QUARTZ AND CRISTOBALITE BALLEN AGGREGATES FORMED BY DEHYDRATION OF SHOCK-GENERATED AMORPHOUS PHASES IN IMPACT MELT ROCKS FROM THE RIES IMAPCT STRUCTURE (GERMANY)

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Introduction: Quartz and cristobalite ballen aggregates have been detected in impactites from a number of terrestrial impact structures, predominantly from impact melt rocks, suevites, and target rock clasts affected by high post-shock temperatures (T ≥ 1200 °C), [1], [2], [3]. They are characterized by aggregates of globular quartz and/or cristobalite that can in seldom cases contain small inclusions of coesite [4]. [2] distinguished three types of quartz ballen, which have been interpreted to crystallize at various shock pressures from an impact generated diaplectic glass that can preserve the shape of the original quartz grain and retains remnants of the original crystalline structure.

Up till now, the detailed formation mechanism of the ballen shape and especially the role of multiple phase transformations from quartz to amorphous phases and back to cristobalite and/or quartz, as well as the conditions under which the ballen form, remain still unclear [4]. The existing ballen classifications are based on the dominant phase comprising the ballen (quartz or cristobalite) and the optical extinction characteristics [2].

To elucidate their formation mechanism, ballen aggregates (Fig. 1) from impact melt rocks of the Ries structure, Germany, are analyze by polarized light microscopy, scanning electron microscopy (SEM) and Raman spectroscopy. The crystallographic orientation characteristics are analyzed by the SEM-based electron backscatter diffraction (EBSD) technique.

Samples The investigated ballen aggregates occur in impact melt rocks exposed southwest of Polsingen in the megablock zone, beyond the inner ring of the 15 Ma-year old Ries impact structure [5]. These impact melt rocks are characterized by a large amount of granitic gneiss fragments. In the granitic gneiss clasts, ballen aggregates, vesicles, and decomposed biotite are common.

Results The ballen aggregates are mostly composed of pure α-quartz and more rarely partly composed of α-cristobalite. Commonly, a rim of brownish cristobalite is surrounding ballen aggregates when it is in contact to a vesicle within the impact melt rock (Fig. 2).

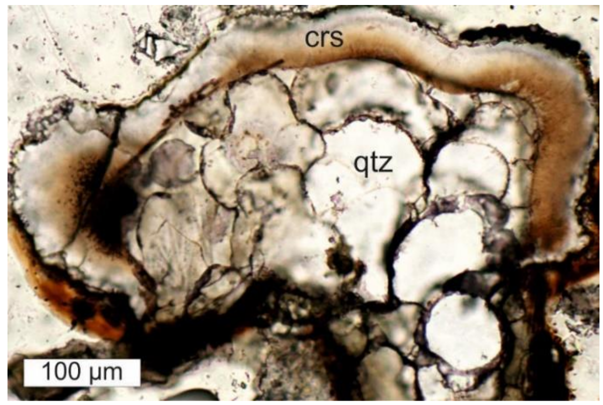

Fig. 1. Polarization microscope image of a quartz ballen aggregate (qtz). The brownish rim consists of cristobalite (crs).

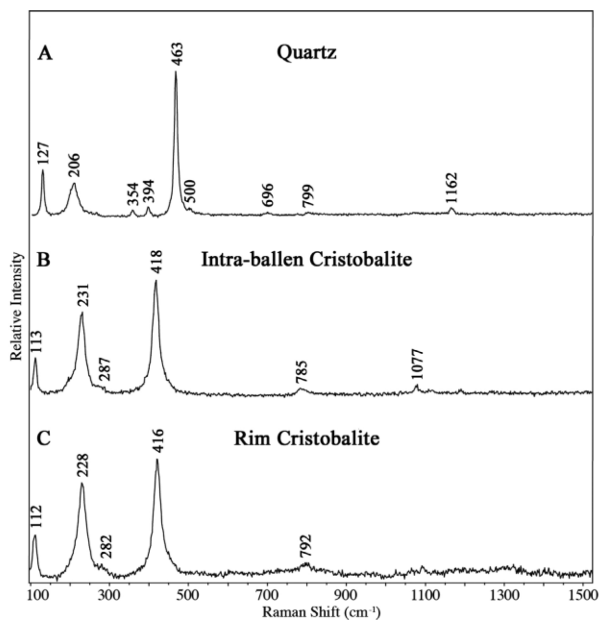

Fig. 2. Raman spectra of (A) α-quartz and (B) α-cristobalite ballen aggregates. In (C), the Raman spectra of a-cristobalite at the rim surrounding ballen aggregates in contact with vesicles are shown.

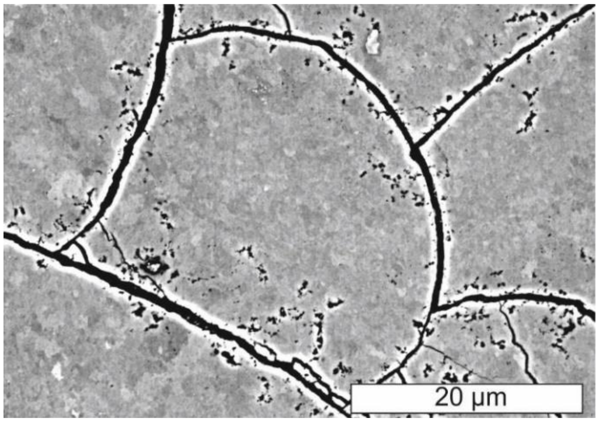

Fig. 3. Scanning electron microscope image. The quartz ballen are defined by curved fractures, associated with pores (black).

The individual ballen in the aggregates are defined by curved interfaces between each other (Fig. 3). The individual ballen are polycrystalline but commonly show one dominant orientation, as indicated by EBSD data (Fig. 4). We suggest that the investigated ballen aggregates represent former fluid-inclusion-rich quartz grains from the granitic gneiss protolith. Upon shock loading they transformed into an amorphous phase that partly retained information on the precursor structure. Volatiles from inclusions dissolved into the amorphous phase. During decompression and cooling, dehydration takes place and causes fracturing of the amorphous phase and disintegration into small globular ballen. The fluid is expelled along the curved fractures (Fig. 3). A similar formation of small globules due to dehydration of silica-rich glass is known for perlitic structures of volcanic rocks. Remnants of the precursor structure are present in the amorphous phase guided topotactic crystallization of quartz leading to the crystallographic preferred orientation (Fig. 4). Crystallization of more distorted parts of the amorphous phase led to random orientations of the quartz crystals (Fig. 4). Ballen comprised of cristobalite formed from a dehydrated amorphous phase with no structural memory of the precursor. Dendritic cristobalite exclusively occurring at the rim of quartz ballen aggregate (Fig. 1) is interpreted to have crystallized directly from a melt enriched in fluids that were expelled during dehydration of the amorphous phase [6].

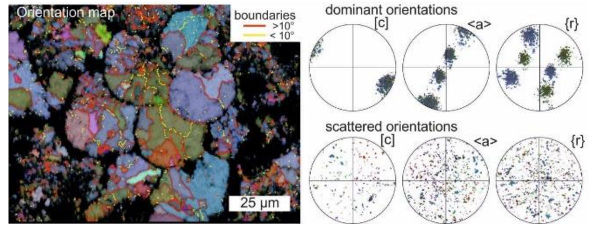

Fig. 4. Orientation map of a quartz ballen aggregates. The different colors represent different crystallographic orientations shown in the stereographic projections of the lower hemisphere. The dominant orientation is interpreted to be inherited from the original quartz grain within the granitic gneisses. "New", almost random orientations do not show any crystallographic relationship to the dominant orientation.

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References:

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