
A variety of x-ray diffraction techniques were applied to investigate the shock induced lattice breakdown of a number of silicates and to supplement and/or refine optical criteria concerning various degrees of shock metamorphism.

SINGLE GRAIN DEBYE-SCHERRER TECHNIQUES:

A strong correlation of increasing lattice disorder with increasing shock pressure was reported by (1), using experimentally shocked single crystal silicates and single grain Debye-Scherrer techniques. The methods of (1) were applied to Climax Stock granodiorites from the Piledriver nuclear event (kindly provided by I. Borg). Their respective shock histories were well documented by in situ stress gages (2). Thus they appeared valuable in comparing experimentally shocked single crystals and their counterparts in dense, igneous rocks.

Per each of the 6 Piledriver samples, >50 randomly picked individual quartz or feldspar grains were individually x-rayed and assigned a peak pressure using the calibrations of (1). Some results are illustrated in Figs. 1 and 2. The following conclusions are drawn:

a. The significant range of peak pressures observed for grains originating from ~1 cm³ sample volume compliments and significantly extends some optical observations (e.g., 3,4). The data demonstrate that component phases within a dense rock may suffer significantly different shock deformation(s). The distribution of shock effects in dense, crystalline rocks is highly controlled by reflections and rarefactions on grain boundaries leading to large, localized stress concentrations akin to those described for porous materials (5,6).

b. Presently used optical criteria for pressure calibration of shocked rocks (e.g., 7,8) rely generally on the most severely shock damaged components within any given rock and thus do not reflect an average peak pressure for the entire sample. Thus present optical calibration is less quantitative than the x-ray technique in assigning average peak pressures to the entire rock. The mean pressure determined by x-ray techniques is always smaller than that based on present optical methods because it uses a number of randomly selected grains and thus better assesses the range and mean pressures experienced by all minerals. Clearly these considerations are important in attempting to derive pressure and thereby total energy estimates in studies relating to cratering mechanics.

c. The mean pressures determined in this study using the calibrations of (1) do not agree with the in situ stress gage calibrations (2) as illustrated in Fig. 2 which also includes some data from experimentally shocked Climax Stock granodiorites. These trends are in keeping with (2) who suggests a variety of factors (e.g., temperature, strain rate, stress differential) why the Piledriver samples may display less shock damage than their experimental counterparts, e.g., no diaplectic feldspar glasses at 263 kb. However, the absolute difference between the two sets of calibrations is unexpectedly large and we can offer no ready explanation.

POWDER DIFRACTOMETER TECHNIQUES:

The initial broadening and subsequent disappearance of specific diffraction lines observed in the Debye-Scherrer work (1) was refined by using powder...
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diffractometer techniques. Single crystal quartz and orthoclase were shocked, ground into powders of <50 μm grain size, mixed with an internal Al₂O₃ standard, and then x-rayed (9). Fig. 3 shows some general diffractometer patterns for the orthoclase. Fig. 4 illustrates some details for the quartz (101) peak. Finally, Fig. 5 displays the ratio of the (101) quartz peak amplitude and half-width of the peak (measured at half the amplitude).

After establishing these calibrations, a suite of optically well documented Ries samples (kindly provided by D. Stöffler) were subjected to the same procedure; the materials included a variety of granitic and gneissic rocks. As illustrated in Fig. 6, a general correlation of amplitude/half width does exist, however the data are characterized by significant scatter. The scattering may be caused by a variety of factors: (1) varying phase assemblage of rock materials, i.e., different amounts of quartz present, (b) differences in "average" peak pressure obtained by the diffractometer technique versus optical "calibration", and (c) possible recrystallization effects in the Ries samples. All of the above factors may contribute. At present the optical classification of these shocked rocks (10) may appear more suitable to establish relative pressure histories than the x-ray diffractometer method, however, we will attempt, in the future, to isolate some of the above parameters for possible further refinement of the diffractometer technique as a rapid means to assess the pressure histories of shocked rocks.

References:

(1) Hörz, F. and Quaide, W. L. (1973), The Moon, 6, 45-82.
(2) Borg, I. Y. (1972), Geophysical Monograph Series, 16, 293-311.
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Fig. 1: Debye-Scherrer (D.B.) derived pressure estimates for individual grains from Piledriver Granodiorite (S.G. - stress gage calibration; N = number of grains analysed).

Fig. 2: Debye-Scherrer (D.B.) derived pressure estimates for Piledriver samples and comparison with experimentally shocked specimen (S.G. = stress gage calibration; AC = 20 mm accelerator calibration).

Fig. 3: X-ray diffractometer scans of experimentally shocked orthoclase single crystals (Itarongai, Madagascar).

Fig. 4: Detail of x-ray diffractometer scans of quartz (101) peak and Al2O3 internal standard.

Fig. 5: Ratio (hw) of quartz (101) peak amplitude (CPS) and peak half width (2θ°) as a function of peak pressure (solid circles: 40 KV/11 mA; Pb substrate; open circles: 50 KV/5 mA, Pb substrate; crosses: 40KV/11 mA, glass substrate).

Fig. 6: Correlation of diffractometer studies (hw, see Fig. 5) and optical classification (Stöffler, 1976) for 36 whole rock samples from the Ries Crater, Germany.