PRESSURE DISTRIBUTION IN NATURALLY AND EXPERIMENTALLY SHOCKED GRANODIORITES. R. E. Hanss, B. R. Montague, M. K. Davis, C. Galindo, St. Mary's University, San Antonio, TX 78284 and Friedrich Hörz, NASA Johnson Space Center, Houston, TX 77058

Introduction: Even cursory microscopic inspection of shocked rocks reveals that the shock pressure distribution in such materials is rather heterogeneous; not all mineral grains of the same species (e.g., quartz or plagioclase) display identical shock features; usually a wide range of shock deformations is observed between adjacent grains, if not within individual grains, e.g., diaplectic feldspar glasses may coexist with much more modestly shocked feldspar or conversely may coexist with small amounts of incipient grain boundary feldspar melts. Such heterogeneous pressure distributions are particularily evident in porous materials [1,2,3], though they occur unquestionably also in dense, polycrystalline rocks [4,5,6]. According to the detailed studies by [1] and [2] it is thought that reflection(s) and reverberation(s) of the shockwave at grain boundaries, i.e., changes in accoustic impedance, are largely responsible for localized stress concentrations on microscopic scales. In order to determine the total energy deposited into a shocked assemblage it is therefore necessary to proceed with a statistical approach, i.e., measure the shock deformation of numerous grains [e.g., 7]. The following is such an approach using the Debye-Scherrer x-ray techniques of [8] and it compliments and refines the above optical studies.

Experimental Procedures: Using a rotated single grain technique, it is possible to assign individual mineral grains a specific peak pressure by evaluating the degree of lattice disorder obtained from Debye-Scherrer (D S) x-ray films [8]. We therefore crushed shocked granodiorites and randomly picked quartz and feldspar grains from the .30-.35 mm diameter fraction. Each grain was individually x-rayed and the resulting DS patterns were compared with film standards developed from experimentally shocked single crystals of quartz and oligoclase [8]. The present sample materials originated from 3 distinctly different shock environments: (a) Climax Stock granodiorite from the Piledriver nuclear event ([g], kindly provided by I. Borg), (b) the same material experimentally shocked in the JSC 20 mm Flat Plate Accelerator and (c) naturally shocked granites from the Ries Crater, Germany (kindly provided by D. Stöffler). Approximately 1 cm^3 was crushed from samples a and c; only ≈25 mg were available per each flat plate accelerator sample. Though neither the mode nor precise mineral-chemistries of these samples are identical, their shock behavior is largely characterized by their dominant quartz-feldspar mineral assemblages.

Results : Though consuming almost the entire sample mass, only 20-25 single grains could be analyzed per each flat plate accelerator shot. The pressures obtained in individual grains are plotted in a cumulative frequency plot per each shock experiment (Fig. 1). The median pressures (at 50% level) compare favorably with the pressure calibration for the shock experiments originally obtained from a graphic impedance match solution [e.g., 3,5,8]. The median DS pressures (xx/-) versus original accelerator (AC) pressures (--/xx) are as follows: Shot 404 (32/51 kb); Shot 498 (135/144 kb); Shot 400 (175/198 kb); Shot 397 (255/244 kb) and Shot 395 (>300/310 kb; the DS

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technique fails >300 kb [8]). Considering that the accelerator pressures are accurate to ±3% and that the basic DS calibration not only rests on single crystal shock work but is accurate only to ≈20% [8], the agreement between DS and AC pressures appears favorably and the DS technique can therefore be applied to study the distribution of shock pressures in other polycrystalline targets.

Fig. 2 presents identical data from 6 Climax Stock granodiorites shocked during the Piledriver nuclear event. Note similar cumulative pressure distributions as in Fig. 1. Fig. 3 displays similar results for 3 Ries samples, i.e., biotite-granite clasts recovered from suevite [5]. Median pressures obtained for Otting 604, Zipplingen 352 and Aumühle 174 are 71, 92 and 219 kb respectively, which is consistent with the optical characterization in terms of relative peak pressure histories; however, the absolute DS median pressures are significantly lower than those traditionally quoted from microscopic observations [3,4,5,6], because such optical studies are based on the highest shocked species per any given thin section and especially because optical characterization does not necessarily include the weak to modestly shocked components. It is therefore suggested that detailed shock histories of naturally shocked specimen may only be assigned if a statistically significant number of randomly selected grains is investigated.

Another interesting result - though at present poorly understood - is illustrated in Fig. 4 by plotting the median pressure (= 50% level of Figs. 1, 2 and 3) versus the range of pressures; in order to avoid potential statistical flukes due to relatively small sample numbers, especially for the AC results, "range" is defined as the 10% - 90% level of Figs. 1, 2 and 3, i.e., frequency values <10% and >90% were deleted. A striking difference between the AC and Ries samples is found, the latter ones displaying a much wider range (Figs. 1-4), which is of statistical significance. Whether the AC and Piledriver ranges observed are statistically significant remains the subject of future studies. However a tentative conclusion is offered that the range of peak pressures may be dependent on peak pressure pulse duration which is measured in terms of a few microseconds for the AC experiments versus seconds in the natural Ries impact. Longer pulse duration, possibly also a significantly more complex target stratigraphy, may allow more complicated reflection(s) and rarefaction(s) geometries to take place, resulting in more multiple wave passages and more complex wave geometries on microscopic scales.

References:
[1] Kieffer, S. W. (1971) J. Geophys. Res., 76, p. 5449-5473. [2] Kieffer, S. W. et al. (1976) Contrib. Mineral. Petrol. 59, p. 41-93. [3] Gibbons, R. V. et al. (1975) Proc. Lunar Sci. Conf. 6th, p. 3143-3171. [4] Chao, E. C. T. (1966) Fortschr. Mineral. 44, p. 139-163. [5] Stöffler, D. (1971) J. Geophys. Res. 76, p. 5541-5551. [6] Schaal, R. B. and Hörz, F. (1977) Proc. Lunar Sci. Conf. 8th, p. 1697-1729. [7] Robertson, P. B. and Grieve, R. A. F. (1977) Proc. Symposium "Planetary Cratering Mechanics," The Lunar Science Institute, in print. [8] Hörz, F. and Quaide, W. L. (1973) The Moon, 6, 45-82. [9] Borg, I. Y. (1972) Geophysical Monograph Series, 16, p. 293-311.

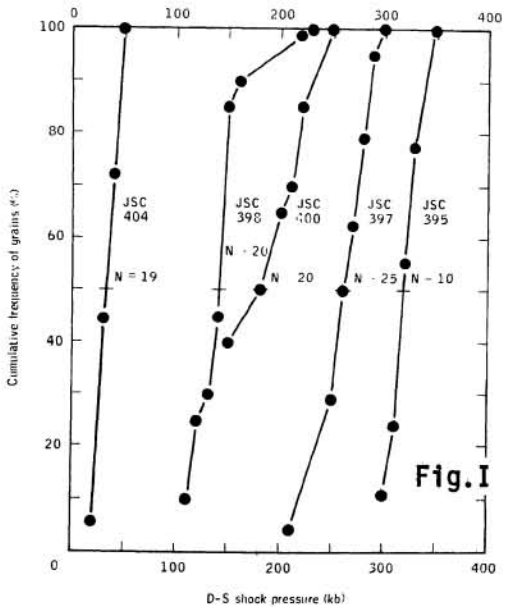

Fig. I

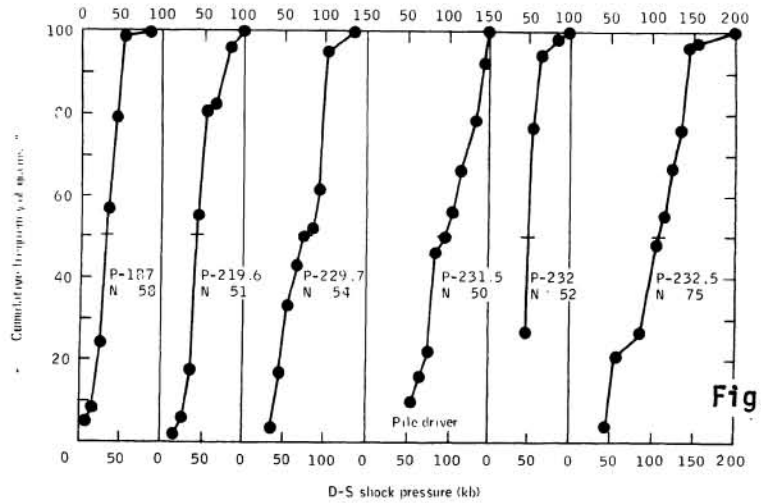

Fig. 2

Fig. 1: Debye-Scherrer (D-S) pressure distribution for individual quartz and feldspar grains from experimentally shocked climax stock granodiorite samples.

Fig. 2: Debye-Scherrer (D-S) pressure distribution for individual quartz and feldspar grains from climax stock granodiorite shocked in the Piledriver nuclear event.

Fig. 3: Debye-Scherrer (D-S) pressure distribution for individual quartz and feldspar grains from Ries crater samples.

Fig. 4: Range of pressure vs. median shock pressure for Riès, Piledriver, and JSC-accelerator samples.

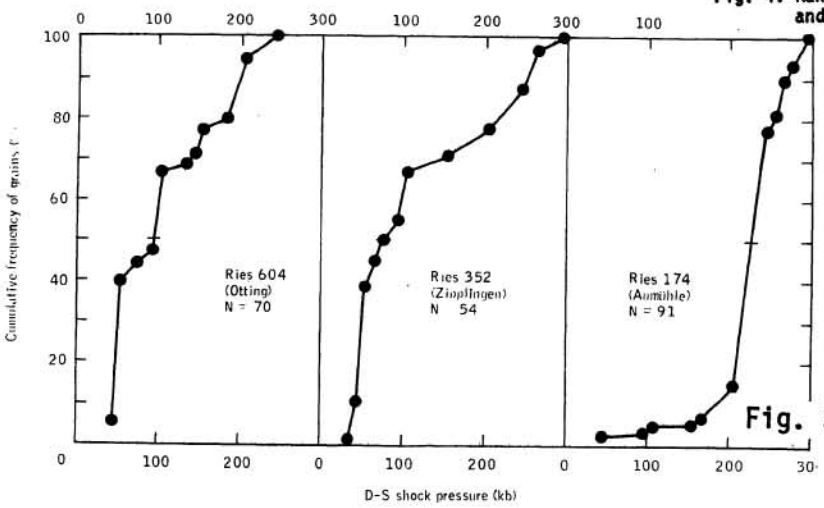

Fig. 3

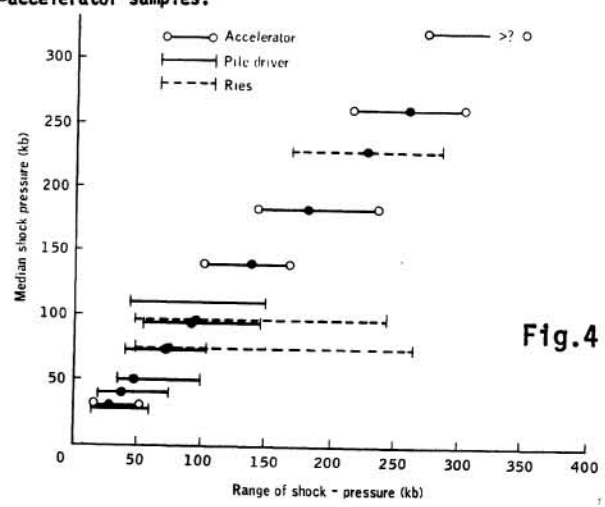

Fig.4