kamil specimens, and G. Pratesi for one of the Tenoumer specimens. This study is partially financed by the DFG (research unit FOR-887; He-2893/8-1).

References: [1] Veksler I. et al. (2007) *J. Petrol., 48,* 2187–2210. [2] Philpotts A. R. (1982) *Contrib. Mineral. Petrol., 80,* 201–218. [3] Roedder E. and Weiblen P. W. (1970) *Geochim. Cosmochim. Acta Suppl., 1,* 801–837. [4] Zolensky M. E. and Koeberl C. (1991) *Geochim. Cosmochim. Acta, 55,* 1483–1486. [5] Osinski G. R. and Spray J. G. (2001) *Earth Planet. Sci. Lett., 194,* 17–29. [6] Hamann C. et al. (2013) *Geochim. Cosmochim. Acta, 121,* 291–310. [7] Hecht L. et al. (2013) *LMI V,* Abstract #3115. [8] Ebert M. et al. (2014) *Geochim. Cosmochim. Acta, 133,* 257–279. [9] Fazio A. et al. (2014) *Meteorit. Planet. Sci., 49,* 2175–2200.

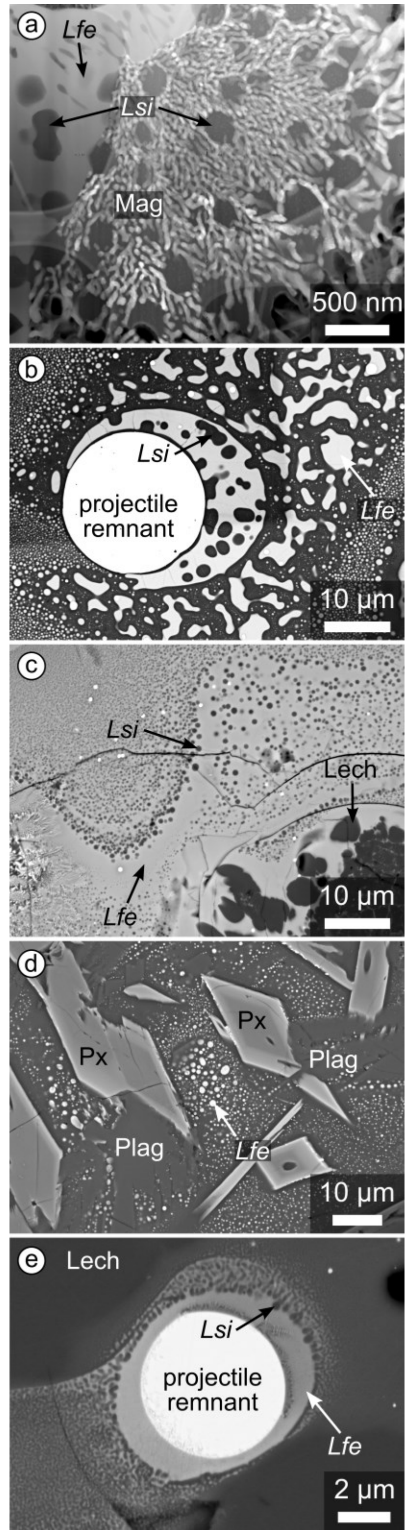

Fig. 1 (a) TEM-HAADF image showing the partially crystallized Barringer *Lsi*-in-*Lfe* emulsion; (b)–(e) BSE images showing the Wabar *Lfe*-in-*Lsi* emulsion (b), the Kamil *Lsi*-in-*Lfe* emulsion (c), the Tenoumer *Lfe*-in-*Lsi* emulsion (d), and the MEMIN *Lsi*-in-*Lfe* emulsion (e).