Shock veins in the central uplift of the Manicouagan impact structure

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Shock veins that developed and penetrate the anorthositic central uplift of the Manicouagan impact structure, Quebec, occur as thin (<2.5 mm wide), linear micro-fault systems that can be traced for several metres in length. They predominantly trend radially from the point of impact. The shock veins are distinguished by the development of maskelynite along vein margins and stishovite in vein matrices. These phases define a shock excursion of up to 30 GPa, in contrast to bulk shock effects of ≤12 GPa defined by development of shatter cones, planar fractures, and planar deformation features in various minerals.

The shock veins at Manicouagan share many similarities with vein systems developed in meteorites. They also provide an in situ context with which to better understand meteoroid source and lofting conditions. In addition to containing high-pressure phases, the shock veins exhibit evidence for high-temperature partial melting of host silicate clasts, with the generation of flow-textured fragments and glasses. Temperature excursions in the veins are constrained by plagioclase melting (~An60 @ >1400°C), partial melting of augite (>1400 to <1500°C), and partial melting of garnet (>1650°C). Plagioclase geothermometry indicates that some melt injections crystallized at ~1350°C (~An_{74}). Geochemical analysis of the melts indicates they are in situ (i.e., native to their host rock) and are not derived from an external source. The formation of microcrystallites and dendrites from some melts indicates rapid cooling.

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A two-stage generation mechanism is proposed comprising an initial high-pressure shock excursion (estimated to last <0.5 s based on projectile size considerations) followed by a longer high-temperature pulse of a few seconds duration. The shock excursion is initiated by target heterogeneities that cause distortions in the hemispherically propagating shock front. This results in radially oriented tearing and vein formation. High-speed displacement along the veins is driven by stress release on rarefaction, which results in frictional melting via adiabatic heating. Future study of these and similar shock veins in other terrestrial craters should provide further insight into the possible launch locations of meteorites on other planetary bodies.