SHOCK METAMORPHISM IN BASEMENT ROCK SAMPLES FROM THE CARSWELL IMPACT STRUCTURE, CANADA. J. Epstein[1], L. Ferrière[1,2] and C. Koeberl[1], [1]Department of Lithospheric Research, University of Vienna, Althanstrasse 14, A-1090 Vienna, Austria (a01548614@unet.univie.ac.at), [2]Natural History Museum Vienna, Burgring 7, A-1010 Vienna, Austria.

Introduction: The Carswell impact structure, ~39-km-diameter and 481.5 ± 0.8 Ma, is located in the northwestern part of the Proterozoic to Mesoproterozoic Athabasca sandstone basin, in the northern Saskatchewan province, Canada [1-3]. Economic interests have led to intensive exploration activities, during which numerous drilling campaigns were completed, as well as open pits and underground mining for the extraction of uranium ore. Its high level of erosion provides a great opportunity to explore the crater subsurface, especially its ~18-km-wide uplifted basement composed of Archean to Paleoproterozoic gneiss units [4]. A large variety of impactites, including shocked basement rocks (with shatter cones), impact (melt-bearing) breccias, impact melt rocks, and pseudotachylite veins have been reported at Carswell [2-5]. Interestingly, not much has been published about shock metamorphism in the impactites of the Carswell structure, although its origin was confirmed as early as 1967 by the discovery of quartz grains with multiple sets of planar deformation features (PDFs).

Here we report microscopic observations of shock metamorphic effects in gneiss samples from the basement of the Carswell structure. We have focused our efforts on the crystallographic orientation of PDFs in quartz to estimate the shock pressure recorded by the investigated samples, with the goal to better constrain the level of erosion and the original size of the impact crater.

Material and Methods: Eleven (polished) thin sections (representing eight different samples) were prepared from gneiss samples from the basement of the Carswell structure. All samples are from the drill core CAR103 recovered near the center (at N58°26'/W109°30') of the Carswell structure by AMOK (Canada) Limited in 1974. Samples were taken at regular intervals between 9.9 and 143.6 m below the present surface. The sample nomenclature used is Core#-Depth# (with depth below the present surface in meters). All thin sections were first investigated using the polarizing microscope, and three of them (i.e., CAR103-9.9, CAR103-61.0, and CAR103-129.5) were further investigated using the Universal stage (U-stage) microscope. The same three thin sections were furthermore studied for possible shock metamorphic features in other minerals by using the scanning electron microscope (SEM) at the Natural History Museum Vienna.

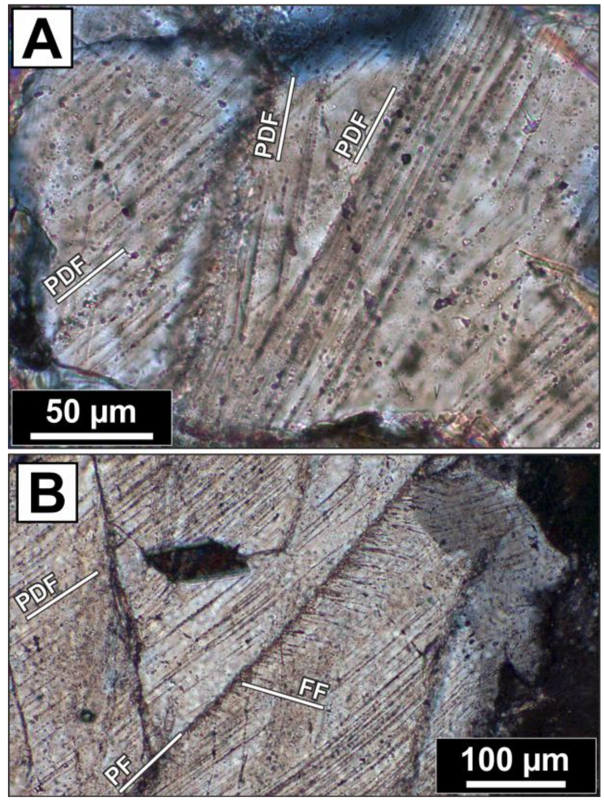

Fig. 1. Microphotographs (cross-polars) of shocked quartz grains in gneiss (CAR103-9.9). A) Three sets of decorated PDFs. B) One set of PDFs and one set of PFs with FFs.

Results: All investigated gneisses are dominated by highly shocked (Fig. 1) and often toasted quartz grains. Feldspars, mostly microcline and plagioclase, garnet, as well as phyllosilicates, including biotite and muscovite, also occur. Phyllosilicates often occur within fractures and around grain boundaries, especially around garnets. Locally, micas (mainly muscovite) show kink banding. The garnet component decreases with depth while the degree of chloritization of phyllosilicates, mostly biotite, increases. Accessory minerals include monazite, rutile, apatite, zircon, and iron sulfides, such as pyrite, chalcopyrite, and rare Fe-Ni-sulfides, as well as graphite.

Quartz grains show a large number of (decorated) PDF sets, as well as planar fractures (PFs) and feather features (FFs) (Fig. 1). Under the U-stage, a few grains with up to ten sets of PDFs were identified. The crystallographic orientations of 395 PDF sets were measured in a total of 73 grains in three different thin sections, which gives an average of 5.4 sets/grain. Grains with five sets of PDFs represent on average 29% of the total, whereas the quartz grains with six and four sets of PDFs represent on average 21% and 16% of the total, respectively. No quartz grains with one set and only one single grain with two sets of PDFs were seen during our U-stage work. In all three samples, between 30 and 40% of the PDFs are oriented parallel to the ω{10-13} orientation, while about 15% of the PDFs in each sample are oriented parallel to {10-14} and π{10-12} orientations, respectively (Fig. 2). Only minor differences in the relative abundances of the different orientations are seen between the three investigated samples (Fig. 2). Further documentation of the PDFs with the SEM shows that they are decorated with tiny vugs or fluid inclusions with a diameter of <1-3 µm.

Discussion and Conclusions: To our knowledge this is the first report of FFs in quartz grains at Carswell, allowing to add it to the list of confirmed impact structures at which this low-shock-pressure indicator was observed [6]. This study is also the most detailed one on shock features in quartz grains from basement rocks from the Carswell impact structure. Based on our U-stage results, and following the shock pressure estimation model of [7], the investigated samples record average shock pressures between ~18 and 20 GPa. Furthermore, a number of the PDFs are decorated with vugs or tiny fluid inclusions (Fig. 1), indicating that the PDFs were subjected to a postshock thermal episode.

We plan to investigate additional gneiss samples recovered from other sectors of the Carswell structure to map the “lateral” shock attenuation, which is expected with increasing distance from the center of the structure (i.e., no “vertical” shock attenuation with increasing depth was seen in this work due to the limited vertical section, i.e., 120 m in total, that was investigated).

Acknowledgements: A. Deutsch is acknowledged for the donation of the samples that were used for this study. Thanks to G. Batic for the preparation of the thin sections.

References: [1] Currie K. L. (1967) *Nature, 213,* 56–57. [2] Currie K. L. (1969) *Geological Survey of Canada Paper, 67-32,* 60 p. [3] Alwmark C. et al. (2017) *GSA Bulletin, 129,* 1442–1449. [4] Genest S. et al. (2010) *GSA Special Paper 465,* 543–570. [5] Hilke C. (1991) Unpublished Ph.D. thesis, Westfälische Wilhelms-Universität Münster, Germany, 188 p. [6] Poelchau M. H. and Kenkmann T. (2011) *J. Geophys. Res., 116,* B02201. [7] Holm-Alwmark S. et al. (2018) *Meteoritics & Planet. Sci., 53,* 110–130. [8] Ferrière L. et al. (2009) *Meteoritics & Planet. Sci., 44,* 925–940.

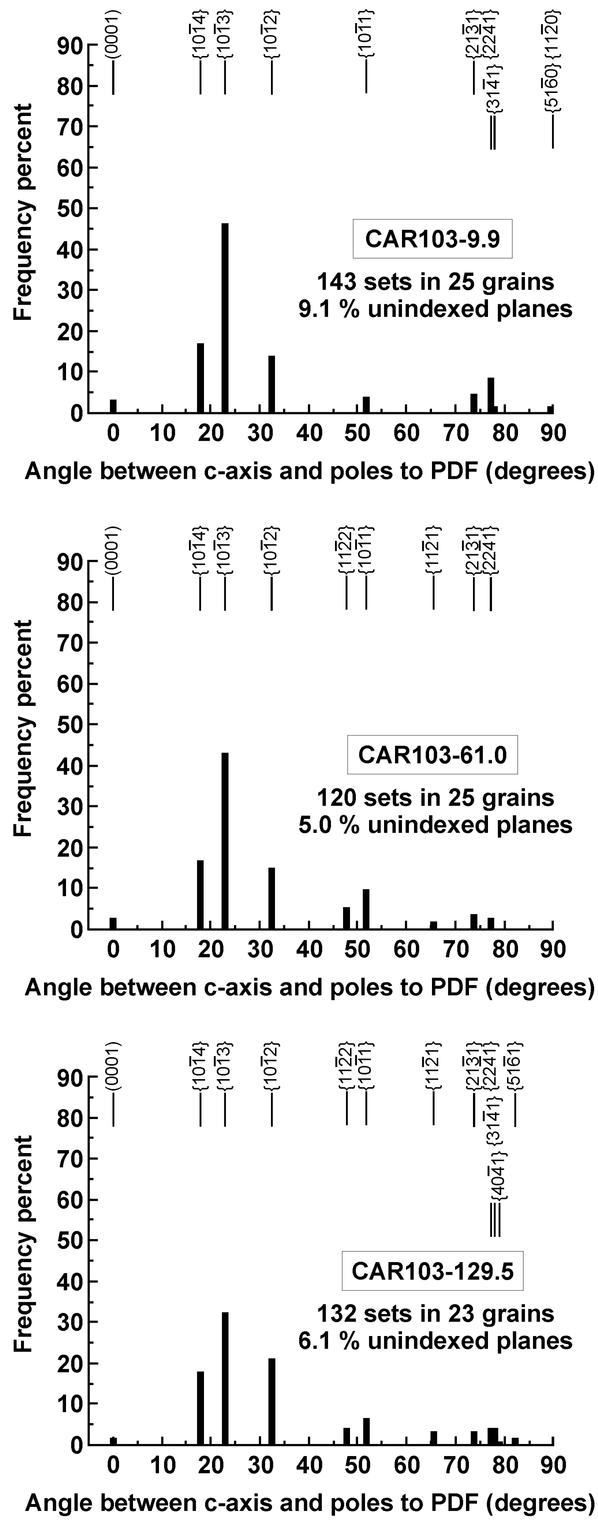

Fig. 2. Histograms of the absolute frequency percent of indexed PDFs (recalculated to 100% without unindexed PDF orientations) in quartz grains from thin sections CAR103-9.9, CAR103-61.0, and CAR103-129.5, as determined by following recommendations in [8].