High-pressure minerals in RC106 provide evidence for a very large impact.

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Introduction: Many meteorites contain so-called melt veins and melt pockets. The veins are analogous to pseudotachylites and consist of sheets of material that melted locally and was quenched by conduction to surrounding cold material. Psuedotachylite formation is conventionally considered to be the result of localized deformation (frictional heating, adiabatic shear). There is some experimental evidence that this mechanism could account for melt vein formation in meteorites (1). However the convoluted network of veins observable in many meteorites seems too complex to be explained via such a simple mechanism. Another mechanism, pore collapse (2) might account for the formation of melt pockets. For our purposes, the formation mechanism is irrelevant. We simply note that melt veins exist.

It has previously been shown that the high pressure minerals in meteorite melt veins can constrain the shock conditions in the parent body (3, 4). Vein mineralogy constrains the shock pressure. If one assumes that the melt vein formed on arrival of the shock front, then calculation of the vein cooling history constrains the shock duration. One of the problems in earlier work was the lack of information relevant to the initial temperature of the melt vein. One knew only that the temperature was above the liquidus (about 2200 K) over the pressure range constrained by the high pressure mineralogy.

Current work: We have recently examined RC106, an L6 chondrite found in 2001 in Roosevelt County, New Mexico. We concentrate on a 1.3 mm wide melt vein, one of the largest we have examined to date. The melt vein consists primarily of majorite garnet crystals in a matrix of intergrown magnetite and ferropericlase. Portions of this melt vein are bordered by a fine-grained (less than micro grain size) region, about 20 microns wide, consisting primarily of ringwoodite. Our current interpretation of this region is that the material was melted by contact with the melt vein and rapidly quenched by conduction. If this interpretation is correct, then the initial temperature of the melt vein must have been well above the liquidus, in the range of 3500 to 4000 K.

Calculations: We used a finite element heat transfer code to calculate cooling of the vein. Handbook data on heat capacity as a function of temperature of the mineral constituents were used to construct a mass fraction weighted average curve for the calculation. The heats of fusion were similarly averaged, and we used the oxide composition to calculate a constant heat capacity for the liquid by Navrotsky's method.

We also used available data on thermal conductivity as a function of temperature in the calculation. To approximate the effect of pressure on thermal conductivity, we increased the one atmosphere values by 20%. One stumbling block was the absence of data on the thermal conductivity of silicate liquid at high pressure. Most silicate liquids have very low conductivity (less than 1 W/mK) at one atmosphere. Via iterative heat flow calculations we determined that the effective thermal conductivity would have to be about 4 W/mK to produce the inferred contact melting. This value seems reasonable, given the possibility of a contribution from convection as well as the higher Si-O coordination and higher density of the melt.

Result: Our calculations indicate that the melt vein solidified over a period of about 3.3 seconds (Fig. 1). Since the vein mineralogy was uniform across its width, the pressure must have remained in the stability field of majorite (15-25 GPa) for at least that length of time. Additional time at pressure would be required to permit cooling of the high pressure phases to a low enough temperature to survive on pressure release. Here we lack sufficient information on the inversion of high pressure phases. Our current estimate is that a shock duration of about 8 s is required. We used the Autodyn™ hydrocode to make calculations of impacts between chondritic objects at velocities ranging from 3 km/s (Fig. 2) to 7 km/s (Fig. 3). In order to obtain a shock duration of 8 s over the range of 25 to 15 GPa, the smaller body would have to be about 100 km diameter. The calculations scale. If one needs only 4 s in that pressure range, the smaller body would be about 50 km diameter. Allowing for uncertainties in the input to the heat flow calculations, this would be a lower limit for the size of impactor that resulted in RC106 vein formation.

Reference: 1. Kenkmann et al, (2000) MAPS 35: 1275-1290. 2. Melosh (1989) *Impact cratering:A Geologic Process* , Oxford University Press. 3. Langenhorst and Poirier (2000) EPSL 184:37. 4. Sharp et al. (2003) abstract 1278, 34th LPSC.

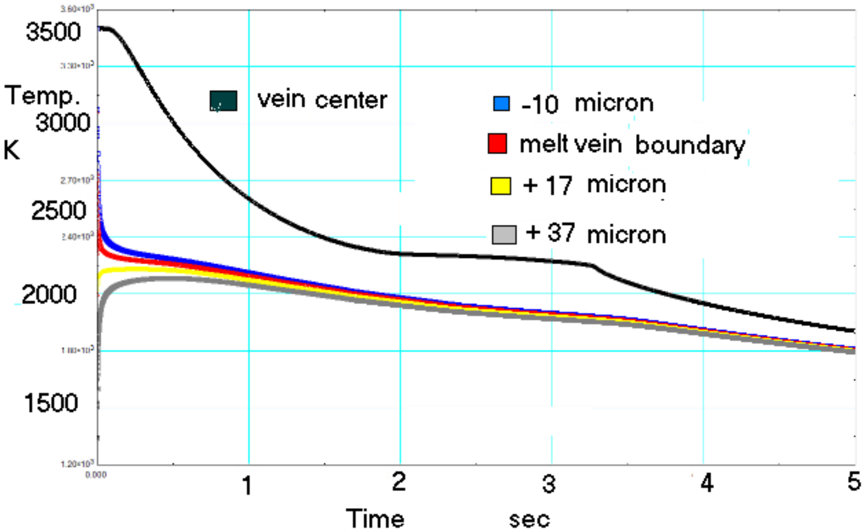

Fig. 1. Cooling calculation

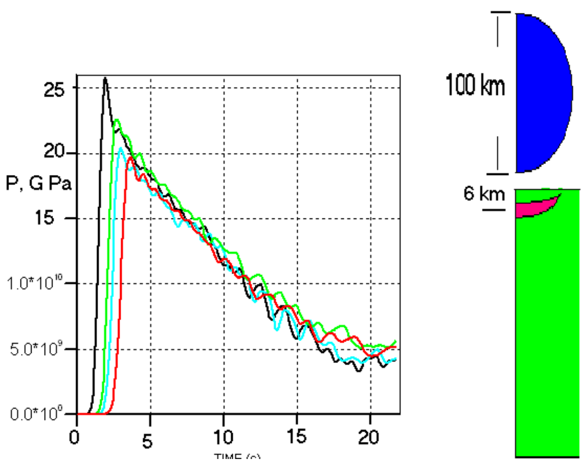

Fig. 2. Shock calculation for 3 Km/s impact

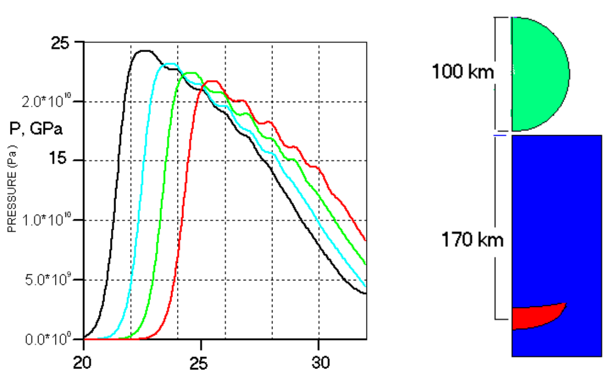

Fig. 3. Shock calculation for 7 Km/s impact