SHOCK VEINS IN L6 CHONDRITE RC106 AND CONSTRAINTS ON THE IMPACT HISTORY OF THE L6 PARENT BODY.

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Introduction: High-pressure minerals that occur in and adjacent to shock-induced melt veins in chondrites provide constraints on the pressures and temperatures of shock metamorphism in these samples. In particular, the mineral assemblages that result from the crystallization of silicate melt at high pressure provide strong evidence for shock pressure up to about 25 GPa in highly shocked samples such as Tenham, Sixiangkou, Umbarger, Acfer 040 and Yamoto 791384 [1-5]. From such estimates of shock pressure, one can put constraints on the minimum velocity of the impact that produced the melt veins.

The duration of the shock pulse in such samples can be constrained by either using silicate-transformation kinetics [5-7] or by modeling melt vein cooling [1, 8-9]. The use of transformation kinetics is strongly dependant on inferred temperatures during transformation as well as details of the transformation mechanism. Estimates of pressure-pulse durations from transformation kinetics in highly shocked L6 chondrites are generally several seconds [5-7, 10]. The recognition that melt veins cool predominantly by thermal conduction to the surrounding meteorite host rather than by adiabatic decompression allows one to estimate the shock-pulse duration using thermal modeling of melt-vein quench. This approach results in minimum duration estimates of 10s to 100s of ms, [1, 11]. From such duration estimates, one can constrain the size of the impacting bodies.

Use of pressure and duration estimates to constrain impact velocities and impactor sizes can be done in two ways. First, one can use shock physics and a simple planar-shock-wave approximation to investigate impact velocities impactor thickness for simple geometries [1,5]. However, in such an estimate, one needs to make assumptions about the location of the sample in the parent body relative to the impact site. An alternative is to use hydrodynamic calculations, which allow one to use more complex geometries and velocities and then search the parent body for regions that would experience a shock pulse similar to that estimated from shock effects in the sample [12].

The purpose of this study is to use the highly shocked L6 chondrite RC106, combined with melt-vein characterization and hydrodynamic calculations to explore possible impact conditions and sample locations on the L6 parent body.

Samples and Methods: RC106 was found in Roosevelt County, New Mexico and provided to us by the Center for Meteorite Studies at Arizona State University. It has melt veins up to ~ 4mm wide with ubiquitous ringwoodite inclusions. Melt-vein textures and mineralogy have been characterized using polarized light microscopy, Raman spectroscopy, scanning electron microscopy, electron microprobe analysis and transmission electron microscopy. Melt-vein quench has been modeled using the Finite Element Heat Transfer (FEHT) analysis program, version 7.126 (32-bit) (Klein *et al*., © 1995-2000). Boundary conditions for melt vein cooling were based on experimental high-pressure melting data and on estimates of the bulk shock temperature calculated from a synthetic Hugoniot equation of state for RC106. Hydrodynamic modeling was done using the program Autodyn™.

Results:

Melt-vein mineralogy and texture. The melt vein in this sample is typically about 1.3 mm wide, but occurs up to 4-mm wide. The melt-vein matrix consists of an assemblage of majorite garnet plus intergrown periclase and magnetite. This oxide intergrowth is inferred to be the product of magnesiowüstite breakdown after pressure release, indicating that majorite and magnesiowüstite crystallized at high pressure. There are two important features of this assemblage: 1) the mineralogy is constant throughout the veins, implying that melt-vein crystallization occurred under near isobaric conditions between 18 and 25 GPa; and 2) the vein contains a striking textural transition from large equant majorite garnets (up to 30-μm wide) in the vein center to finely dendritic majorite near the melt-vein edge (Fig. 1). In addition, much of the melt-vein margins have a blue to brown transition zone that is too fine to resolve with conventional SEM (Fig. 2). Droplets of sulfide within these zones indicate that they were molten during shock. Field-emission SEM images of this material show that it is a nano-crystalline assemblage of silicate and oxide. The mineralogy of this material is under TEM investigation.

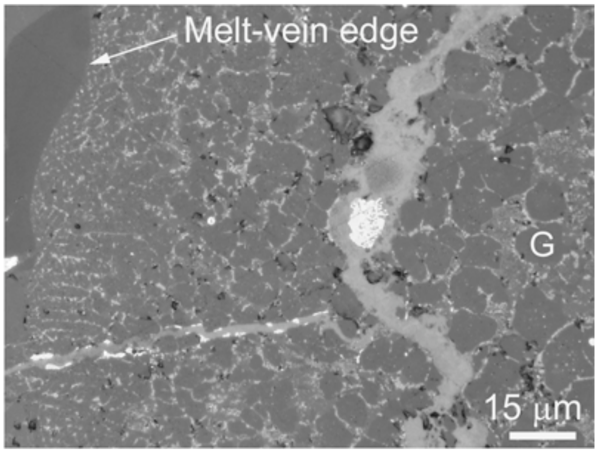

Fig. 1 Back-scattered electron image of the melt-vein matrix showing the transition from dendritic to equant majoritic garnets.

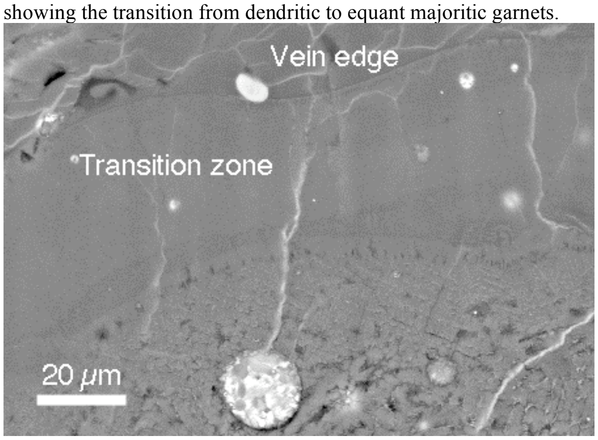

Fig. 2 Back-scattered electron image of a transition between the vein edge and the dendritic majorite assemblage.

Thermal modeling of vein quench. The textures observed in the melt veins in this sample are consistent with rapid cooling of the vein margin by conduction to a relatively cool host rock. Melt-vein cooling was modeled by assuming a planar melt vein at an initial temperature of 2500 K, surrounded by the solid host rock at 400 K, approximated by synthetic Hugoniot post-shock temperature calculations and heat capacity data. Using thermal conductivity values of 10 and 3 W/m^2, the center of a 1.3-mm melt vein would quench to the solidus in 165 and 550 ms, respectively. The uniform crystallization assemblage implies that the shock pressure remained nearly constant for at least 165 to 550 ms as the 1.3-mm vein quenched. The vein margin, where olivine transforms to ringwoodite, heats from 400 K to over 1500 in 75ms. The fact that metastable high-pressure phases survive in and adjacent to the melt vein suggests that the sample remained at high pressure for several seconds, long enough for these transformed areas to cool enough for survival at low pressure.

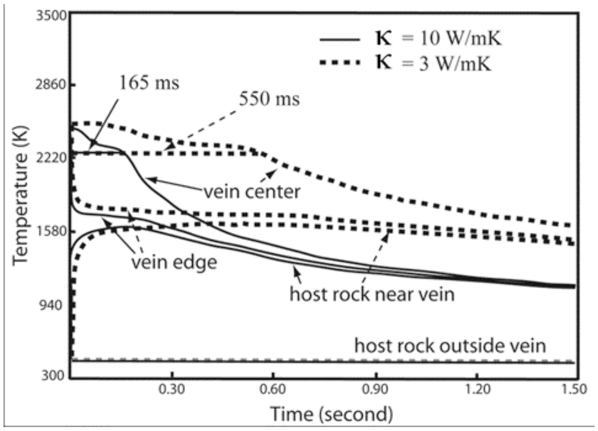

Fig. 3 Plot of temperature (K) versus time showing cooling of the melt-vein center and edge as well as the 86 µm into the host rock.

Hydrodynamic modeling. To model possible impact scenarios, we assume an L-chondritic composition of the impacting body. We also assume a spherical impactor striking a much larger body. By placing pressure gauges throughout the model, we can investigate the pressure-time history of any position in the parent body. In these caluculations, we vary impact velocity and then look for regions within the parent body that have pressures from 18 to 25 GPa and pressure pulses of 1 second. Assuming a porous surface regolith on the parent body, a 4km/s impact with a 10 km chondritic object can produce an RC106-like shock pulse for a sample at 8 km depth in the L-chondrite parent body.

Conclusions: The RC106 L6 chondrite experienced a 18-25 GPa shock pulse at least 165 to 550 ms and likely several seconds. A 1-second pressure pulse to 18 – 25 GPa could have been formed at a depth of 8 km in the L-chondrite parent body by the impact with a 10-km chondritic object at 4km/s.

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