THE IMPACT SHOCK TEMPERATURES OF INDIVIDUAL MINERALS WITHIN LUNAR ROCKS, John D. O'Keefe* and Thomas J. Ahrens**

*Department of Planetary and Space Sciences, University of California, Los Angeles, Ca. 90024

**Seismological Laboratory, California Institute of Technology, Pasadena, Ca. 91109

We have previously (1) used the theory of interacting continua (2,3) to synthesize the Hugoniots of lunar rocks from their individual mineral equations of state. The pressure-density, temperature, shock velocity and particle velocity states were determined and inferences made as to the high pressure phase crystal structures present. We have examined further the effects of the interaction of the mineral grains on the calculated shock states and demonstrated that although the pressure-density, shock and particle velocity states are relatively insensitive to the mineral grain interaction model assumed, the shock temperatures of the individual minerals species depend critically upon the interaction assumptions. We have explored the range of acceptable interaction models on thermodynamic grounds in terms of the mineral interaction energy Q^i in the Rankine-Hugoniot energy equation for each one of the minerals (4),

$$E^i - E^i = \left[n_0^i \rho_0^i \ \ U \right]^{-1} \left[n^i \ \ P \ \ (U-u) \ + \ Q^i \right]$$

where n_0^i and n^i are the volume fractions of the mineral i at the initial and shock states and E, ρ, P, U, and u are the internal energy, density, pressure, shock and particle velocity respectively.

The range of interaction energy, Q^i, which is thermodynamically allowed is found to vary from a maximum value, which corresponds to the state of isentropic compression of the lowest specific entropy mineral, down to a minimum value which corresponds to a state of maximum entropy (all minerals at same temperature). In general the temperature bounds derived from these calculations, are smaller than previously determined, either by assuming that the mineral temperatures are given by the individual mineral Hugoniot (5), or, that the interaction energy is zero (1), i.e., the flow of heat between grains is just compensated by the mechanical interaction energy. Moreover, the relative magnitude of the temperatures are in some cases the reverse of those previously determined.

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For example, the effect of the interaction energy on the individual mineral temperatures at a shock pressure of 100 kbars is shown in figure 1. The rock is lunar sample 15,418 and is considered to be a mixture of plagioclase (74% vol) and pigeonite (26% vol). Referring to figure 1, larger values of interaction energy correspond to less heat transfer between minerals. The range of allowable interaction energies is delineated on the figure and results in a maximum spread of shock temperatures of 350K for the plagioclase, and 320K for the pigeonite. The shock temperatures calculated with the assumption of zero interaction energy (plotted on the ordinate in figure 1) are reversed in relative magnitude from the thermodynamically admissible solutions.

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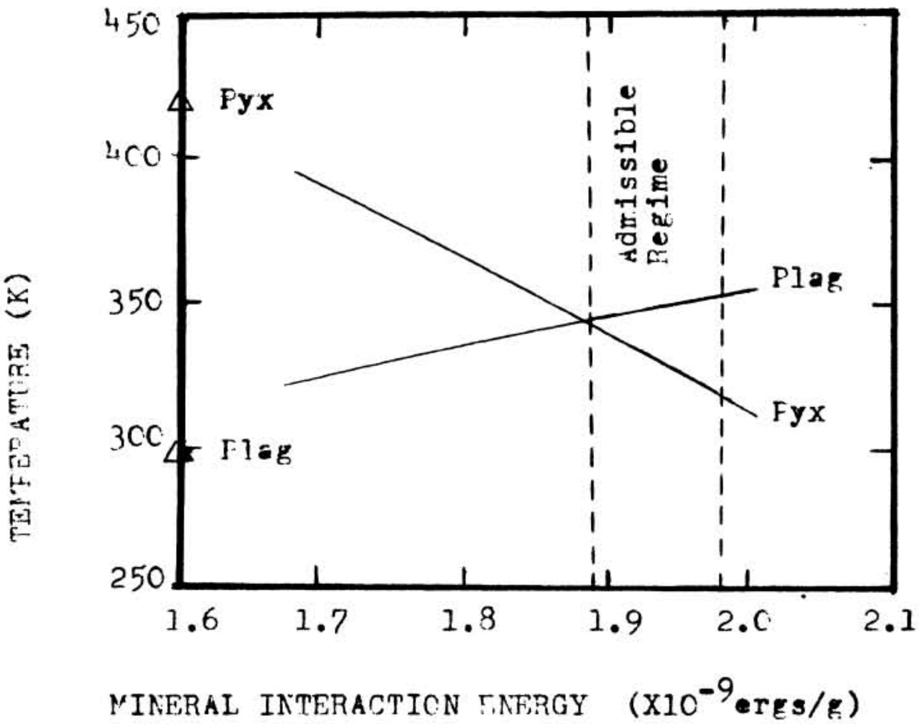

FIGURE 1

Shock temperatures of minerals in lunar sample 15,418 as a function of mineral interaction energy. Shock pressure is 100 kbars. Points on ordinate axis are mineral temperatures when interaction energy is zero.