BALLEN FRACTURES IN IMPACTITES AND FULGURITES A. Chanou[1], R. A. F. Grieve[1], and G. R. Osinski[1,2] [1]Dept. of Earth Sciences/Centre for Planetary Science and Exploration and [2]Dept. Physics and Astronomy, Western University, 1151 Richmond St., London, Ontario, Canada N6A5B7 *achanou@uwo.ca

Introduction: So-called "ballen" occur in silica (most commonly quartz) clasts within microcrystalline impact melt rocks and melt-bearing breccias. Although, they are not officially considered a diagnostic shock feature their occurrence has been correlated with high pressures and an indicator for P-T paths e.g.,[1,2] Ballen is considered to be the result of the volumetric changes due to the transformation of diaplectic glass or silica melt (lechatelierite) to cristobalite and, in most cases, ultimately quartz [2,3]. Ballen texture can be described as arcuate fractures that develop successively and terminate on each other and is usually treated as a growth texture [2,4]. Contemporaneously the usage of the term "ballen", has pointed to a stereological description of the shape as being consisted of spherical domains. Although, this may be true, three dimensional shapes are yet to be observed and true shapes could be any shape the section of which appears sub-circular on a surface projection. In this study we present ballen textures from impactites and fulgurite samples.

Samples and methods: Samples include impact melt-bearing breccias from the Popigai (Russia), Deep Bay (Canada) and Mistastin (Canada) impact structures. Fulgurite samples are from the fulgurite event of Torre de Moncorvo, Portugal. The Torre de Moncorvo fulgurite was formed after lighting struck a small electricity pylon and its base material of granitic composition [5]. The fulgurite is mainly composed of glass and consists of radial and axial facies, with the axial facies being the primary discharge path [5].

Observations:

Ballen texture was observed in both the impactites and fulgurite samples. The average size for individual ballen domains differ between the fulgurites and impactites. Fulgurite ballen domains are on average smaller than their impactite-occurring counterparts. Individual ballen domains are commonly less than 10 μm. Impactite-occurring ballen show a wider range of sizes (i.e., a few microns to ~ 100 μm) Fig.1,2. Fulgurite ballen is always in association with the fulgurite glass in both the axial and radial facies.

All ballen in the impact breccias was observed in quartz inclusion clasts within the vitric clasts and have large shape variations [2], from sub-circular to tabular in the same silica clast and appear to propagate in a similar manner to a strain-releasing fracturing network.

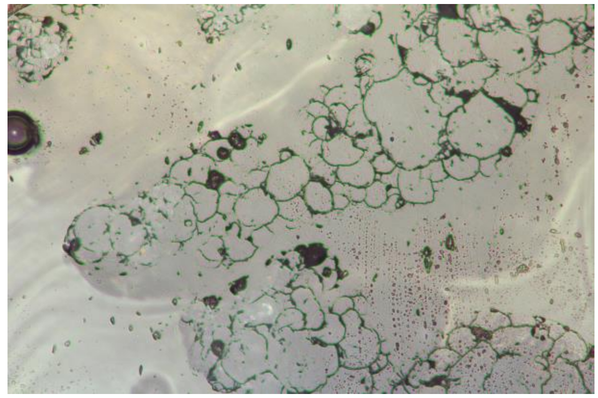

Figure 1: Reflected light image of ballen texture in the Torre de Moncorvo fulgurite (Portugal). Noticeable size and shape variability. Field of view is approx. 400μm

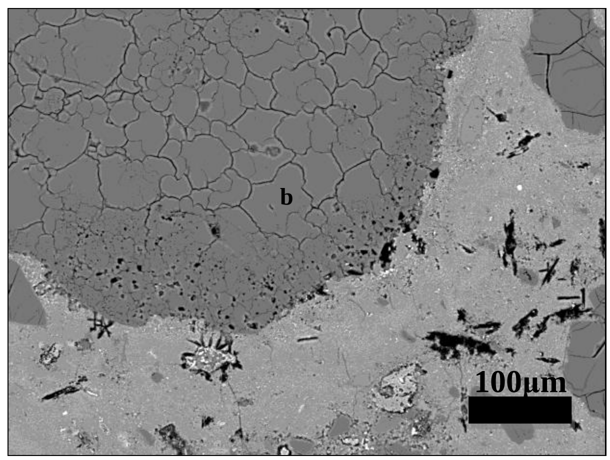

Figure 2: BSE image of ballen bearing clast in impact melt-bearing breccias from Popigai impact structure. **a**) Impact-melt sourced material comprising the vitric clast. **b**) Silica clast showing ballen texture. Notice the great shape and size variation of ballen domains.

Shock induced planar deformation features (PDFs) occur in several ballen bearing textured quartz clasts from the different impact structures. The PDFs appear to co-exist and cross-cut ballen boundaries being continuous across the ballen cracks Fig.3. The co-existence of ballen and PDFs has also been reported by [6] in samples from the Deep Bay impact structure, as well as [7], with the latter being relatively poorly documented.

Discussion: Ballen texture occurs exclusively in association to silicate glass or impact melt. In both cases of the impactites and fulgurite, the target silica clast was rapidly heated and cooled. In the event of the impactite, in particular, when “cold” quartz clasts are incorporated in initially superheated impact melt, they experience extremely rapid heating. Additional and continuous incorporation of cold fragmented target material rapidly cools down the impact melt, while melt fragments (in the case of impact melt-bearing breccias) undergo fast radiative, as well as conductive cooling due to clast load, melt disaggregation and incorporation in particulate groundmass. Overall, this fast cooling process leads to a secondary rapid cooling thermal shock or “cold” thermal shock event. Ballen texture shows characteristics of a hierarchical fracturing network with successive fracturing and different levels of maturity. Larger ballen domains appear to contain the development of secondary and (occasionally) sub-secondary fractures Fig.2. We suggest that the degree of circularity (or how well developed is the texture) depends on the temperature and time, rather than pressure. The co-existence of PDFs with ballen is suggestive of an alternative (and/or additional) formation mechanism that does not require an amorphous stage and phase changes. PDFs are crystallographically controlled features that would have been destroyed through an amorphous stage and phase changes. Apart from PDFs being present they appear to be continuous across the individual ballen fractures Fig,3.

Conclusions: The observations here indicate that ballen is a network of hierarchical physical fracturing, in response to the accumulation and release of internal stress (on a grain scale) as a result of sudden thermal shock. Micro-cracking of quartz has been recorded by acoustic emission near the α/β transition in experiments, with much lower thermal extremes and rates than that of clast incorporation in impact melt [8]. PDF-bearing ballen has not undergone phase transitions higher than the α/β quartz and is direct evidence to the mechanical behavior of quartz under extreme changes in thermal conditions. Ballen do occur in silica that has gone through phase changes (e.g., cristobalite, amorphous) but such a phase transition may not be a necessary pre-requisite. Finally, these observations suggest that the formation of ballen in quartz can be solely a thermally induced texture and its occurrence does not reflect directly, or indirectly, information on shock pressures levels. That is, the occurrence of ballen in quartz may be a characteristic of some impactites but it can clearly occur in other settings of extreme thermal shock, such as that of fulgurite formation.

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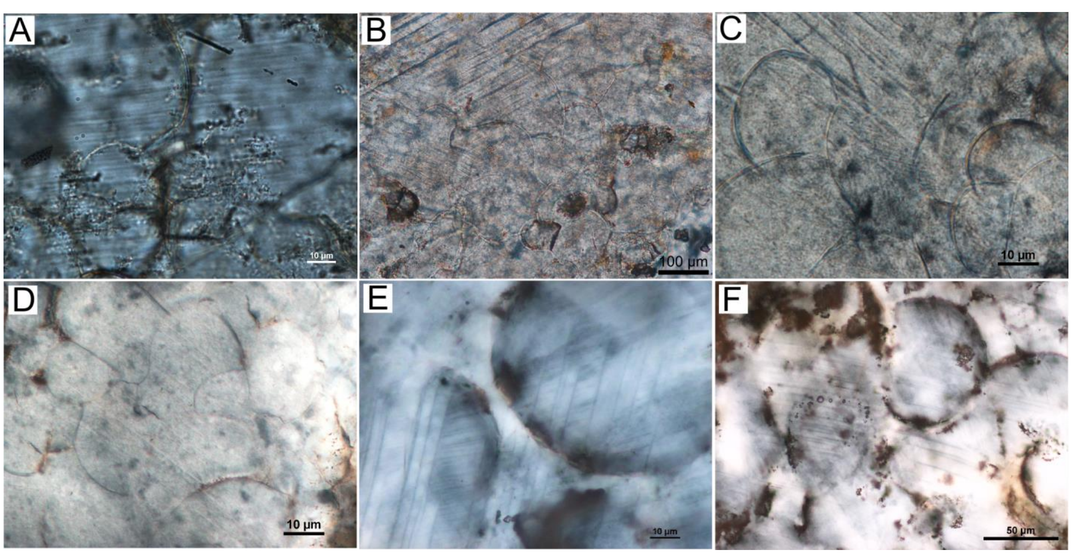

Figure 3: Photomicrographs of planar deformation features (PDFs) in ballen clasts. A: PDF-bearing clast from Mistastin, plane polarized light (PPL); B-D: PDF-bearing clast from Popigai, PPL and conoscopic illumination. E and F: PDF-bearing clasts from Deep Bay, PPL and conoscopic illumination.