Introduction: Meteorite impact craters are the dominant surface feature on most terrestrial planetary bodies and, as such, they provide important information about planetary evolution [1]. The extreme temperatures and pressures generated by hypervelocity impact events generate a variety of microscopic shock metamorphic effects in minerals, such as planar fractures, planar deformation features (PDFs), and diaplectic glass [1] – which are exclusive to impact – as well as non-exclusive shock-related features such as undulose extinction and pervasive fracturing.

The shock effects present in a material are indicative of the peak pressure to which that material was exposed during impact [1]. The peak pressures to which the material was exposed can be used to reconstruct where in the pre-impact stratigraphy the material originated.

Studies of shock effects in feldspar group minerals have been limited due to the complexity of the crystal structure and the comparatively rapid rate at which feldspars weather, making them difficult to study using conventional optical techniques. As a result, feldspar is often ignored in favour of the optically more simple quartz for use as a shock barometer. This has resulted in a limited, and purely qualitative, shock scale for feldspar [e.g., 2 and references therein], despite some studies having suggested that feldspar can be just as useful as quartz, especially on the lower end of the pressure scale [e.g., 3]. An understanding of the shock effects in feldspars is also important for planetary studies and meteoritics, where rocks contain little or no quartz – a prime example is anorthosite, which is a dominant rock type on Earth’s Moon.

Mistastin Lake impact structure: The ~36 Ma Mistastin Lake impact structure [4], known locally as Kamestastin, is located in central Labrador, Canada (55°53’N; 63°18’W). The ~28 km diameter complex structure, although now eroded, still preserves a wide range of impactites (rocks effected by impact) [5]. The Mistastin target rock is comprised of three main lithologies: anorthosite, granodiorite, and mangerite (pyroxene-rich quartz monzonite) [6, 7]. The presence of anorthosite in the target rock makes the Mistastin Lake impact structure an excellent scientific lunar analogue given that anorthosite is the main constituent of the lunar highlands. This provides a major motivation for this study.

Field Work: Samples of shocked impactites were collected over the course of two field seasons (2010-11) from a range of locations throughout the crater: the central uplift, the crater floor, ejecta deposits, and the rim. Samples for this study were restricted to feldspar-rich lithologies from the central uplift.

Petrography and µXRD: Polished thin sections were made from representative samples of anorthosite and mangerite. They were studied by petrographic microscope revealing microtextural variation within minerals and various shock metamorphic effects. They were also examined using micro X-ray diffraction (µXRD) to identify high-pressure stages, and correlate optically derived shock stage to streak length along the Debye rings (χ) in two-dimensional GADDS images.

Figure 1: Mosaic/pseudo-fibrous patchy extinction pattern in plagioclase feldspar grains. A) pattern is restricted to alternating twin lamellae. Fractures which run perpendicular to twin planes stop abruptly at the modified twins. B) Pattern is abruptly cut off at the grain boundary in middle left, but crosses the boundary and takes on a vein-like character on the right.

Anorthosite samples are dominated by plagioclase feldspar, weathering along fractures to zeolite minerals (levyne-Ca) and/or kaolinite, with minor amounts of...
quartz, pyroxene, and sulfides. The plagioclase crystals are large and well formed. They exhibit excellent poly-
synthetic twinning and are heavily fractured through-
out. Small dark rod-like minerals appear as inclusions along cleavage planes within the crystals. All grains exhibit undulose extinction. Twin lamellae are often offset by the pervasive fracturing, always in the same direction. In one thin section of anorthosite, two quartz grains were observed to exhibit multiple sets of pristine (i.e. undecorated) PDFs.

Approximately 10% of the plagioclase exhibits an odd mosaic/pseudo-fibrous patchy extinction pattern (Fig. 1). This pattern is sometimes restricted to alternating twin lamellae (Fig. 1a), or truncated by crystal boundaries, but has also been observed as a more vein-
like texture cross-cutting crystal boundaries (Fig. 1b). Many of the pervasive fractures throughout the crystals are truncated by this texture (Fig. 1). However, where this texture is not restricted to alternating twins, twin planes and the small dark crystals, which permeate the plagioclase crystals, penetrate the texture.

*Mangerite* samples are also dominated by plagi-
oclase feldspar. The remainder of the rock is composed of pyroxene, quartz, alteration products infilling frac-
tures, and sulfides. Again the entire sample is heavily fractured. All minerals exhibit undulose extinction. Plagioclase grains are large (mm) in size and well-
formed, exhibiting sharp polysynthetic twinning. Four out of five quartz grains observed show multiple sets of well-preserved PDFs. One grain of plagioclase ex-
hibits possible diaplectic glass in alternating twin la-
 mellae.

Fig. 2: 2-D GADDS image from µXRD. Arcs stretching the full extent of the image result from polycrystalline materials (in this case clay or zeolite). Partial arcs (streaks) result from single crystals (in this case plagioclase) which have been strained.

In *situ* µXRD of various locations within the thin sections revealed crystalline, polycrystalline, and strained textures (appearing as spots, rings, and “streaks”, respectively, on the GADDS (General Area Diffraction Detection System) images (Fig. 2.) [8]). The majority of images show streaks rather than indi-
vidual spots. The µXRD patterns for plagioclase crys-
tals match anorthite and zeolite (levyne-Ca).

**Discussion:** The presence of PDFs in quartz, coupled with the lack of diaplectic feldspar (maskelynite) and quartz glass, suggests that the peak shock pressure to which these rocks were exposed is between 10-35 GPa, and that none are shocked beyond stage 1 according to the scheme of Stöffler 1971 [9], and none beyond stage 4 according to the scheme of Singleton *et al.* [10]. These are acceptable shock values for rocks sampled from a central uplift. French and Koeberl [1] report from references therein that PDFs in quartz and feldspar form at approximately the same pressures (~10-30 GPa). The presence of PDFs in quartz in these sections, coupled with their absence in feldspar, im-
plies that PDFs form in plagioclase less frequently and/or that PDFs in feldspars are more difficult to rec-
ognize and/or that they are more easily destroyed. The pristine nature of PDFs in quartz grains here suggests that not enough time has passed since their formation to anneal. It also indicates a lack of post-impact altera-
tion consistent with the state of other minerals in the surrounding rock. It therefore seems unlikely that al-
teration or annealing could be the cause for lack of PDFs in feldspars.

The unique mosaic/patchy extinction pattern exhibited by some feldspars in the anorthosite is possibly indicative of a mid-stage between pure crystalline feld-
spar and maskelynite, though it requires further inves-
tigation to confirm.

In summary, petrographic observations and *in-situ* X-ray diffraction data show that the minerals in these rocks have been exposed to peak pressures not exceeding ~35 GPa [9, 10]. Future work will expand to rocks from other locations than the central uplift in the ex-
pectation of finding a wider variety of shock metamor-
phic effects from areas exposed to different peak pres-
sures during the impact event.


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