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High-resolution cathodoluminescence spectroscopy on shocked quartz grains

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Introduction

Meteorite impacts can have a profound effect on the (geological) environment. During an impact a crater is formed from which a large amount of material is ejected. Furthermore, rocks melt and deform under the extreme temperatures and pressures caused by the impact. Initially such an impact crater and corresponding ejecta layers can easily be identified but over time its features can fade/change. As such, it becomes more challenging to properly identify and distinguish it from other geological features based on macroscopic geometrical features. Alternatively, studying the microstructure of rocks can aid in identifying and localizing impact systems and to learn about their effects and history.

When subjected to a shockwave from an impact event or nuclear weapon detonation, specific microscopic features can form in minerals such as quartz. Planar deformation features (PDFs) in quartz are an example of a shock-induced feature. PDFs are sets of thin, closely spaced (typical spacing < 2 μm) planar features that develop parallel to particular crystallographic planes. Fresh PDFs are thin, amorphous lamellae, which can heal (recrystallize) post-impact. Healed PDFs consist of planes of high dislocation density [1] and can usually be recognized as traces of fluid inclusions. Often multiple sets of PDFs develop in a single quartz grain, with the number of sets per grain increasing with shock pressure. PDFs are usually penetrative through a whole grain, but do not cut across grain boundaries, fractures or planar fractures, unless these form at a later stage than the PDFs [2].

PDFs in quartz are considered to be one of the most reliable indicators of impact related shock metamorphism and as quartz is highly abundant and stable it forms and ideal marker for this purpose [2,3]. Proper identification and understanding of PDFs is critical however, for a correct interpretation. In particular, the inability to distinguish between PDFs and other (tectonic) deformation features in optical microscopy can be problematic. By using scanning electron microscopy and cathodoluminescence, PDFs can be properly characterized and identified at the relevant length scales, preventing misidentification.

In this note, we study two shocked quartz grains in a suevite breccia sample from the Nördlinger Ries crater in Bavaria (Germany) which formed in the Miocene 14.8 million years ago. This sample along with several other samples from other impact sites, have been studied extensively with color-filtered CL imaging by Hamers et al. in earlier work [4]. It was found that amorphous and healed PDFs can be distinguished using CL imaging [5]. Here, we expand upon these studies by performing high-resolution hyperspectral CL mapping on both amorphous and healed PDFs occurring in two grains in this sample.