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Shock metamorphic features of olivine, orthopyroxene, amphibole, and plagioclase in phlogopite-bearing ultramafic-mafic inclusions in Sublayer, Sudbury Igneous Complex, Sudbury, Canada

Y Wang, CM Lesher, PC Lightfoot, EF Pattison, JP Golightly

Mineral Exploration Research Centre, Department of Earth Sciences, Good Man School of Mines, Laurentian University, Sudbury, Ontario P3E 2C6

The Sudbury Structure is one of the world's oldest, largest, and best exposed impact structures and contains some of the world's largest Ni-Cu-PGE deposits. Most of the mineralization is associated with inclusion-rich Sublayer Norite and Quartz Diorite, both of which are characterized by abundant phlogopite-bearing (0-15% in peridotite, up to 25%-30% in some pyroxenites) ultramafic-mafic inclusions (UMIs) that have no counterparts in the adjacent country rocks. Their origin, whether cognate (crystallized from impact melt) or exotic (derived from unexposed target rocks), remains a subject of debate. Petrographic and scanning electron microscope (SEM) studies indicate that olivine, orthopyroxene, plagioclase, amphibole, and phlogopite in many of the UMIs appear to contain shock metamorphic features such as kink banding, recrystallized mosaic textures, recrystallized maskelynite (diaplectic glass), and planar microstructures. Olivine commonly forms elliptical or irregular clusters of polygonal crystals (Fig. 1). The clusters have the same dimensions as unmodified olivine crystals, and are interpreted to represent recrystallized shock-induced "mosaic" textures. Plagioclase, which coexists with shocked olivine, occurs as finer-grained clusters with similar dimensions (Fig. 1), which are interpreted to be recrystallized maskelynite. Orthopyroxene and amphibole in amphibole pyroxenite and olivine melanorite exhibit well-developed planar fracture sets (PFs) that are similar to shock metamorphic features described in the literature, including planar fractures and planar deformation features. SEM studies indicate that some of the fractures are filled with chromite lamellae and that some contain droplets of clinopyroxene and plagioclase that appear to have exsolved from orthopyroxene and to have been thermally recrystallized (Fig. 2). Coarse phlogopite oikocrysts are commonly present in pyroxenite, and exhibit kink banding. Thermal metamorphism during incorporation into the original SIC impact melt has clearly modified the mineralogy and textures of the UMIs through the processes of recrystallization, refertilization, homogenization, transformation, and re-equilibration, and this has complicated their interpretation. Although none of the features described above provides unique and unequivocal evidence for shock metamorphism, all are consistent with this process and together they provide compelling evidence for an exotic rather than a cognate origin.

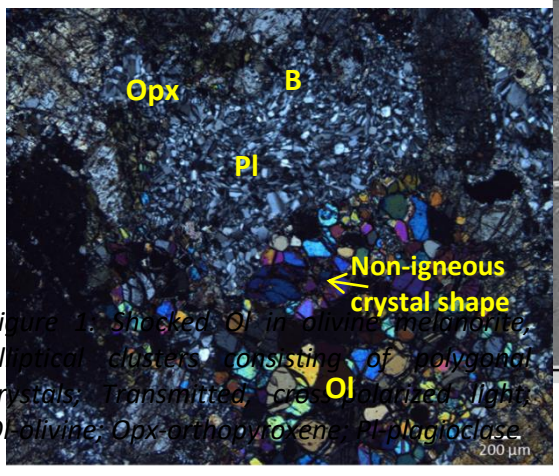

Figure 1: Shocked Ol in olivine melanorite, elliptical clusters consisting of polygonal crystals; Transmitted, cross-polarized light; Ol-olivine; Opx-orthopyroxene; Pl-plagioclase

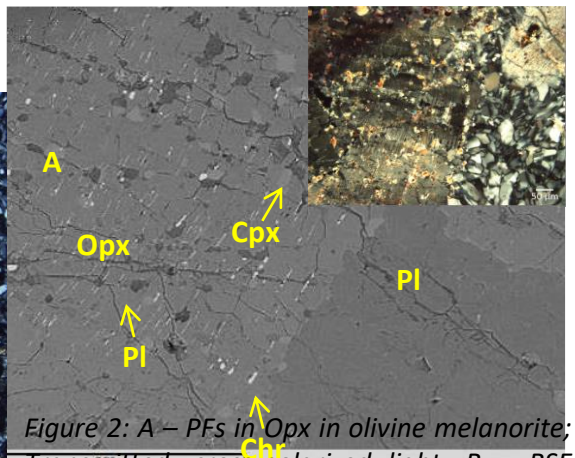

Figure 2: A – PFs in Opx in olivine melanorite; Transmitted, cross-polarized light; B – BSE image of same area, exsolutions in Opx; Cpx-clinopyroxene; Chr-chromite