FINDING, CHARACTERIZATION, AND SIGNIFICANCE OF SHOCKED QUARTZ GRAINS.

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Introduction: As of today, about 190 impact structures and dozens of impact deposits/ejecta layers have been unambiguously confirmed on Earth, based on the finding and characterization of diagnostic indicators for shock metamorphism, such as shatter cones, planar deformation features (PDFs) in minerals, high-pressure mineral phases and glasses, and/or anomalies in platinum-group elements or isotopic anomalies in specific geological settings [e.g., 1 and references therein]. The finding of shocked quartz grains is often used as the "smoking gun" for the confirmation of a new impact structure or impact deposit, but special care should be taken for its identification and proper characterization because some features commonly found in quartz (and also in other minerals) – tectonic deformation lamellae, irregular fractures, trails of fluid inclusions, or mineral needles inclusions (or cleavages for a number of minerals) – may superficially look like shock microstructures [1, 2]. The search for shocked minerals can be long and tedious, as, in some cases, a ratio of one shocked grain to hundreds or thousands of unshocked grains. Shocked planar microstructures in quartz are mainly of two types: (1) planar fractures (PFs), which are planar, parallel, thin open fissures, (2) PDFs, which are narrow, individual planes of originally amorphous material (i.e., often recrystallized to quartz and decorated) comprising straight, parallel sets spaced 2–10 μm apart that generally occur as multiple sets per grain [1-3]. Feather features is also diagnostic of low-shock-pressure; they occur along PFs as short, parallel to subparallel lamellae with spacings similar to those of PDFs [4]. All these microstructures are crystallographically controlled and, thus, their orientations can be determined using universal stage and/or transmission electron microscope (TEM). We discuss here two recent cases of "shocked quartz grains", for which we were not able to confirm the initial observations (i.e., for the Tsenkher structure) or for which, based on the available descriptions and photographs, we can definitely exclude a shock metamorphism origin for the observed features.

Results and discussion: The Tsenkher structure is a 3.7 km crater-like structure located in Mongolia for which an impact origin was suggested (based on remote sensing data) already 20 years ago [5]. In a recent publication, Komatsu et al. [6] report on findings that they interpret as being impact related, including "[…] the presence of a structurally uplifted near-circular rim surrounded by an ejecta blanket, and abundant breccias […]". They also report on a single quartz grain containing "two undecorated PDF sets" and on other non-conclusive geochemical data. As the image of the claimed shocked quartz grain was not totally convincing, we decided to perform FIB-TEM investigations on this grain. Our study showed that a few free dislocations occur in the grain, but no PDFs or other shock diagnostic microstructures were observed. Thus, this quartz grain is not shocked and we can only recommend the authors to look for other shocked grains to confirm an impact origin for this structure.

Drake et al. [7] have recently reported on the discovery of an ejecta layer (located on the Isle of Skye, in Scotland) containing impactor fragments and shocked minerals, namely reidite and shocked quartz. We do not question the impact origin of the layer, but doubt the identification of the "shocked quartz grains". Only two quartz grains are shown (in the supplementary online material), one with "PDFs" that are in fact mineral needle inclusions and another one with "PFs forming a pseudo-cleavage with areas of diaplectic glass" that are definitely not PFs (i.e., we are not sure what the features are, maybe related to thin section preparation (?), but definitely not shock diagnostic).

The problem with the publication of an erroneous observation is that it may further be used for "extraordinary claims", as recently in Chen et al. [8] and Melosh [9], who discuss the "occurrence of PDFs in fulgurites", based on an erroneous observation by Gieré et al. [10], and finally argue that PDFs in quartz are not enough to claim an impact origin of a structure/deposit.

Recommendations: If only one or two "shocked quartz grains" are found, the authors should not only use the universal stage, but also the TEM to uniquely confirm the shock origin of the observed microstructures. It is also recommended to search for other shocked minerals, such as zircon, reidite, and other accessory minerals [e.g., 11, 12], as they appear to be very promising, in particular for old eroded structures/deposits.

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