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An integrated CL, SEM, and optical microscopy study of carbonate impact melts in the Ries suevites

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Abstract

We present a petrographic study of fluidal-shaped carbonate blebs disseminated in pristine silicate glasses in the suevites of the Ries crater, Germany, to contribute to the ongoing discussion on the nature of such textures. In particular, cathodoluminescence imaging reveals potential nucleation sites and crystallization histories of fluidal-shaped carbonates, suggesting that they indeed represent quenched primary impact melts.

1. Introduction

One of the unique consequences of hypervelocity impacts of asteroids and comets is the production of impact melts that form during pressure release from both the projectile and specific parts of the target. While the response of silicate rocks and minerals to shock compression and decompression are well understood, the question of whether carbonates melt or decompose if released from high shock pressures (>50–70 GPa, i.e., sufficiently high to melt coexisting silicates) remains contentious [1,2]. Specifically, the canonical view that carbonates decompose upon impact has been challenged in recent years by observations on terrestrial impactites [3–5] and results from numerical modeling [6] which cumulatively suggest that calcite impact melts may indeed readily form in typical impact scenarios.

Several studies have characterized potential impact-generated carbonate melts by means of optical or scanning electron microscopy (SEM) [3–5]. The salient point of these studies is the observation of textures indicative of liquid immiscibility between carbonate and silicate melts. Here, we return to the original description of potential carbonate impact melts by [3,5] and present a cathodoluminescence (CL), SEM, and optical microscopy characterization of fluidal-shaped carbonates in the suevites of the Ries crater, Germany.

2. Results and discussion

Carbonate-bearing suevite specimen were collected by S. Siegert during several field trips to the Ries. In the present study we focus on the suevites from Aufhausen, Bollstadt, and Otting, which are known to typically and abundantly bear fluidal-shaped or globular calcite disseminated in pristine silicate impact glass [3,5]. Following thin sectioning, the suevite samples were investigated using a combination of optical microscopy, CL, and SEM methods at Museum für Naturkunde Berlin.

Textures indicative of liquid immiscibility between primary carbonate and silicate impact melts were frequently encountered in all our samples. They are similar to the textures described by [3–5] and comprise carbonate (generally calcite) globules, blebs, and schlieren in pristine silicate glass (Fig. 1a–c). Often, the carbonate shows distinct amounts of Si and Al in SEM-EDX analyses; the surrounding silicate glass is, in some cases, complementarily and locally enriched in Ca. The interfaces between the two phases are always sharp compositional and mineralogical boundaries (Fig. 1d), reminiscent of menisci formed by silicate–silicate liquid immiscibility. Interestingly, the carbonate is almost always separated from the silicate by thin rims of phyllosilicate (presumably montmorillonite; cf. [3,5]). Furthermore, sub-micrometer size crystallites of presumably Ca,Mg-rich composition have nucleated in the silicate glass close to the phase boundary (Fig. 1d). Often, pristine silicate glass exists in the form of droplets and blebs in large carbonate bodies (Fig. 1b, c); the interface between these two phases is again sharp but decorated by rims of phyllosilicate (Fig. 1e). Occasionally, textures indicative of carbonate degassing (i.e., vesicles, fading grain boundaries) were observed that are similar to those recently described by [7]; in other cases, fluidal-shaped carbonate entrained in silicate glass contains fossils similar to those encountered in the pre-impact limestone of the Ries target. The fluidal-shaped carbonate blebs often show feathery crystals habits (Fig. 2a) indicative of rapid quenching [3], and likewise feathery, predominantly orange luminescence patterns that originate from round, concentric, poorly luminescing spots that are localized close to the coexisting silicate glass (Fig. 2b). Together with the feathery crystal habit, we interpret such CL patterns as nucleation seeds from which crystallization of the material started. In the case of large carbonate blebs, we observed several of these sites, suggesting that nucleation of large volumes of carbonate started simultaneously at multiple locations. In agreement with previous studies [3,5], these findings suggest that the fluidal-shaped, feathery carbonates in the Ries suevites indeed represent quenched primary impact melts.

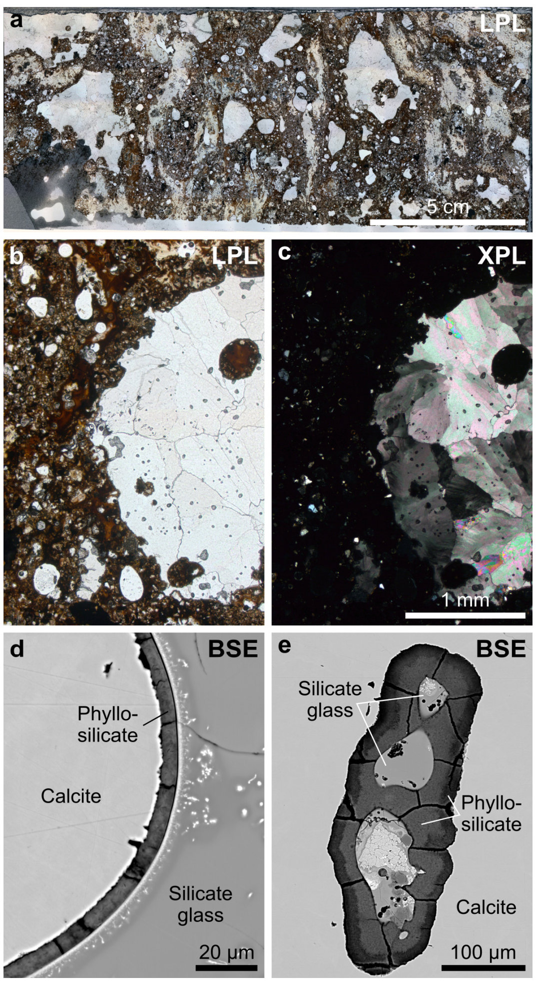

Figure 1: Optical photomicrographs (a–c) and BSE images (d, e) of carbonate impact melts in the Aufhausen suevite.

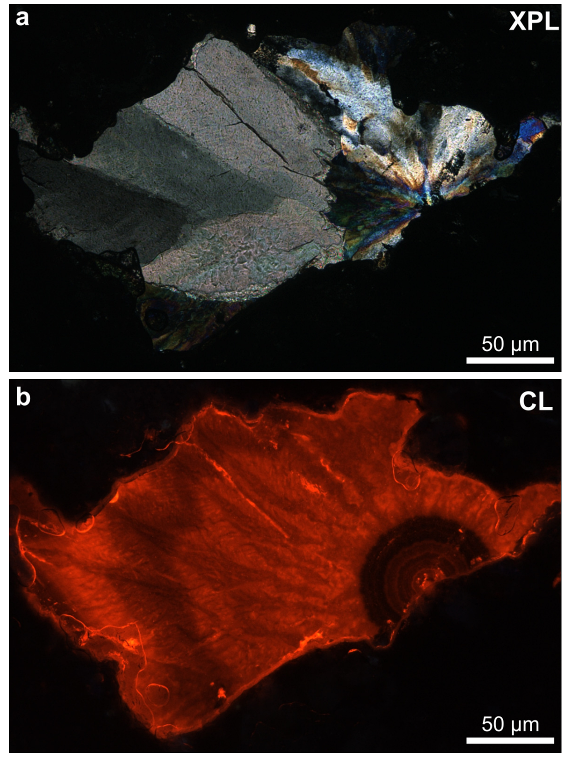

Figure 2: Optical photomicrograph (a) and corresponding CL image (b) of rapidly quenched carbonate impact melt in the Aufhausen suevite.

References

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