# COMPARISON OF LOW-PRESSURE SHOCK-METAMORPHIC EFFECTS IN QUARTZ FROM BARRINGER CRATER, ARIZONA, AND KENTLAND DOME, INDIANA.

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**Introduction:** The recognition of low-pressure shock-metamorphic effects in quartz is of increasing importance in studies attempting to verify an impact origin for highly eroded structures [1], recognize sedimentary-target impacts characterized by a wide range of shock-pressure regimes, and identify distal impact-ejecta layers or impact-tsunamiites where high-pressure indicators may be rare or highly diluted. Low-pressure effects in quartz, if occurring in isolation without other supporting impact indicators, cannot normally be used as *diagnostic* evidence of shock metamorphism [2]. However, this lack of utility may be in part due to a dearth of studies systematically documenting these effects at verified impact sites.

Our study is a petrographic and universal stage (U-stage) microscope comparison of low-pressure shock-metamorphic effects in quartz from a proximal ejecta lithic clast of the Lower Permian Coconino Sandstone at the ~0.05 Ma, 1.2-km-diameter Barringer (Meteor) Crater, AZ, and from the Middle Ordovician St. Peter Sandstone exposed on the flank of the ~4-km-diameter central uplift of the <97 Ma, 13-km-diameter Kentland Dome structure, IN. Numerous classic studies verify an impact origin for Barringer Crater (see recent summary in [3]) and multiple lines of evidence support a similar origin for Kentland Dome [4–7].

**Shock-Metamorphic Effects:**

*Coconino Sandstone, Barringer Crater.* Unshocked Coconino Sandstone (sample MET-1-2) consists of a fine- to medium-grained, moderately well-sorted, rounded to well-rounded quartz arenite containing ~4% chert, ~1% feldspar, and ~1% accessory mineral framework grains, and ~20 vol% porosity. Quartz is characterized by sharp to slightly undulatory extinction under cross-polarizing light. The examined shocked sample (MET-1-4) matches the previously defined shock class 1b [8], which is recognized as weakly shocked sandstone that lacks remnant porosity and contains abundant grain comminution and fracturing (Fig. 1), common radial grain-contact concussion fractures (Fig. 2), and little or no intergranular high-pressure quartz polymorphs such as those defining the higher shock classes [8]. Rare planar microstructures are present, consisting of planar fractures (PFs) and poorly developed, incipient, non-decorated planar deformation features (PDFs), which have indexed Miller crystallographic orientations [9] equivalent to $c(0001)$, $\omega\{10\bar{1}3\}$, and $\pi\{10\bar{1}2\}$ (Fig. 2). About 50% of the quartz grains display marked grain mosaicism that is distinct from undulatory extinction in the unshocked quartz. This observation is qualitatively supported by comparison of U-stage-measured optic-axis spread within individual quartz grains from both unshocked and shocked samples [10] (Fig. 3).

*St. Peter Sandstone, Kentland Dome.* Unshocked St. Peter Sandstone (sample ST PETE-2) consists of a fine- to coarse-grained, poorly sorted to moderately well-sorted, subrounded to rounded quartz arenite containing ~2% accessory mineral framework grains, common syntaxial quartz overgrowths, common slightly undulatory extinction, and ~7 vol% porosity. Like the shocked Coconino sample, the shocked St. Peter Sandstone sample (KENT-5) is characterized by little or no remnant porosity, abundant grain comminution and fracturing (Fig. 4), and rare radial grain-contact concussion fractures. Optic mosaicism, distinct from undulatory extinction, is present in ~75% of the quartz grains (Fig. 3). Planar microstructures, which are common and quite different from those observed in the Coconino sample, consist of common open PFs with $c(0001)$ orientation and incipient, partially decorated PDFs with higher index orientations including $r\{10\bar{1}1\}$, $\xi\{11\bar{2}2\}$, $s\{11\bar{2}1\}$, $x\{51\bar{6}1\}$, and $\{21\bar{3}1\}$. The incipient PDFs are commonly truncated by or developed off of longer, through-going PFs, forming “feather textures” that closely match similar features previously described from the Rock Elm structure, WI [1] (Fig. 5).

**Discussion:** In both shocked samples MET-1-4 and KENT-5, the lack of remnant porosity, the abundant grain comminution and fracturing, the abundant grain mosaicism, the common PFs with characteristic orientations, and the lack of well-developed PDFs all suggest maximum shock pressures of ≤10 GPa [9]. The very dissimilar development and orientations of incipient PDFs between the two shocked samples, however, may reflect important differences in shock impedance within the heterogeneous, porous sedimentary target rocks. Pre-impact porosity and target saturation, grain-boundary interactions during shock compression, and setting within the evolving crater (proximal ejecta vs. central uplift) may have all played a role in determining the resulting planar microstructures. Future work should examine other verified impact structures both to further catalog low-pressure shock effects as potential diagnostic indicators of shock metamorphism and to evaluate the influence of target lithology on the resulting observed shock effects.

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**References:** [1] French B. M. et al. (2004) *GSA Bull., 116*, 200–218. [2] Reimold W. U. (2007) *Meteoritics & Planet. Sci., 42*, 1467–1472. [3] Kring D. A. (2007) *LPI Contrib. No. 1355*, 150 p. [4] Cohen A. J. et al. (1961) *Science, 134*, 1624. [5] Gutschick R. C. (1987) *GSA Field Guide, North-Central Section*, 337–342. [6] Koeberl C. and Sharpton V. L. (1993) *Meteoritics, 28*, 382. [7] Bell M. S. and Sharpton V. L. (1996) *Meteoritics & Planet. Sci., 31*, A13. [8] Kieffer S. W. (1971) *JGR, 76*, 5449–5473. [9] Grieve R. A. F. et al. (1996) *Meteoritics & Planetary Sci., 31*, 6–35. [10] Dachille F. et al. (1968) *Shock Metamorphism of Natural Materials, Mono Book Corp.*, 555–583.

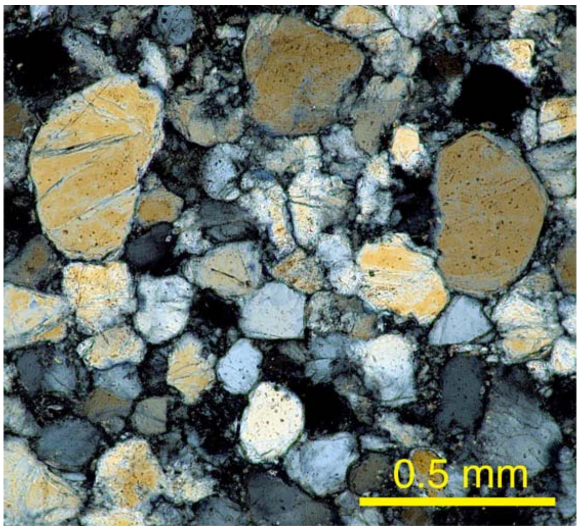


**Figure 1.** Photomicrograph of shock class 1b Coconino Ss., Barringer Crater. Sample MET-1-4, XP.

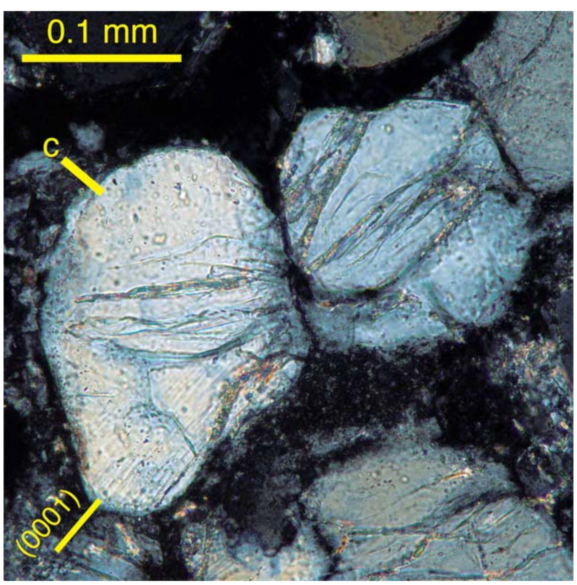


**Figure 2.** Photomicrograph of radial concussion fractures and incipient (0001) PDF set, shock class 1b Coconino Ss., Barringer Crater. Sample MET-1-4, XP.

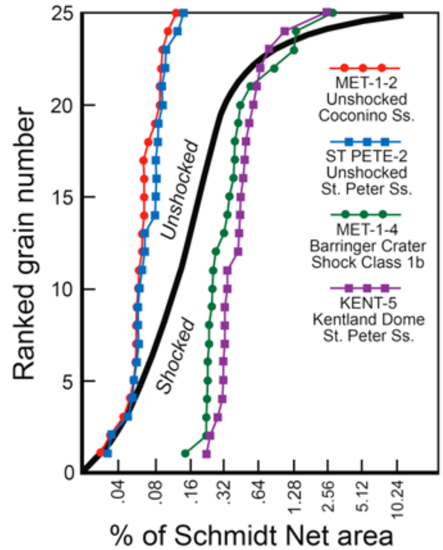


**Figure 3.** U-stage-measured quartz optic-axis spread, distinguishing unshocked and shocked samples. Solid black curve is based on empirical data in [10]. Method described in [10].

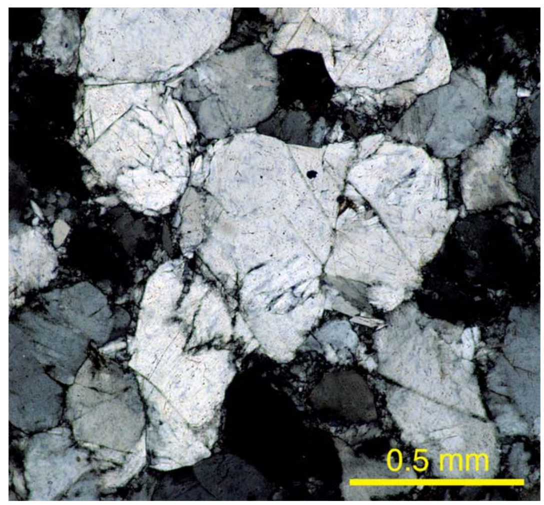


**Figure 4.** Photomicrograph of shocked St. Peter Ss., central uplift, Kentland Dome. Sample KENT-5, XP.

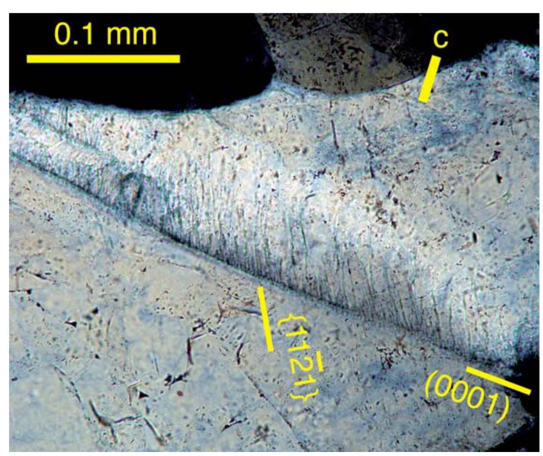


**Figure 5.** Photomicrograph of (0001) PF and incipient PDF sets forming “feather texture”. Sample KENT-5, XP.