

ing-Petit value—is inappropriate for calculating T_h from E_t . In quartz, typical of common silicates, C_v varies by a factor of 1.6 between room temperature and 800°K [Kelley, 1949]. Note that, as in calculation of shock temperature in porous metals, the specific heat of the porous rock or mineral is given in terms of mass and is assumed to be the same as that of the solid material—consistent with the assumptions used in obtaining (18). Pressure affects specific heat (at constant pressure) along an adiabat by an amount which is approximately proportional [Birch, 1952, p. 257] to the square root of the density ratio of uncompressed and compressed solid material. In the following, specific heat is assumed to be independent of stress since the maximum compression of solid quartz in regimes II and III is about 9%, corresponding to only a 3% decrease in specific heat. Thus in regimes II and III the specific heat is assumed to be only a function of the temperature achieved in shock compression.

Kelley's measurements provide C_p as a function of temperature, from which C_v is calculable (although the difference for the present purpose is negligible). Often C_v or C_p is expressed as a function of temperature in the form

$$C_v = a + bT - c/T^2 \quad (19)$$

where a , b , and c are experimentally determined constants.

Then

$$E_t|_{II} = \int_{T_0}^{T_h} C_v dT \quad (20)$$

For states in regime II the temperature may implicitly be expressed as

$$0 = T_h^3 + \frac{2a}{b} T_h^2 - \frac{2}{b} \left[\sigma \frac{(V_0 - V)}{2} + aT_0 + \frac{bT_0^2}{2} + \frac{c}{T_0} \right] T_h + \frac{2c}{b} \quad (21)$$

where (18) and (19) were substituted into (20). Equation 21, a cubic equation, may be solved for T_h , the temperature achieved in a shock compression to volumes in the range $V_q \leq V \leq V_c$.

In regime III a partition of shock energy is assumed. The total internal energy change due to the shock is

$$E|_{III} = (V_0 - V)\sigma/2 = \int_{T_0}^{T_h} C_v(T) dT + E_k \quad (22)$$

The low value of thermal expansion coefficient for nonmetallic materials such as silicates and, in particular, quartz suggests that the 0°K isotherm can be approximated by an isothermal compression curve like the one determined statically at room temperature by Bridgman. Thus the 0°K isotherm is approximately given by the Murnaghan equation 15, where again $\beta = 42.75$ kb, $\xi = 8.390$, and V_0 is associated with V_q . The compressional shock energy is given by

$$E_k \approx \int_{V_q}^V -[\sigma dV] 0^\circ K \quad (23)$$

which upon substitution of (15) and integration becomes

$$E_k = V_q \beta \left[\frac{(V_q/V)^{\xi-1} - 1}{\xi - 1} + V/V_q - 1 \right] \quad (24)$$

Therefore, the temperature of porous sandstone at final states of compression in regime III may be implicitly written as

$$0 = T_h^3 + \frac{2a}{b} T_h^2 - \frac{2}{b} \left\{ \sigma \frac{(V_0 - V)}{2} - V_q \beta \left[\frac{(V_q/V)^{\xi-1} - 1}{\xi - 1} + V/V_q - 1 \right] + aT_0 + \frac{bT_0^2}{2} + \frac{c}{T_0} \right\} T_h + 2c/b \quad (25)$$

where (24) and (19) are substituted into (22).

The fact that the volumes achieved by shocked sandstone are less than those achieved by quartz upon isothermal compression must be considered in calculating the temperature for regime IV. At a given state in regime IV it is assumed (see Discussion, below) that the shocked material contains a mixture of quartz and stishovite which has a specific volume given by $V = qV_q + (1-q)V_s$.

In terms of volume, q is written as

$$q = (V - V_s)/(V_q - V_s) \quad (26)$$

For purposes of computation, V_s and V_q are taken to be specific volumes along an assumed

slabs of Coconino sandstone.

n. This is justified because the elastic limit in both porous sandstones and limestones varies with a velocity approximately equal to the adiabatic longitudinal-wave velocity. In regime I, therefore, the Hugoniot curve lies close to the adiabat. The adiabatic temperature increase is calculated from

$$T_0 \exp [\Gamma_0(V_0 - V)/V_0] \quad (17)$$

In nonporous solids, Γ/V is thought to be constant; therefore, the use of (17) is justified even for porous mediums because of the small variation in σ and V in regime I. For Coconino sandstone, for example, the temperature increase achieved upon shock compression from the HEL from (17) is approximately 100°K. This temperature increase can be neglected compared with the much greater temperature changes resulting from stronger shocks. Regime II may be defined as consisting of compressed states lying between volumes V_q and V_c . In this region shock compression is thought to be consisting primarily of crushing of sandstone to the volume of uncompressed single-crystal quartz. The inherent irreversibility of such a process suggests that the shock energy will go to thermal energy. The assumption is made that recoverable energy and contributions to E_t from surface energy are negligible. Some of these assumptions are to be discussed later. The shock energy is then written as

$$E|_{II} = E_t = \sigma(V_0 - V)/2 \quad (18)$$

In regime II, in the case of silicate minerals, the temperature is higher than the shock temperature; therefore, a constant value of C_v —such as 6 cal/mole deg, the Dulong-Petit value—is inappropriate for calculating T_h from E_t . In quartz, typical of common silicates, C_v varies by a factor of 1.6 between room temperature and 800°K [Kelley, 1949]. Note that, as in calculation of shock temperature in porous metals, the specific heat of the porous rock or mineral is given in terms of mass and is assumed to be the same as that of the solid material—consistent with the assumptions used in obtaining (18). Pressure affects specific heat (at constant pressure) along an adiabat by an amount which is approximately proportional [Birch, 1952, p. 257] to the square root of the density ratio of uncompressed and compressed solid material. In the following, specific heat is assumed to be independent of stress since the maximum compression of solid quartz in regimes II and III is about 9%, corresponding to only a 3% decrease in specific heat. Thus in regimes II and III the specific heat is assumed to be only a function of the temperature achieved in shock compression.