Detrital shocked quartz in modern sediments eroded from the Rock Elm impact structure, Wisconsin, USA

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Introduction: It has recently been demonstrated that detrital shocked minerals eroded from large impact structures can be transported and preserved in siliciclastic sediments [1,2,3]. The goal of this study is to evaluate if a detrital shocked mineral record is created during the erosion of a small impact structure. We investigated siliciclastic sediments eroded from the ~6.5 km Rock Elm impact structure (USA) in a modern fluvial system for the presence of detrital shocked quartz. Preliminary results confirm the presence of shocked quartz in modern alluvium with the same shock microstructures previously documented in shocked quartz from the central uplift. The detrital shocked quartz in modern sediments documented here demonstrates that a lasting sedimentary record is created from the erosion of a relatively small impact structure.

The Rock Elm Impact structure: Rock Elm is a deeply eroded and poorly exposed impact structure located in west-central Wisconsin, and is distinguished from the regional geologic setting by having an anomalously circular area of deformed rocks, approximately 6.5 km in diameter [4, 5]. Various geologic elements make up the lithology and structure of Rock Elm: a ring boundary fault, a central uplift, a sediment-filled ring basin within the boundary fault, and deformed blocks of Prairie du Chien dolomite. Paleontological evidence from the basin-filling sedimentary unit designates that the Rock Elm structure has a minimum age of Middle Ordovician [4,5]. The central uplift exposes the Cambrian Mount Simon Sandstone.

Shocked minerals at Rock Elm: Planar deformation structures in quartz grains form from shock pressures (<5 to 25 GPa) and are one of the most accepted indicators of meteorite impact. Previous studies have documented shocked quartz grains in the Mount Simon sandstone exposed in the central uplift [4]. Shock microstructures documented include planar fractures (PFs) in up to four orientations, and also 'feather features' [4,7], a low pressure (5-10 GPa) microstructure in quartz that occurs along some orientations of PFs.

Results: Detrital shocked quartz in modern alluvium. Two thin sections of detrital quartz from modern alluvium collected in Plum Creek, a small stream eroding the western side of the structure, were examined for the presence of shocked quartz grains using transmitted light microscopy.

Quartz grains with planar fractures (PFs) in 1 to 4 orientations were documented in multiple grains from each thin section from Plum Creek (Figs. 1, 2); the crystallographic orientation of the PFs have thus far not been indexed, and is the subject of ongoing work. A total of 31 grains with PFs were identified in our preliminary survey. The shocked quartz grains are subangular [8] to rounded (Fig. 1). The PFs occur as both continuous and discontinuous features, and range from parallel to subparallel. PF spacing is high variable, ranging from 40 to 100 µm. In addition to PFs, 'feather features' (FFs), a relatively newly recognized shock microstructure in quartz [6,7], and one that was first documented at Rock Elm [4] were also found (Fig. 1b). The FFs emanate from only one set of PFs, and

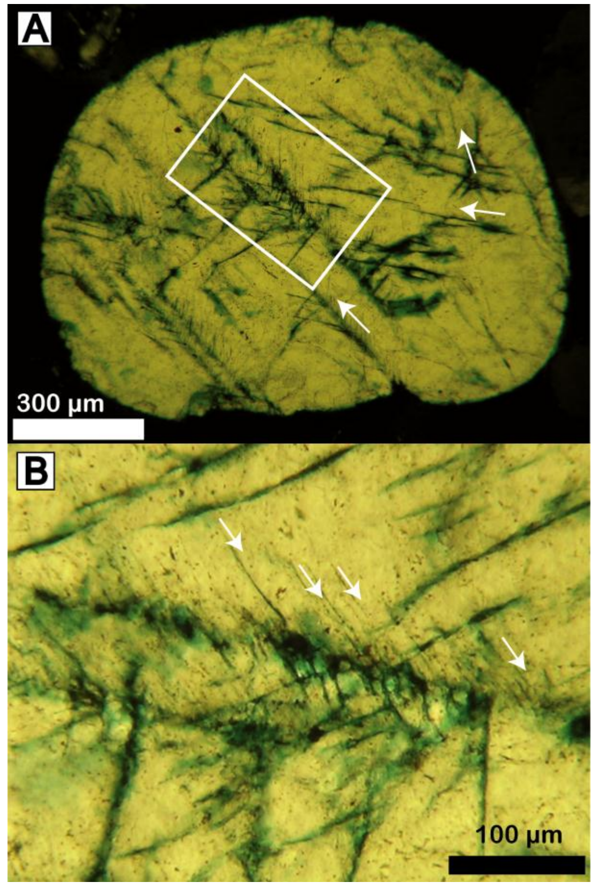

Figure 1: Example of detrital shocked quartz grain 11RE01-26 in modern sediment from Plum Creek. (A) Transmitted light image of a rounded quartz grain showing spaced sets of PFs in three orientations. (B) Close-up of inset box from (A). Arrows identify 'feather features' radiating from one of the PF orientations. The colored hue in fractures is from blue dye in the epoxy.

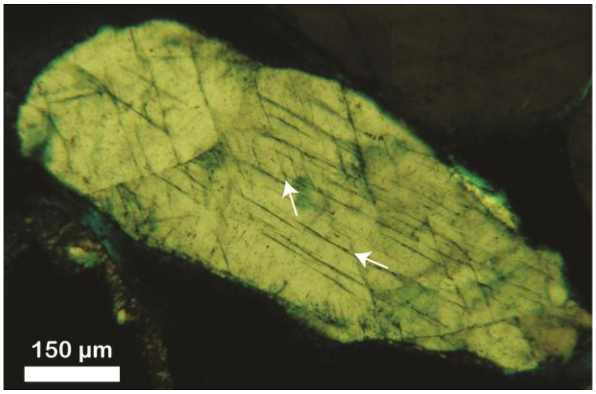

Figure 2: Example of detrital shocked quartz grain 11RE01-28 in modern sediment from Plum Creek. The transmitted light image shows an elongated sub-rounded quartz grain showing sets of PFs in two orientations indicated by arrows.

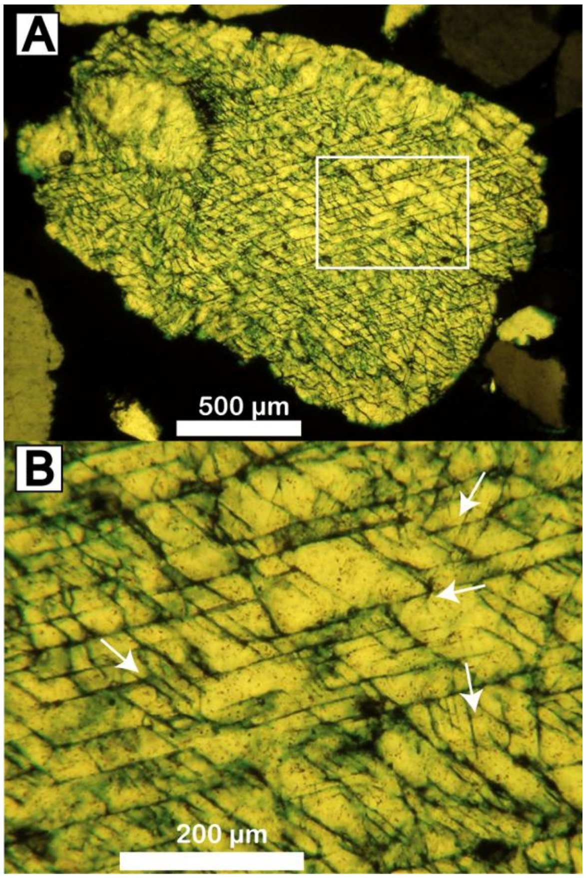

Figure 3: Shocked quartz grain from the Mt. Simon sandstone. (A) Transmitted light image of shocked quartz grain 11RE02-12, showing four orientations of well-developed PFs. (B) Close-up of inset box showing the closely spaced PFs.

always in the same direction (Fig. 1a). The acute angle formed by the FFs and host PF range from 40 to 41°, in agreement with the quantitative description of FFs by [7], which indicate that acute angles formed by FFs are always >34°.

Results: Shocked quartz in Mt Simon sandstone. Thin sections were also made of quartz grains from a sample of Mt. Simon sandstone exposed in the central uplift. Multiple grains of shocked quartz were identified, with PFs in up to four different crystallographic orientations (Fig. 3). The shock microstructures identified in Mt. Simon sandstone here are essentially the same as that identified by [4], and include PFs and FFs.

Discussion: Planar fractures (PFs) were documented in detrital quartz grains in modern sediment from Plum Creek, thus confirming the hypothesis that shocked quartz grains are present in modern siliciclastic sediments eroding from the Rock Elm impact structure. The highly rounded morphologies (Fig. 1) suggest that the Plum Creek grains are (at least) second cycle sediments, having been eroded from exposures of shocked Mt. Simon sandstone in the central uplift. The rounding likely occurred prior to deposition in the Mount Simon sandstone, as the location of our Plum Creek sample is <1 km from the center of the structure. The presence of PFs and feather features in the detrital shocked quartz grains is consistent with microstructures previously documented in bedrock, and record shock pressures of 5-10 GPa [4,7]. To our knowledge, these results are the first report of planar fractures and feather features in detrital shocked quartz grains.

References: [1] Cavosie et al. (2010) GSA Bulletin, [2] Erickson et al. (2013) Am. Min., [3] Erickson et al. (2013) GCA, [4] French et al. (2004) GSA Bulletin. [5] Cordua (1985) Geology, [6] Stoffler and Langenhorst (1994) MAPS, [7] Poelchau and Kenkmann (2011) JGR, [8] Cavosie et al. (2013) LPSC.