DISTINGUISHING BETWEEN SHOCK AND TECTONIC LAMELLAE WITH THE SEM;
Bruce F. Bohor[1], Diane K. Fisler[2], and Andrew J. Gratz[3],
1) U.S. Geological Survey, MS 972, Box 25046, Denver, CO 80225,
2) Dept. of Geosciences., Penn State U., Univ. Park, PA 16802,
3) Deceased, formerly with LLNL, Livermore, CA 94550.

Much of the controversy over the origin of "planar features" in quartz grains is due to the method of examination. Use of the optical microscope alone for characterization of these planar features is inadequate for distinguishing between lamellar features formed by shock metamorphism and those formed by tectonic deformation. However, application of the scanning electron microscope (SEM) with its greater range of magnification, combined with hydrofluoric-acid (HF) etching of the quartz grains, allows for a positive distinction to be made between these two types of lamellar features.

Researchers who advocated a volcanic origin for K/T boundary sediments argued against the use of shocked quartz as a unique indicator of impact for these layers [1]. "Shocked" quartz most commonly is characterized by the presence of multiple sets of planar deformation features (PDF), which may consist of open fractures, twins, or glass-filled *planar* lamellae. Advocates of a volcanic origin for the K/T sediments claimed that they had observed similar lamellae in various pyroclastic ejecta deposits, and that examples of "shocked" quartz and feldspar could be identified not only in the K/T boundary layers, but also in other clay layers above and below the boundary [2]. Their criteria for "shocked" quartz and feldspar was expanded to include so-called "mosaicism", which may accompany higher levels of shock metamorphism but is neither uniquely associated with shock nor necessarily caused by it [3]. We discuss only PDF's here.

At the scale of observation routinely possible with an optical microscope, it is difficult to distinguish between shock-induced lamellae and those caused by tectonic deformation. The former are usually sharper and thinner, more planar, and generally continuous; the latter are often somewhat curved (wavy), indistinct, and often discontinuous [4]. However, examination at the higher magnifications possible in an SEM clearly distinguishes between the narrow (<1μm) glass-filled lamellae formed by hypervelocity shock metamorphism (Fig. 1) and the wider, ladder-like rows of dislocation loops that are due to slow-strain-rate tectonic deformation (Fig. 2). Pre-etching with HF preferentially dissolves the quartz glass within the shock lamellae and makes them more visible in the SEM, but does not noticeably affect the appearance of tectonic dislocations because the latter do not contain glass. Glass-filled PDF's often show "pillaring" (segmentation) after etching with HF (Fig. 1), due to the presence of narrow crystalline sheets intersecting the wider glassy lamellae [5].

Thus, it is the formation of quartz glass within fractures caused by high-strain-rate shock waves associated with impacts

DISTINGUISHING SHOCK FROM TECTONIC LAMELLAE: Bohor, B.F. et al.

[6,7] that allows a definitive distinction to be made at the micron scale between these shock PDF's and the glass-free dislocations trails marking slow tectonic deformation. We surmise that the so-called "shock lamellae" identified in quartz grains from layers above and below the K/T boundary, as well as those identified in some volcanic ejecta, are tectonic deformation dislocations. When subjected to HF-etching and examination in an SEM, they should appear distinctly different from those shock lamellae commonly observed in quartz grains from K/T boundary sediments. Laboratory simulations of explosive volcanism have shown that shock metamorphic effects such as PDFs cannot be produced by this process [8].

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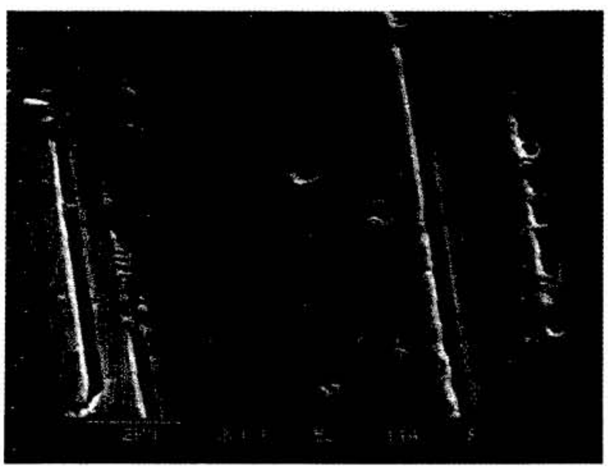

Fig. 1. Shock-induced PDFs in quartz from Haughton impact crater, Canada.

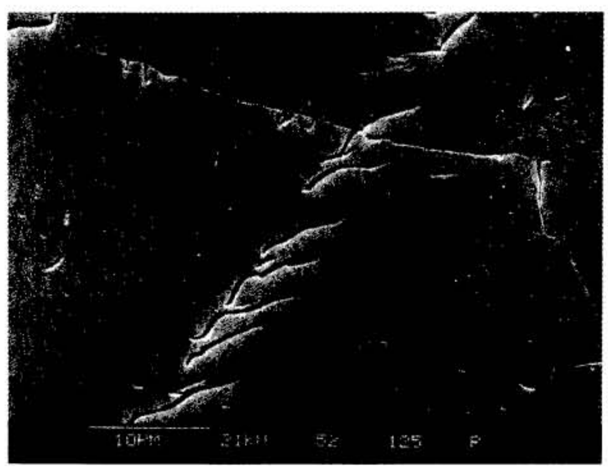

Fig. 2. En echelon tectonic dislocation loops in orthoquartzite from Arkansas.