PLANAR DEFORMATION FEATURES FROM THE ONAPING FORMATION OF THE SUDBURY IMPACT STRUCTURE, CANADA. D. Anders[1], G. R. Osinski[1] and R. A. F. Grieve [1,2], [1]Dept. of Earth Sciences/Centre for Planetary Science and Exploration, Western University, Canada (dander53@uwo.ca, gosinski@uwo.ca), [2]Earth Sciences Sector, Natural Resources Canada, (rgrieve@nrcan.gc.ca).

Introduction: Planar deformation features are single or multiple sets of parallel and narrow (spacing of 2–10 µm) lamellae, composed of amorphous silica glass [1], and provide diagnostic criteria for impact events. PDFs in quartz were first discovered and measured within the Onaping Formation by French (1967) [2], who, thus, provided evidence for an impact origin for this enigmatic lithology and, by extension, the Sudbury structure. However, units like the Onaping Intrusion, which is an impact melt rock, possess few PDFs [3, 4]. Some have been measured within the frame of a Bachelor Thesis by Brillinger in 2011 (unpublished). This study focused on the search, documentation and measurements of additional PDFs within the Onaping Intrusion.

Samples and Analytical Methods: A total of 41 thin sections of the Onaping Intrusion collected in the Summer 2010 from the Joe Lake area [4] were available. Fourteen thin sections were selected based on the existence of quartz clasts. Detected PDFs were documented and photographed by using a Nikon polarized microscope. Measurements of the crystallographic orientations of the quartz grain c-axis and the orientation of PDFs were carried out using an XY universal stage microscope. The obtained data was indexed using the ANIE program [5]. Specific conditions for the indexing were [5]:

- An angular error of 5% was indicated, which describes the distance from a crystallographic axis that is still considered an indexed plane.
- For indexed planes within the overlaped zone between {1013} and {1014} the orientation with the lowest error was used.
- Indexing is based on the average value of the data.

Observations: The search for PDFs proved to be difficult. Few PDFs were detected and some of them could not be measured, as they were located beyond the central area of the thin section accessible for the universal stage measurements. Despite this, 36 sets within 24 grains were measured.

The samples consist of igneous textured, typical Onaping Intrusion, composed of a matrix characterized by an intergrowth of quartz and feldspar. The matrix contains clasts, some of which consist of quartz ranging from xenocrysts of several 100 µm to tiny grains of 10 µm in size. The quartz minerals are sometimes characterized by a grainy, brownish surface appearance and contain a lot of inclusions. Quartz grains exhibiting PDFs are mostly larger than 200 µm and occur within clasts or clusters of quartz minerals; no PDFs in quartz grains forming the igneous matrix of the Onaping Intrusion were detected. Two of the analysed quartz grains exhibit undulose extinction and, thus, possess more than one crystallographic c-axis.

PDFs within the Onaping Intrusion always occur as decorated PDFs; they are covered by small inclusions and sometimes annealed. They are in general weakly to moderate developed and mostly present as one set, up to a maximum two sets, per grain (Fig. 1). The histograms, created by the program ANIE, show a broad distribution of the angle between c-axis and poles, as well as PDF orientation. The most abundant Miller-Bravais Indices are {1011} at 14% and {1013} at 11%. Only 3 analysed PDFs were unindexed, which make up 8.3% of all measurements.

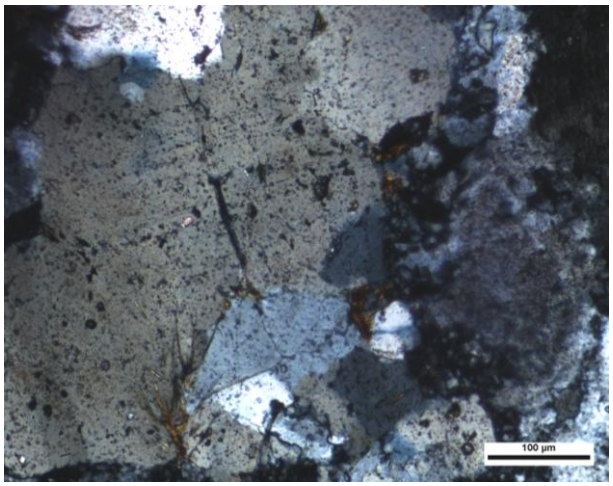

Figure 1: Microscopic picture (crossed polars) of one set of decorated to highly annealed PDFs within a quartz grain of sample SBD 024.

Interpretation: The detection of additional PDFs within the Onaping Intrusion confirms the hypothesis of it being an impact melt rock, as postulated by Brillinger [4]. The presence of exclusively decorated PDFs points to post-impact alteration processes. Decorated PDFs are secondary features formed as a result of post-impact annealing and alteration of fresh, non-decorated PDFs leading to a complete exsolution of the amorphous silica

lamellae [1, 6]. Compared to the data obtained by Brillinger (unpublished), where the angles between c-axis and poles of PDFs only range from 0 to 51°, the angles from this study show a wide distribution from 5 to 90°. Brillinger noted the dominant angle between 21 and 25°, with ~13% of frequency; whereas, in this study the majority of PDFs display an angle of 75-80° with 11%, followed by 70-75°, 80-85°, 20-25°, and 55-60°, in each case with 8%.

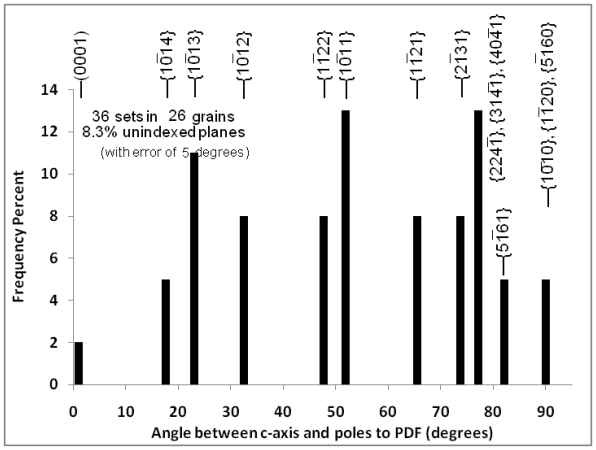

Figure 3: Histogram showing the absolute frequency percent of indexed PDFs.

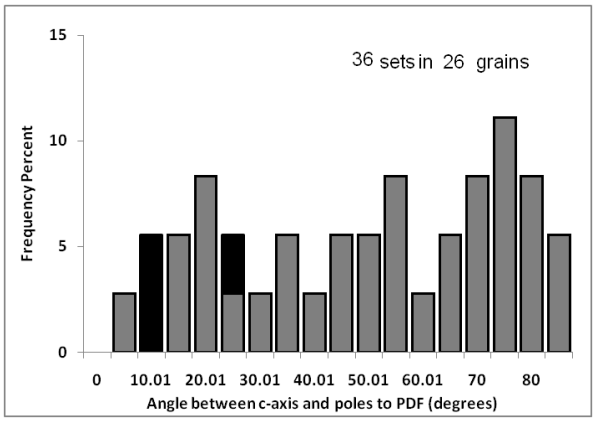

Figure 4: Histogram showing the absolute frequency of the angle between c-axis and poles to PDF (indexed planes in grey, unindexed planes in black).

The detection of Miller-Bravais Indices {1012}, {1013}, {1122} and {1122} suggest that the Onaping Intrusion contains strongly shocked material between a pressure range of 20 to 25 GPa or more at ambient temperatures. Based on the results of shock experiments of quartz at ambient temperatures and high pressures, the crystallographic orientation of PDFs varies with shock pressures and post-shock temperatures [7]. PDFs with orientations corresponding to {1013} are most abundant at 20 GPa and their frequency decrease with increasing pressure while {1122} only occur at 20 GPa, {1122} only at 25 GPa and {1012} at pressures of at least 25 GPa [7]. The small number of detected PDFs and the existence of mainly 1 set per grain also point to shock pressures of 20 to 25 GPa [7]. However, it is interesting to note that a wide distribution of angles ranging from 5 to 90°, as documented in this study, has only been seen in experiments of preheated quartz to temperatures of 630°C; whereas, all above mentioned features were carried out in experiments at ambient temperatures [7].

Conclusions: This work is the first detailed study of shock metamorphic features in the Onaping Intrusion at the Sudbury impact structure, Canada. Based on these observations, the Onaping Intrusion has been exposed to distinctive post-impact alteration and annealing processes. Miller-Bravais indices indicate a high pressure range of 20 to 25 GPa and ambient temperatures or probably preheated temperatures of 630°C.

The total number of PDFs is probably too low to make accurate statements about pressure and temperature conditions. Although the number of unindexed PDFs is with 8.3% quite low, mainly quartz grains with only one set of PDFs were detected and measured, which cannot be uniquely indexed.

This study was supported by NSERC, CSA, and MDA through their Industrial Research Chair support to GRO.

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