SHOCK-RELATED TEXTURES IN THE CORE OF THE CENTRAL UPLIFT OF THE VREDEFORT DOME: RAPID COMPRESSION AND DECOMPRESSION IN AN IMPACT REGIME .

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Introduction: The mechanism of formation of central uplifts in impact craters is poorly constrained, largely due to a paucity of field examples. We provide a detailed compositional and textural analysis using back-scattered electron microscopy (BSE) and energy-dispersive spectrometry (EDS), of shock-induced microtextures in impactites from the eroded central uplift of the 2.02 Ga Vredefort Dome. These data serve as natural examples of attenuated shock metamorphism at depth.

Sample characterization: The rocks of the Steynskraal impactites (5-10 km from crater centre) are described as having a migmatitic garnet-cordierite-biotite paragenesis[1,2]. At the time of the impact these rocks are estimated to have been at at least 15 km below surface and were shocked to >35 GPa [3–5]. Of particular interest are features associated with the 200-1000 µm garnet porphyroblasts (Alm_{69}-$Gr_{2.6}$-$Py_{18.9}$-$Spess_{9.1}$); orthopyroxene-cordierite symplectites, inclusions and orthopyroxene coronas (Figs. 1 and 2). The symplectites comprise an intergrowth of vermicules of orthopyroxene and spinel with interstitial cordierite. Geothermobarometric analysis places the P-T conditions of symplectite formation at 0.3 GPa, >700 $^{\circ}$C[3]. The orthopyroxenes are characterized by a significant Mg-Tschermak component (~ 17 wt % MgO; ~ 7 wt % Al_2O_3). This unusual symplectite is formed exclusively in association with garnet: enclosing garnet grain boundaries, inhabiting fractures within garnet and the rims of garnet inclusions. The shock-induced symplectites observed in the Steynskraal garnets are more chaotic and have lower order control on crystallization than typical symplectites. Inclusions range in size from 10 – 300 µm within the garnet and comprise mostly quartz, plagioclase, and lesser orthopyroxene, biotite, cordierite and K-feldspar. Aluminous orthopyroxene coronas, formed due to shock compression, enclose these inclusions. Textural relationships revelaed in BSE images indicate that the formation of coronas and symplectites was coeval. The garnet porphyroblasts exhibit (a) multiple sets of fractures, (b) random fractures that are overprinted by later Hertzian and (c) planar fractures associated with impact-induced compression, and subsequent decompression (Fig. 1). Fracturing of the garnet was facilitated by shock –induced strain that was focused along inclusion boundaries, due to the impedance contrast between the host garnet and inclusion. A later garnet phase is developed in some of the intragranular fractures in the garnet host. This garnet has an Fe-rich majoritic composition and is interpreted as a possible high pressure phase. BSE images show feldspar in the gneiss matrix containing misoriented subdomains of intragranular, perthitic exsolution lamellae. The albite lamellae (less than 1 µm thick) are present within the orthoclase host. The symplectitic textures are crosscut and disrupted by a clast-rich melt phase (CLM) predominantly composed of shocked metamorphosed feldspars, orthopyroxene, cordierite and spinel crystallization products (Fig. 3). The orthopyroxene crystallites in the CLM have the same composition as those in the garnet symplectites. The CLM crystallites range in size from 1 – 10 µm, and are blocky in shape, suggesting pinning at the time of crystallization. The CLM contains angular fragments of resorbed garnet porphyroblasts, the symplectites and coronas of which have been delaminated into the CLM matrix.

Conclusions:

The data presented here are in favour of an impact-induced process, controlled by a rapid change in volume due to the formation of the central uplift during the crater modification process. The preservation of multiple sets of fractures in garnet porphyroblasts, and their colonization by symplectites and coronas records the peak compressive and decompressive strains experienced by the rock package during the passage of the shock wave. The microtextures associated with the CLM lead us to interpret it as a shock melt, produced by the rapid decompression of the central uplift body as its volume expanded.The combined microstructural observations involving multiple minerals in this study, corroborate the interpretation that they are features produced by attenuated shock metamorphism at depth. As such these features are informative with respect to understanding how the country rock well below the melt sheet is affected by impact. There is potential for some of the observed microstructural features to be used as shock indicators for other exhumed central uplifts.

References:

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Figures

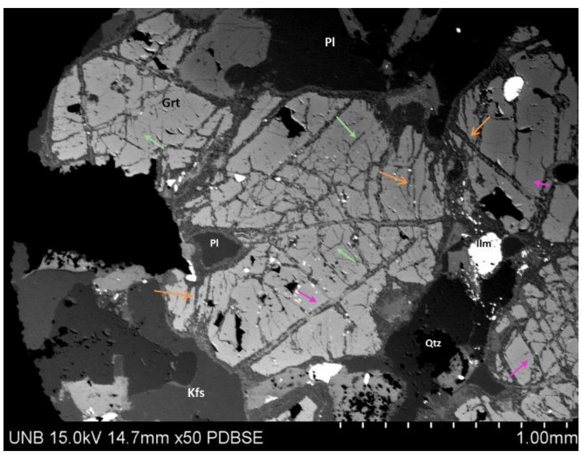

Fig. 1 BSE image of garnet porphyroblats with mutiple intragranular fracture sets: Green arrows indicate random fractures, orange arrows, Hertzian fractures, and pink arrows, planar features. Note the fractures are filled with symplectites

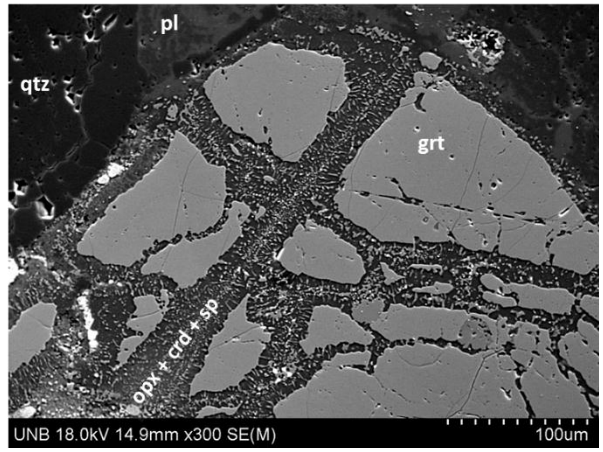

Fig. 2 BSE image of intragranular fracture symplectites in garnet porphyroblasts.

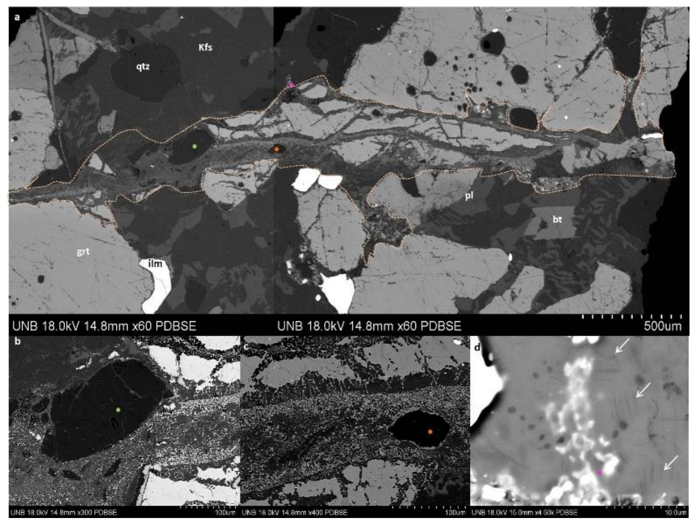

Fig. 3 BSE imaging of clast laden melt (CLM) shown to cross-cut the garnet porphyoblasts and their associated symplectites and inclusions. The location of orange and green dots in (a) are shown in (b) and (c). (d) detail of misoriented planar features in feldspar, pink dot in (a).