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Shock metamorphism in shock induced melt veins of L chondrites: Constrain shock pressure and duration.

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Shock metamorphism resulting from hypervelocity collisions between planetary bodies, is a fundamental processes in the solar system. The term "shock metamorphism" is used to describe all changes in rocks and minerals resulting from the passage of shock waves. Most meteorites have experienced collisions and have a record of shock metamorphism, which include brecciation, deformation, phase transformation, local melting and crystallization. The key to reading this record is to use the shock features to estimate the pressure and duration of shock event, which can be related back to velocity and size of the impacting bodies. A widely used shock-classification scheme for chondrites was proposed by Stoffler et al. 1991. This shock classification system is easy to apply and correctly represents the progressive shock-pressure sequence from weak to strong. However, pressure calibration based on shock recovery experiments is problematic for some shock features, such as phase transformations, which depend on reaction kinetics.

An alternative means of estimating shock pressure is to use the mineralogy of melt veins to estimate crystallization conditions based on phase relations determined in static high-pressure experiments. Shock-induced melt veins contain two lithologies. One consists of polycrystalline grains that transformed from host rock fragments by solid-state mechanisms. The other consists of quenched silicate and metal-sulfide grains that crystallized from shock-induced melts. The crystallized mineral assemblages can be used to constrain the crystallization pressure of the melt based on phase equilibrium data, and then infer the shock pressure. The shock duration can be constrained by using transformation kinetics, such as the crystallization rate of the melt-vein matrix, or growth rate of the high-pressure minerals, or using elements diffusion rate between two minerals.

Here we report the TEM observations of the mineral assemblages in the shock-induced melt veins in several L chondrites of shock stages S3 to S6. The mineral assemblages combined with phase equilibrium data are used to constrain the crystallization pressures. The goal is to see how crystallization pressures are related to the shock pressures inferred from Stoffler's shock classification. Based upon the assemblages observed, crystallization of shock veins can occur before, during or after pressure release. When the assemblage consists of high-pressure minerals and that assemblage is constant across a melt vein or pocket, the crystallization pressure corresponds to the equilibrium shock pressure. Equilibrium shock pressures inferred from the mineralogy of shock-induced melt veins suggest that the pressure calibration of Stoffler et al. is too high by a factor of at least two for highly shocked (S5-S6) chondrites.