THE KARDASHIANS OF SHOCKED MINERALS- CATCHING UP WITH TRENDS IN ACCESSORY MINERAL STUDIES.

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Introduction. The study of how accessory minerals respond to shock deformation has been ongoing for over 50 years [1, 2]. Contemporary approaches to study the microstructural evolution and geochronological response keep shocked accessory minerals at the forefront of impact studies. Data are now available for shocked apatite, magnetite, monazite, titanite, xenotime, zircon, and other minerals. Despite ever-growing recognition of the importance of accessory minerals, many important topics remain at the 'edge of understanding', and merit further investigation. Several are described below, including aspects relevant to zircon.

Lack of Experimental Constraints. Dynamic shock recovery experiments provide 'ground truth' calibration of microstructural changes. Few dynamic experiments exist for accessory minerals, and none exist for accessory minerals in natural host rocks. Two of the most widely cited dynamic experiments for zircon involve either single crystals [3] or zircon powder [4]. Results of dynamic experiments on zircon in porous host rock (sandstone) are presented for the first time here [5]; no dynamic experiments have been published on any accessory minerals in crystalline host rocks. A plethora of new experiments are needed to calibrate empirical observations for all accessory minerals.

Microstructure Quantification (EBSD) vs Description (Transmitted Light, BSE). Microstructures in accessory minerals have historically been documented with optical [e.g., 1-2] and BSE images [e.g., 6]. However, these methods are not capable of quantifying microstructures. The application of electron backscatter diffraction (EBSD) has provided the ability to quantify the nature of microstructures, providing a relatively rapid and non-destructive method to identify and quantify strain, deformation twinning, phase transformations, high-pressure polymorphs, and other features [eg 7]. BSE imaging remains useful as an imaging tool, but needs to be complemented with quantitative EBSD analysis in order to resolve the microstructure of accessory minerals.

Significance of *Ex Situ* Shocked Minerals. The recognition that shocked minerals can survive post-impact thermal conditions, uplift, erosion, sedimentary transport, deposition, metamorphism, and magmatic recycling has revealed Earth's sedimentary record to be a relatively unexplored archive of detrital shocked minerals [8-10]. However, the presence of *ex situ* shocked accessory minerals was recently cited to confirm an impact origin for the buried Hiawatha structure in Greenland [11]. Given the demonstrated longevity of shocked minerals in detrital systems [12], *ex situ* shocked minerals should probably not be cited as confirmatory evidence for an impact origin.

Planar Fractures in Zircon. Planar fractures are commonly observed in shocked zircon [6, 9, 13]. They occur as both open and closed fractures, and have been shown in some cases to contain deformation twins. However, in the absence of a microstructure diagnostic of high-pressure deformation (e.g., {112} twins or reidite), planar fractures do not represent diagnostic evidence of impact, and are insufficient for the identification of shocked zircon.

Effects of Shock Impedence. During shock compression, density contrasts among adjacent minerals give rise to variations in shock pressure (i.e., shock impedence), which can generate local pressure amplifications that vary significantly from average (bulk) pressure. Such effects have recently been proposed to explain the occurrence of reidite in crystalline target rocks from Chicxulub [13] where pressure estimates based on PDF in quartz indicate 16 to 18 GPa [14], substantially below reidite stability [3]. If the shock impedence reported in the Chicxulub granites is common, reidite should be found much more frequently in crystalline rocks. There is thus a need to evalulate the effects of shock impedence in empirical studies of all accessory minerals.

FRIGN Zircon. FRIGN zircon is a granular zircon that forms when zircon transforms to reidite, and then reverts to neoblastic zircon with characteristic disorientation relations among neoblasts. Recent identification of preserved reidite in FRIGN zircon from multiple impact structures confirms the key role reidite plays in its genesis [15].

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