

SHOCK-RELEASE OF VAPOR FROM CALCITE,

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The most abundant non-hydrous volatile-containing minerals in the terrestrial planets are the carbonates. Carbonates make up a significant fraction of the surface materials of Earth and probably Mars and Venus, so impacts into these materials are likely to have an effect on the early composition and evolution of the atmospheres of these planets. The magnitude and nature of this effect depend on the quantity and composition of vapor released by the carbonate rocks when they are shocked. The release of volatiles during impact is also an important controlling factor in the mechanics of the cratering process in carbonate terrains, and may manifest itself in the crater morphology (1).

Two experimental approaches were taken to investigate this problem. First, Hugoniot and release data were obtained for a single crystal of calcite shocked to 35 GPa. The release path was determined at two points (Fig. 1) using the rear surface buffer impedance-match method (2). These two points define a shallow release path to low densities (high specific volumes) suggesting possible vaporization upon release from the peak pressure.

The second approach was to measure the released vapor directly. Two solid/vapor recovery experiments were carried out using targets described by (3), on samples of calcite cut from the same crystal used in the release adiabat experiment. In the first recovery experiment, a 0.297 g sample was shocked to 17.4 GPa. About 0.8 μmol of CO_2 were recovered, which corresponds to 0.012 wt percent of the initial sample, or 0.027 wt percent of the available CO_2 . An approximately equal amount of additional gas, which would not condense in a liquid nitrogen cold trap, was also recovered. In the second experiment, a 0.371 g sample of calcite was shocked to 18.8 GPa. This time, 2.2 μmol of CO_2 were recovered, accounting for 0.026 wt percent of the sample, or 0.059 wt percent of the available CO_2 . Also, 25.1 μmol of the "uncondensable" fraction were recovered. Of this, 14.1 μmol were found to be H_2 , which presumably came from interstitial hydrogen lost from the stainless steel container. The remaining fraction consisted of 8.4 μmol of CO , leaving 2.6 μmol of some other uncondensable gas or gasses. The most likely candidate for this other gas is O_2 , but 4.2 μmol of O_2 are required to balance the 8.4 μmol of CO , if the only vapor products of the CaCO_3 are CO_2 , CO , and O_2 . With H_2 contaminating the system, it is likely that some H_2O and/or $\text{Ca}(\text{OH})_2$ may have formed, accounting for the missing O_2 . The uncondensable portion of gas from the first recovery experiment is thought to have been of similar composition, but it was not analysed. In order to demonstrate that the CO_2 , CO , and O_2 are definitely from the calcite and not the stainless steel, it will be necessary to perform a control experiment, in which an empty target cylinder is shot and an analysis is performed on the released gas.

In the release adiabat experiment, the calcite was shocked to a pressure at which, according to theoretical calculations (4,5), incipient vaporization may take place. The observed shallow release adiabat is therefore consistent with these calculations. In the two recovery shots, however, peak pressures were well below the minimum estimate for incipient vaporization. The amounts of gas released in these experiments are extremely minute fractions of the available volatiles in the samples, and the liberation of vapor at these

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pressures can probably be attributed to the inhomogeneous deposition of shock energy (6). This is the same process that may control the incipient release of vapor from aragonite (4) and serpentine (3) shocked to pressures below those predicted by theoretical considerations.

Carbonates in nature are generally porous and therefore less dense than the single crystals shocked in these experiments. At a given shock pressure, therefore, higher temperatures and specific entropies will be obtained during natural impact events. Thus we expect that the percentages of vapor release observed in the two recovery experiments is a lower bound; however, even these small quantities may have a significant effect on cratering processes and atmosphere formation.

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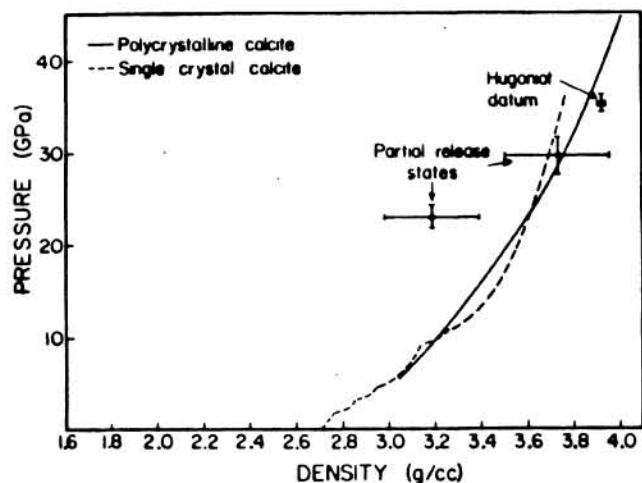


Fig. 1 Hugoniot and two partial release states for calcite shocked to 35 GPa. Release states obtained using magnesium and polycarbonate (lexan) materials.