THE KEURUSSELKÄ STRUCTURE (FINLAND) – IMPACT ORIGIN CONFIRMED BY UNIVERSAL-STAGE CHARACTERIZATION OF PLANAR DEFORMATION FEATURES IN QUARTZ GRAINS. L. Ferrière[1], S. Raiskila[2], G. R. Osinski[1], L. J. Pesonen[2], and M. Lehtinen[3], [1]Department of Earth Sciences, University of Western Ontario, 1151 Richmond Street, London, ON, N6A 5B7, Canada (ludovic.ferriere@uwo.ca), [2]Department of Physics, P.O. Box 64, 00014, University of Helsinki, Finland, [3]Kastevuorenkuja 3 I 152, 02360, Espoo, Finland.

Introduction: A total of eleven proven impact structures are recognized in Finland [1], but most of them remain relatively poorly studied, including the most recently-discovered Keurusselkä structure. The Keurusselkä structure was suggested as being of meteorite impact origin, with the discovery of conical fracture surfaces interpreted as shatter cones in Paleoproterozoic rocks [2,3]. The structure, located in central Finland, ~220 km north from Helsinki, is named after the large Keurusselkä lake which is in part included in the supposed limit of the impact structure. The original diameter of the Keurusselkä impact structure is uncertain because of intense erosion, but is estimated to be on the order of ~30 km [4] with a centre located at ~62°08'N, 24°37'E [3].

We report here on detailed petrographic and shock metamorphic investigations of *in-situ* shatter cone samples from two places, namely Jylhänniemi (KE) and Valkeaniemi (VN), located within the Keurusselkä structure. The purpose of this study is to provide observations on the occurrence and petrographic properties of shocked minerals (mainly quartz) within shatter cone samples, as well as the abundance and crystallographic orientations of planar deformation features (PDFs) in quartz grains based on universal stage (U-stage) microscope examination.

Our investigations were motivated by the aim to confirm the impact origin of the Keurusselkä structure and to estimate the peak shock pressure recorded by the shatter cone samples. This is particularly timely as a recent paper by Kinnunen and Hietala [5] has called into question the impact origin for this structure at which no microscopic feature unique to shock metamorphism has been reported for *in-situ* samples. This study also represents part of an ongoing study of shatter cones from several terrestrial impact structures.

Results and discussion: The six investigated shatter cone samples from site "KE" consist of fine-grained granodiorite whereas the one from site "VN" consists of orthogneiss. Our petrographic investigations show that different types of planar microstructures occur in quartz grains (Fig. 1) and also in a few plagioclase feldspar grains; namely planar fractures (PFs) and PDFs. The PDFs in quartz grains rarely occur as narrow planes of amorphous material, but more commonly as bands of aligned tiny fluid inclusions (decorated PDFs; Fig. 1), spaced 2–10 µm apart. The PDFs commonly occur as multiple sets per grain, generally 2 sets (Fig. 1a), and up to 3 to 5 sets when seen under U-stage. The PDFs are generally decorated with tiny fluid inclusions, usually less than 1-2 µm in diameter (in some cases up to 3–4 µm). The fluid inclusions are globular to elongate in shape, or with the shape of negative crystals, and they commonly contain two phases (a liquid and a vapor phase).

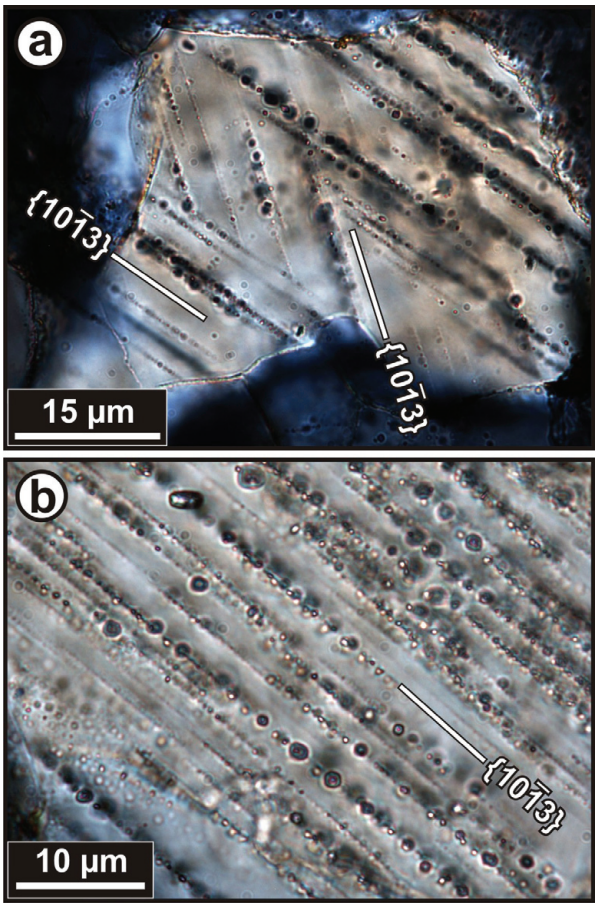
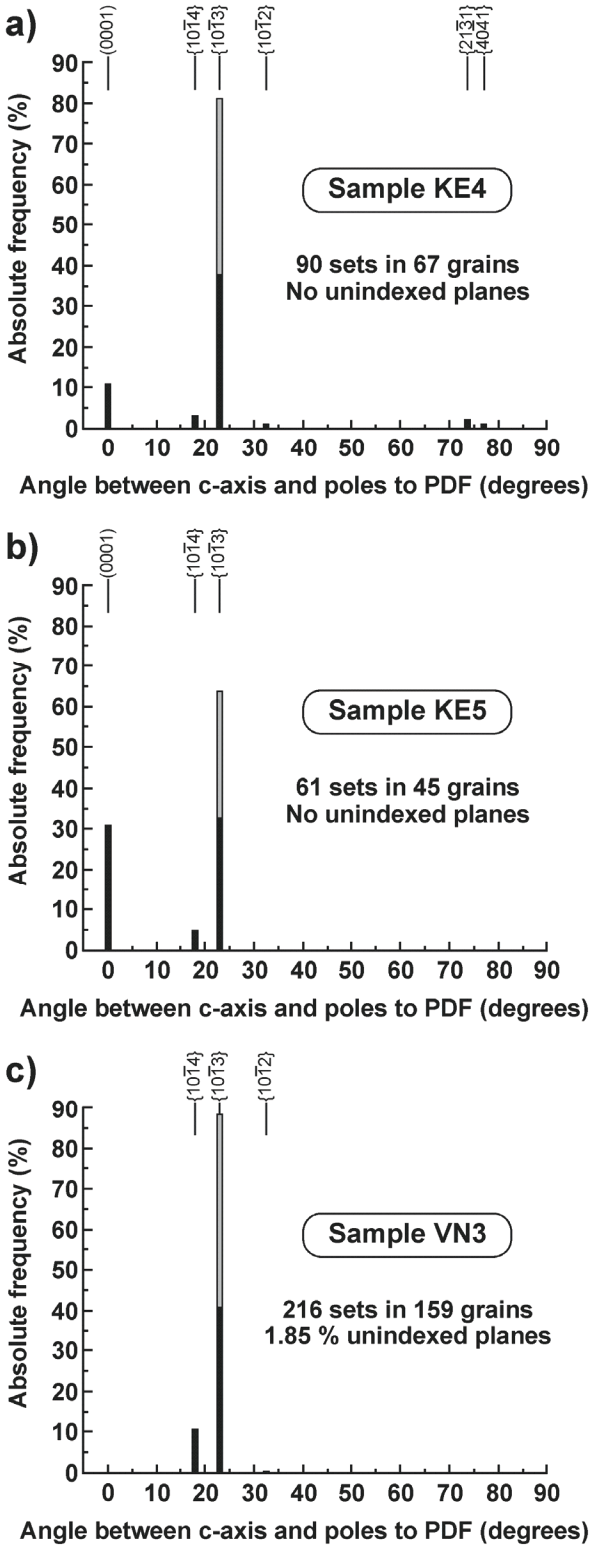


Fig. 1: Photomicrographs (in cross-polarized light) of shocked quartz grains in shatter cone sample VN3 from the Keurusselkä impact structure. a) Quartz grain containing two decorated PDF sets with ω{10$\bar{1}$3}-equivalent orientations. b) Highly decorated PDF set with ω{10$\bar{1}$3}-equivalent orientation.

The crystallographic orientations of 372 PDF sets in 276 quartz grains were measured for the five dis-

tinct samples showing PDFs in quartz. Results for the three samples in which enough PDFs were measured in respect to reach an acceptable level of precision [6] are shown in Figure 2.



A large proportion of all the poles to the PDF planes are oriented at ~23° to the c-axis, corresponding to the ω{10$\bar{1}$3} orientation, but large differences occur in terms of PDF crystallographic orientations and relative abundances between the three samples (Fig. 2). However, surprisingly, the number of PDF sets per grain is almost exactly the same, ~1.35 for the three samples. Our study shows that the investigated samples have experienced somewhat different peak shock pressures; samples KE1 and KE3 were subject to shock pressures ranging between ~2 and 5–8 GPa, as no PFs were observed in quartz grains from these samples; samples KE2, KE4, KE5, KE6, and VN3 were subject to shock pressures ranging between 12–20 GPa. Based on the results shown in Figure 2, we can further estimate that sample VN3 was shocked at relatively higher pressure than samples KE4 and KE5.

Conclusions: (1) The occurrence of PFs and PDFs in quartz and in plagioclase grains substantiates an impact origin for the Keurusselkä structure. (2) Based on our U-stage measurements of the PDFs orientations in quartz grains, we can estimate that the investigated shatter cones samples have experienced peak shock pressures comprised between about 2 GPa to slightly less than 20 GPa for the more heavily shocked samples. (3) The decoration of most of the PDFs indicates that these originally amorphous shock features were altered by post-impact processes, such as hydrothermal activity. (4) Based on our field observations, it is clear that a large part of the uppermost part of the impact structure was removed by erosion, and thus, that the exposed surface corresponds to the shocked basement.

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Fig. 2: Histograms of the absolute frequency percent of indexed PDFs in quartz grains from three shatter cone samples (KE4, KE5, and VN3, respectively), as determined using the new stereographic projection template for the indexing [6]. PDF planes that fall 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.