NEW OBSERVATIONS OF SHOCK-METAMORPHIC EFFECTS IN MINERALS FROM SHATTER CONES. L. Ferrière and G. R. Osinski, Department of Earth Sciences, University of Western Ontario, 1151 Richmond Street, London, ON, N6A 5B7, Canada (ludovic.ferriere@uwo.ca).

Introduction: Shatter cones are the only diagnostic evidence of hypervelocity impact that develop on a macro- to megascopic scale [e.g., 1]. They have been reported for more than half of the currently 177 proven impact structures on Earth, in extremely different lithologies, with large variations of cone size (cm to m), and generally occurring *in-situ* only in the central part of the impact structure. In a few cases, shatter cones occur within clasts in crater-fill impact breccias and melt rocks, and also, rarely, within megablocks of the ballistic ejecta blanket [e.g., 2,3]. Different models for their formation exist in the literature [4-9], but none of them account for all of the current field observations of shatter cones [2,3,9]. Surprisingly, very few studies of shock-metamorphic effects in minerals associated with shatter cones have been conducted [e.g., 3,10].

We report here on detailed petrographic investigations of shatter cone samples from the Charlevoix, Haughton, and Keurusselkä impact structures. This work is part of an ongoing study of shatter cones from several impact structures, combining observations on the occurrence, distribution, and characteristics of shatter cones at the scale of the impact structure with macroscopic and microscopic observations of (shocked) minerals, to infer the course of events that result in the formation of shatter cones [3].

For the first time, quantitative investigations of the distribution of shocked quartz grains within shatter cones, at the thin section scale, are presented. The abundance and crystallographic orientations of planar deformation features (PDFs) in quartz grains, based on universal stage (U-stage) microscope examination [11], was also studied to estimate the peak shock pressure recorded by the different samples.

Results and discussion: The shatter cones studied here developed in gneiss at Charlevoix, in sandstone at Haughton, and in orthogneiss at Keurusselkä. Our petrographic study confirms that shatter cones from these three impact structures display a large number of micro-deformation features, including random penetrative fractures, kink bands (mainly in micas and rarely in quartz and feldspar grains in samples from Charlevoix), planar fractures (PFs) and PDFs in quartz grains (Fig. 1a). Feather textures are also commonly observed in quartz grains from Charlevoix and Haughton (Fig. 1b).

Detailed U-stage investigations were completed for samples from the three cited impact structures (Fig. 2). In the case of the samples reported in Fig. 2, we estimate that they experienced peak shock pressures comprised between ~10 to 20 GPa. However, considering that for some other investigated samples no PFs and/or PDFs were observed, much lower shock pressures, probably as low as a few GPa, was enough to induce shatter cone formation. Together, these observations, imply that where shatter cones form, the shock wave that propagates through the target rocks is likely highly scattered, refracted, and/or reflected, even at the outcrop scale.

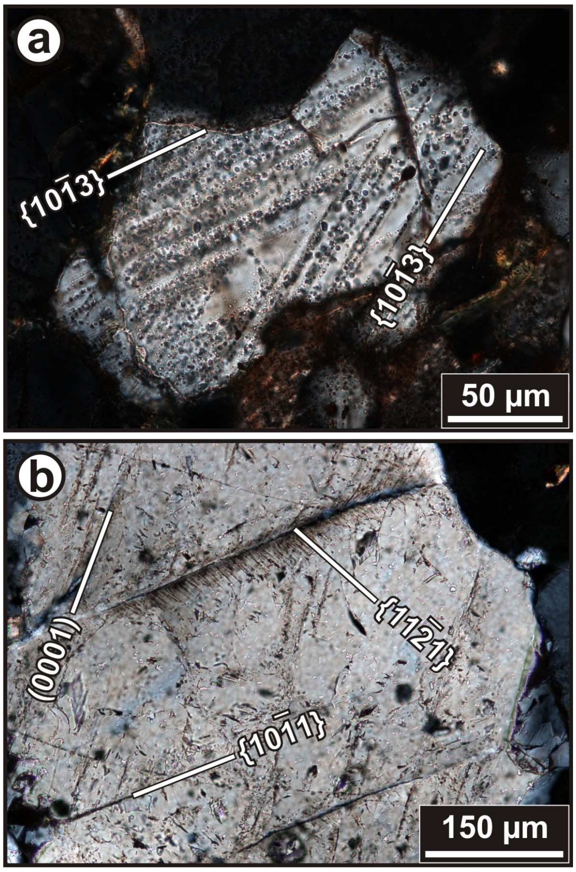

Fig. 1: Photomicrographs (crossed polars) of shocked quartz grains in shatter cone samples. a) Grain with two sets of highly decorated PDFs (orthogneiss sample VN3B from Keurusselkä). b) Grain showing a combination of two sets of PF parallel to c(0001) and $\{10\bar{1}1\}$, and feather features with $\{11\bar{2}1\}$-equivalent orientation (sandstone sample 08-012b-4 from Haughton).

Our detailed mapping of shocked quartz grains at the thin section scale, as illustrated in Fig. 3, shows that shocked minerals are heterogeneously distributed within shatter cone samples. In the case of the thin section map shown in Fig. 3, a total of 329 shocked quartz grained were mapped; their distribution, from the cone surface to within the sample is as following: 0.3 shocked quartz grains per mm^2 between 0-5 mm, 0.5 and 0.4 between 5-10 and 10-15 mm, and 0.6 between 15-20 mm.

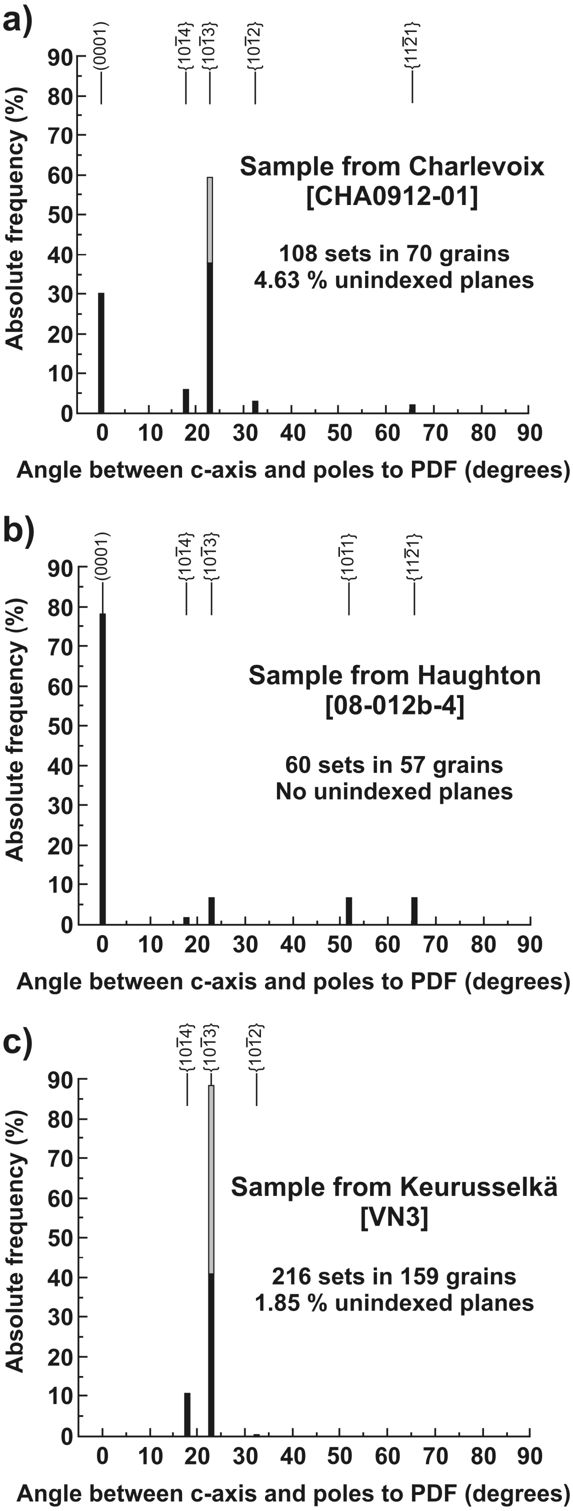

Fig. 2: Histograms of the absolute frequency percent of indexed PDFs in quartz grains from three shatter cone samples, as determined using the new stereographic projection template for the indexing [11]. a) Gneiss sample from Charlevoix. b) Sandstone sample from Haughton. c) Orthogneiss sample from Keurusselkä. PDF planes falling into the overlap zone between $\{10\bar{1}4\}$ and $\{10\bar{1}3\}$ crystallographic orientations are reported in gray on top of the uniquely indexed $\{10\bar{1}3\}$ orientations.

This result is important since it is in total disagreement with what is currently recognized in the literature, namely that PFs and/or PDFs occur in minerals only within 1–2 mm of the cone surface [e.g., 9,12].

Finally, no glassy venners, as reported for shatter cones from Beaverhead [12] and Vredefort [9], were observed in any of the investigated samples.

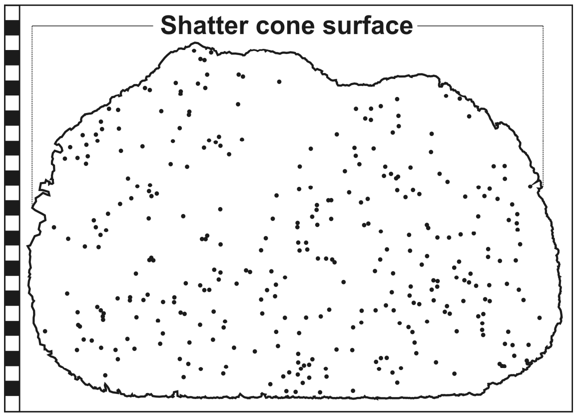

Fig. 3: Thin section map of a shatter cone sample showing the distribution of the shocked quartz grains (all grains larger than 75µm with PFs and/or PDFs are marked with black dots). Note the heterogeneous distribution of the shocked quartz grains at the scale of the thin section (gneiss sample CHA0912-01 from Charlevoix). Scale in mm.

Conclusions: Our study shows that shatter cone samples record variable peak shock pressures, from a few GPa up to ~20 GPa, and that shocked minerals are heterogeneously distributed within shatter cone samples. These new observations provide some important insights into the mechanism of shatter cone formation and they pose some problems for the different proposed models [4-9].

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