diffuse spots indicative of domains 20 A to 100 A in size, and only a few specimens indicated domains of about 250 A to 350 A. Dependence of domain size on shock pressure might be expected (Dawson and Rose, 1963) and is the subject of further investigation. For the present, spot width measurements were made to compensate for the overriding effects of instrument geometry, sample size, and exposure time.

Inspection of the diffraction photographs obtained from natural and experimental samples of shocked and pressurized minerals reveals definite differences which make possible a relative grading of internal damage. Therefore, measurements of length of asterism and of line widths were made to provide relative numerical comparisons. All measurements were made directly from the films, using a low-powered microscope fitted with a calibrated micrometer scale whose smallest division was equal to 0.05 mm. Interpolation to 0.01 mm was possible, but because of gradation of contrast between the edge of the diffraction spots and background on the x-ray film, asterism and line breadth measurements were read with an estimated error of ± 0.025 mm. Since the average line breadth of diffraction spots was 0.25 mm, this value can be in error by ± 10 percent. Most of the asterism measurements, however, were over 1.0 mm, so that they can be in error by

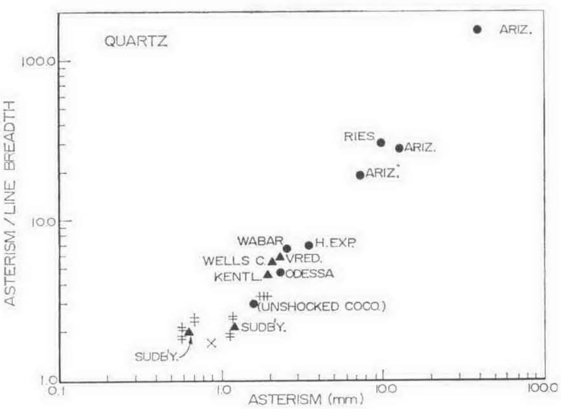

Fig. 6. Trend of the Asterism/Line Breadth ratio as a function of Asterism for quartz grains taken from various sources. The abbreviations refer to samples listed in Table 1. The symbols ‡, +, and × represent quartz grains from metamorphic, volcanic, and single crystal specimens respectively. Samples from shatter cones are indicated by triangles.

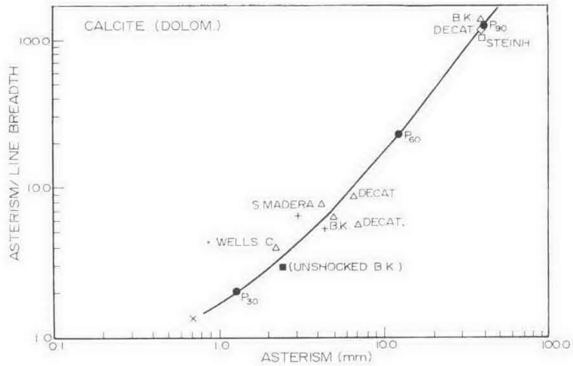

Fig. 7. Trend of Asterism/Line Breadth ratio as a function of Asterism for calcite samples from various sources. Superimposed on the diagram are data from pressure deformation experiments on calcite polycrystalline samples—(vide infra) to illustrate the range of pressure associated with the asterism observed. The abbreviations refer to samples listed in Table 1. The points marked P_{30}, P_{60}, and P_{90} are results obtained from subjecting powder compacts of calcite to pressures of 30 kb, 60 kb, and 90 kb, respectively, in an opposed anvil apparatus. The × refers to the measurements obtained from the pattern of a small undisturbed single crystal of calcite. Samples from shatter cones are indicated by triangles.

± 2.5 percent or less. Because both asterism and line breadth are functions of the 2θ value, all measurements were made on the same 2θ values for a particular mineral. For quartz and calcite the diffraction maxima at 26.7° and 29.4° 2θ respectively (CuKα radiation) were used.

A summary of measurements for quartz and limestone samples is given in Figures 6 and 7, where the ratio, Asterism/Line Breadth, is plotted logarithmically against the Asterism (A/LB vs. A). The error in the Asterism/Line Breadth ratio is about ± 11 percent and is caused mainly by the error in line breadth measurements. The trend to higher values demonstrates increasing crystalline fragmentation in progressing from good single crystals to specimens from volcanic, metamorphic, shatter cone, and impact samples. There is some overlapping (in the region from 0.7 to 1.8 mm on the asterism scale) for samples from Sudbury, unshocked granite, Coconino sandstone, and samples of metamorphics. Nevertheless, the distribution of the asterism in minerals from shatter cones strongly suggests that the intensity of deformation is a result of cosmic impact.

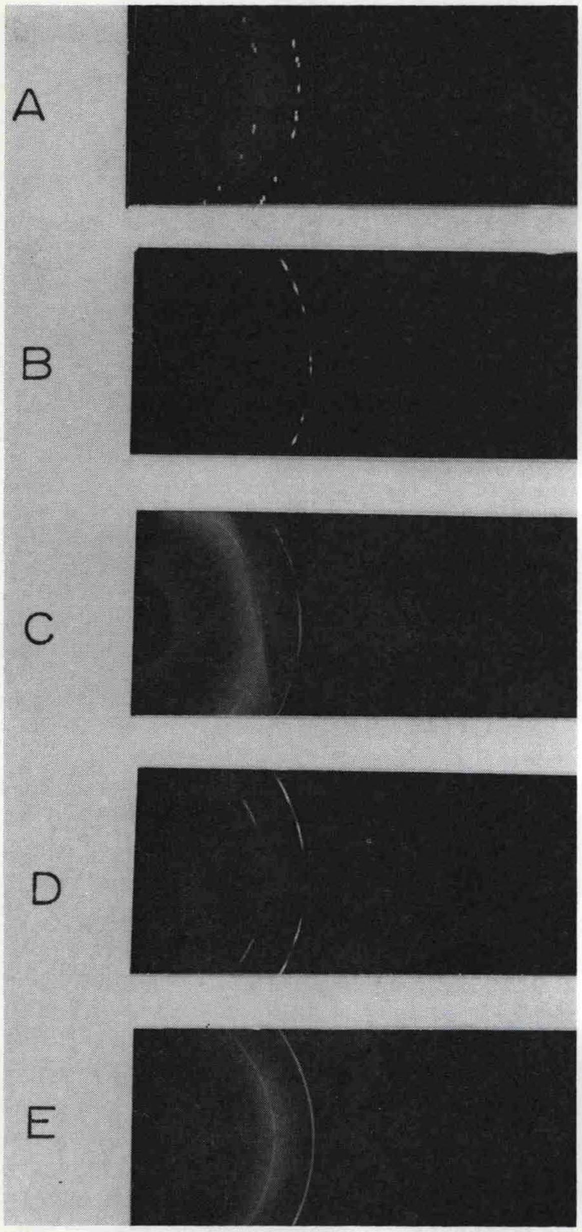

Fig. 8. Progressive asterism developed in quartz grains from polycrystalline compacts under increasing pressures: 10 kb (A), 40 kb (B), 90 kb (C), 100 kb (D), and 120 kb (E).

The following cautionary observations are pertinent: (1) The absolute values should be taken only as guides in forming conclusions. (2) The locations of the shatter cones relative to the centers of the structures from which they came are not known, and attempts to correlate the results with sizes of the structures are not possible. (3) The possibility of recrystallization of minerals after shattering and impact must be considered, e.g. for the older Sudbury and Vredefort samples. Disoriented overgrowths may contribute to apparent asterism of minerals in sediments. (4) The characteristics of minerals in the pre-impact host rocks of any suspected structure must be known. The normal quartz in unshocked Hardhat granodiorite and Coconino sandstone shows asterism close to that of some metamorphic rocks, but, after exposure to shock, there is a large increase in asterism. The initial asterism may have had its origin in the previous thermal and mechanical history of the rock or in the source area of original detrital grains.

QUASI-SHOCK HIGH PRESSURE EXPERIMENTS

To assist in evaluating the pressure dependence of asterism observed in shocked minerals, experiments were conducted in an opposed-anvil apparatus up to 120 kb pressure at room temperature. Apparatus and techniques have been developed in numerous studies over a period of ten years in this laboratory.

The minerals used in these experiments were quartz, calcite, albite, mica, and olivine. Materials were prepared by gently crushing large single crystals and using the fraction between 200 and 270 mesh. Each wafer was prepared by measuring the amount of powder necessary to fill, at theoretical density, the volume enclosed by the nickel ring of the apparatus (dimensions, 0.1875″ O.D.×0.125″ I.D.×0.01″ thick). A new sample was prepared for each pressure.

Three series of runs were made, one at a rate of 5 kb/minute, a second at a rate necessary to attain the required pressure in two minutes, and a third at 60 kb/minute. The latter rate was not wholly an arbitrary choice; it accomodated mechanical limitations and helped to reduce the frequency of shattering of anvils at the highest pressures.

Each sample was held at the required pressure for 5 minutes and then removed for examination. Grains were picked out of both the central and edge regions of the wafer and prepared for x-ray