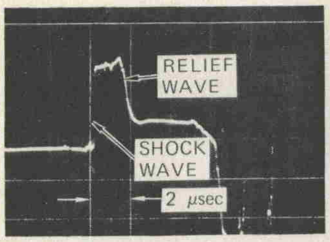
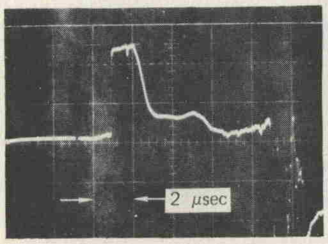
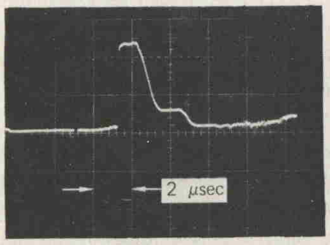


1.72 mm FROM IMPACT INTERFACE



5.17 mm FROM IMPACT INTERFACE



8.49 mm FROM IMPACT INTERFACE

Fig. 2. Manganin stress gage profiles in dolomite. Peak stress is 287 kbar.

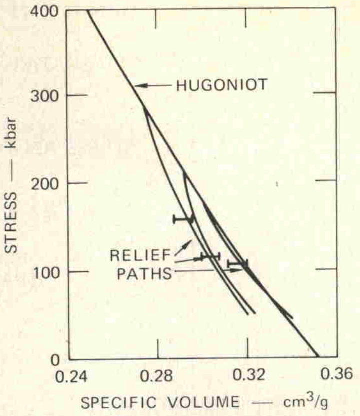
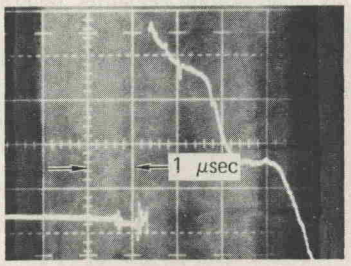


Fig. 3. Unloading paths in dolomite. Error bars are best estimate for unloading curves.

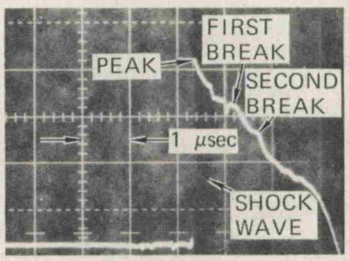
about 270 kbar, stress relaxation occurs due to a rate-dependent transformation of material from a low- to high-density phase. The first break in the profiles at about 270 kbar on unloading corresponds to first arrival of the relief wave from the flyer plate free surface. Details in the stress-volume path in the neighborhood of 270 kbar are questionable because the type of analysis used is subject to increasing error in regions where the stress profile shows increasing flatness. We believe that the second break on unloading at about 220 kbar corresponds to a reverse (high to low density) transformation of the volume fraction that was converted to the high-density phase during shock loading and approximately 1 μs of stress relaxation. This transformation is indicated in the middle figure of Figure 4 by a shallower stress-volume path on unloading below the break at 220 kbar.

SOUND VELOCITIES ON THE HUGONIOT

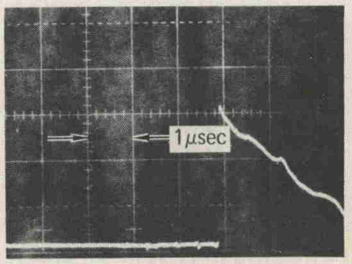
A previous study of the sonic velocity behind a shock wave in silicate rocks [*Grady et al.*, 1975] provided considerable insight into the mechanical processes accompanying shock deformation. A similar examination of the Hugoniot sound velocities obtained in the present work was attempted. As in the silicate work, the first characteristic of the overtaking relief wave provided an estimate of the Lagrangian sound velocity C_L at the Hugoniot state. Because of the immediate stress relaxation in the shots performed above 300 kbar, only those experiments shock loaded to a peak stress of less than 300 kbar were reduced in this manner. The Eulerian sound velocity C for the initial release wave refers to a material at rest and is given in terms of the Lagrangian velocity as $C = (\rho_0/\rho)C_L = (1 - u_p/U_s)C_L$ where ρ_0 and ρ are the initial and Hugoniot specific densities, respectively, u_p is the Hugoniot particle velocity, and U_s is the shock velocity. Since the shock velocity and stress on the Hugoniot are measured directly, the Hugoniot jump relations were used to calculate u_p and thus obtain the Eulerian sound velocities for comparison with equation of



1.58 mm FROM IMPACT INTERFACE

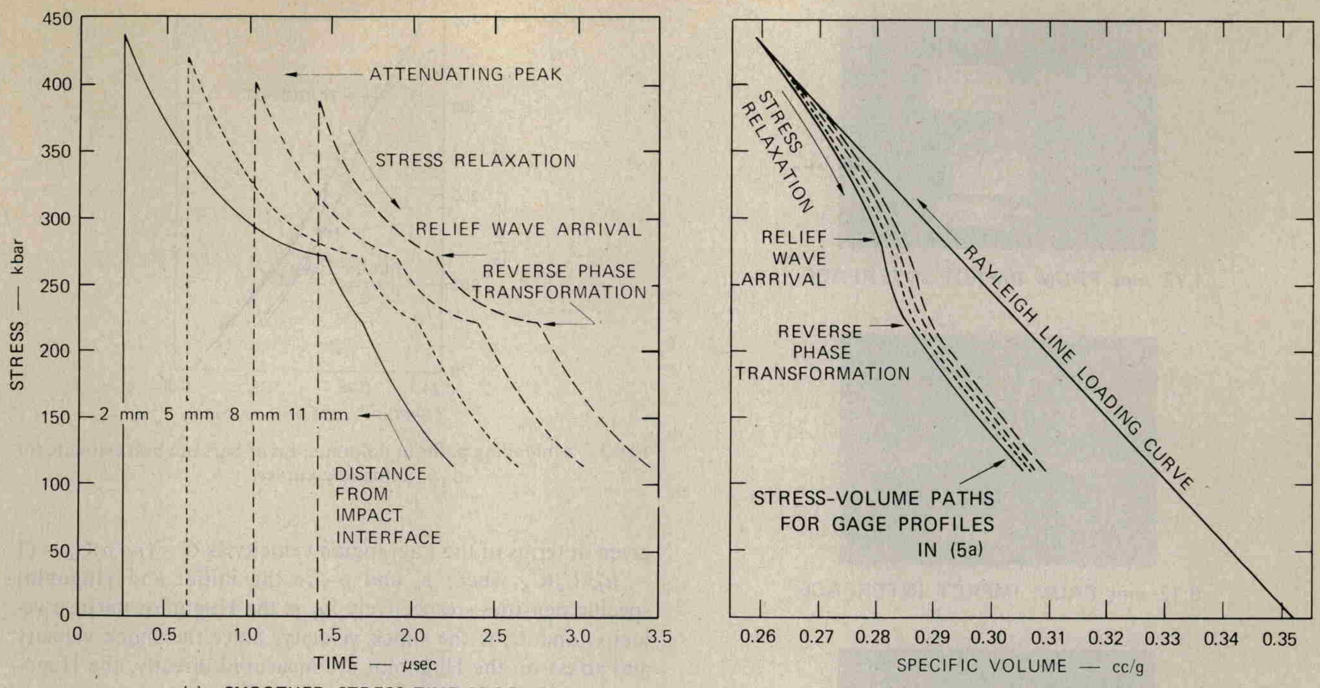


4.80 mm FROM IMPACT INTERFACE



8.17 mm FROM IMPACT INTERFACE

Fig. 4. Stress relaxation in dolomite. Peak stress is approximately 420 kbar. The figure shows three of seven successful gage records obtained in this experiment. In the 4.80-mm profiles, unloading features observed in all the profiles are indicated.



(a) SMOOTHED STRESS-TIME PROFILES (b) STRESS-VOLUME PATHS

Fig. 5. Stress-time profiles and stress-volume paths for material elements corresponding to gage locations.

state predictions. The sound velocities determined by this method are shown in Figure 6.

The bulk sound velocity for dolomite determined from ultrasonic data [*Birch,* 1960; *Press,* 1966; *Heard et al.,* 1973] was extrapolated to high pressure and is also shown in Figure 6. The measured Hugoniot sound velocity is seen to be significantly higher than the extrapolated bulk sound velocity. If the material retains rigidity at the Hugoniot state, initial relief waves will propagate at a longitudinal velocity which will be higher than the bulk sound velocity by a factor $C/C_0 = \{[3(1 - \nu)]/(1 + \nu)\}^{1/2}$, where ν is Poisson's ratio and C_0 is the bulk sound velocity. In Figure 6 we have shown longitudinal sound velocity curves based on the extrapolated bulk sound velocity curves and assumed constant values of Poisson's ratio equal to 0.15 and 0.25. A value of Poisson's ratio for Blair dolomite measured at 1 atm and room temperature is 0.24 [*Petersen,* 1969]. The data agree best with a value of 0.15 for Poisson's ratio, which is not immediately unreasonable. However, studies by *Anderson et al.* [1968] on a number of rock-forming minerals indicate that both the pressure derivative and the temperature derivative of Poisson's ratio are positive in the large majority of cases. On the basis of the initial Poisson's ratio of 0.24, the lower value of 0.15 seems unlikely. We suggest that an alternative explanation for the unusually high Hugoniot sound velocities would be the occurrence of a partial or complete transformation during shock compression to a higher density and less compressible phase.

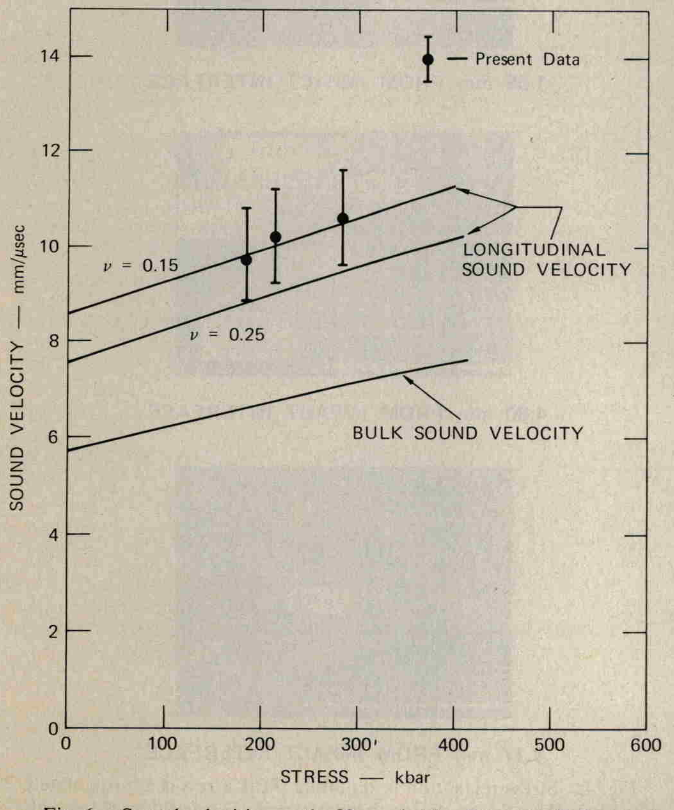


Fig. 6. Sound velocities on the Hugoniot for dolomite. Bulk sound velocity curve is extrapolated from ultrasonic data. Longitudinal sound velocity curves are estimated from the bulk sound velocity and a constant Poisson's ratio ν.

DISCUSSION

We currently believe that the unusual properties observed when dolomite is subjected to high-pressure shock compression are the effects of a rate-dependent low- to high-density phase transformation. A phase transformation is the simplest explanation for the variation from linearity in the shock velocity-particle velocity curve, as suggested by *McQueen et al.* [1970] and for the deviation of the pressure-volume Hugoniot from the Murnaghan curve extrapolated from ultrasonic data. Hysteresis in the relief curves from peak stresses of less than 300 kbar suggests that a phase transformation is occurring. The stress relaxation observed in the experiments performed at stresses above 400 kbar indicates a time-dependent phase transformation occurring during a time comparable to the shock wave transit time in the specimen. The large value of sound velocities measured on the Hugoniot, although possibly an indication of material strength