CALCULATION OF HUGONIOT CURVES AND POST-SHOCK TEMPERATURES FOR H- AND L-CHONDRITES

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Introduction. The shock metamorphism of chondrites provides important information on the collisional and geologic history of asteroidal parent bodies [1]. The most important physical properties for the study of this phenomenon are Hugoniot data. So far, however, Hugoniot curves for only a few chondrites have been measured experimentally [2, 3]. These Hugoniot data are inconsistent, which apparently is an effect of the inhomogeneity of the chondritic samples used in these experiments. For this reason, we have developed a method for calculating Hugoniot curves of H- and L-chondrites. Based on these Hugoniot curves post-shock temperatures can be estimated.

Calculation of the Hugoniot curves. The following assumptions were made for the calculation: (1) The chondritic material is nonporous and behaves hydrodynamic. (2) The constituent minerals are arranged in monomineralic layers. (3) Phase changes of the minerals were disregarded. (4) The average mineral compositions of H- and L-chondrites given by [4] were used for calculation. First, the modal composition was calculated based on the CIPW-norm using mineral densities of [4]. For each shock pressure, the particle velocity of the chondrite was calculated with the formula given by [5]. Pressure dependent densities of the individual minerals, as required by this formula, were calculated from data compiled in ·[6], using a linear relation between shock wave velocity and particle velocity, and the density of the unshocked mineral. The shock wave velocity and pressure dependent density were than calculated from the particle velocity on the basis of the Hugoniot equations [7]. The results of the calculation are shown in Fig. 1.

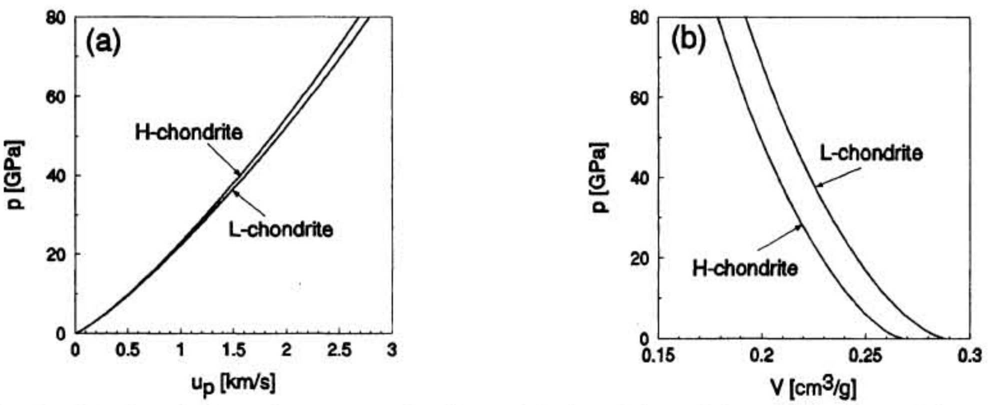

Fig. 1: Calculated Hugoniot curves for H- and L-chondrites: (a) pressure - particle velocity plot, and (b) pressure - specific volume plot.

Calculation of post-shock temperatures. The following assumptions were made in the calculation: (1) Release adiabats were approximated by the Hugoniot curve. (2) Phase changes of the minerals were disregarded. The post-shock temperatures were calculated by using the residual energy, which corresponds to the area between the Rayleigh line and the release adiabat [8]. In the case of nonporous chondrites, the area between p_0V_0, p_1V_1 and the Hugoniot curve (Fig. 2; cross-hatched) was used for calculation. For porous chondrites the area between p_0,V_{0P} (specific volume of the unshocked porous chondrite), p_1V_1 and the Hugoniot curve of the same chondrite without porosity (Fig. 2; hatched) was assumed for the residual energy. Average porosities of 8 % for H5-/H6-chondrites, and 11 % for L5-/ L6-chondrites, as estimated by [4, 9], were used for the calculation. Given the residual energy (E_R), the post-shock temperature (T) can be calculated by the equation $E_R = \int_{293K}^{T} c_p dT$ [8]. The specific heat capacities (c_p) for H- and L-chondrites (Fig. 3) were calculated from the mineral composition of the chondrites [4] and specific heat capacities of the minerals [10, 11]. Fig. 4 illustrates the results of the calculation.

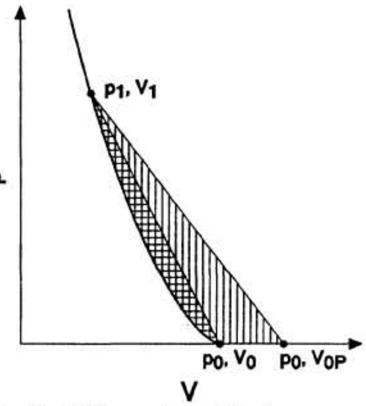

Fig. 2: Different residual energy for nonporous (cross-hatched) and porous (hatched) chondrites.

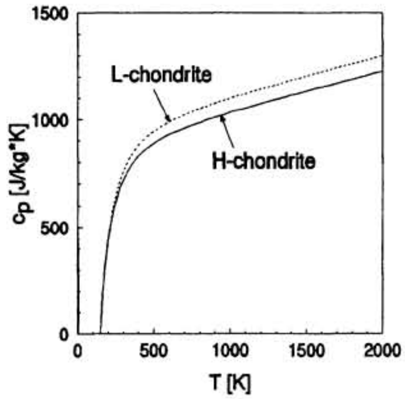

Fig. 3: Specific heat capacities calculated for H- and L-chondrites.

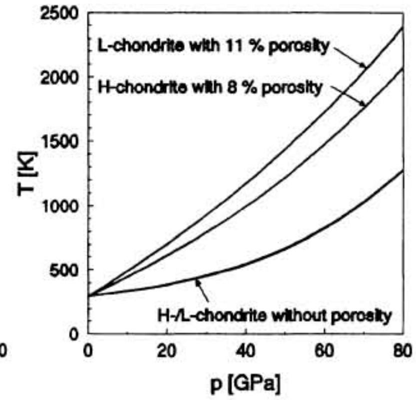

Fig. 4: Post-shock temperatures calculated for H- and L-chondrites.

Results and discussion. The distinct difference between the Hugoniot curves of H- and L-chondrites (Fig. 1) is mainly due to the different metal content of both types of chondrites. The Hugoniot curves are most strongly influenced by the metal and feldspar, as their Hugoniot curves are very different from those of olivine, the predominant mineral constituent. The calculated post-shock temperatures for nonporous chondrites are quite similar for H- and L-chondrites, since the difference in the metal content of both types of chondrites has no distinct effect on the post-shock temperatures. The most important factor for the post-shock temperature of a chondrite is the porosity of the sample (Fig. 4).

The calculated post-shock temperatures for nonporous chondrites are about 100 K lower than measured temperatures for nonporous silicates [12]. This is a result of the metal content of chondrites, because the post-shock temperatures of metals [13] are much lower than those of silicates. In comparison with post-shock temperatures for L-chondrites estimated from metal textures [14], the calculated post-shock temperatures for porous L-chondrites are about 250 K higher. This might be an effect of the inaccuracy of the porosity data available for L-chondrites. The results of the calculation could help explain different shock features in some chondrites of shock stage S3 - S5 [15]. These shock features, which include the occurrence of significant amounts of shock-induced melts and metal textures like coarse plessite or martensite [15], require a high post-shock temperature. Such a high temperature could be a result of a high initial porosity.

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