INVESTIGATING THE IMPACT RECORD WITH DETRITAL SHOCKED MINERALS

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The study of detrital shocked minerals (DSM) merges planetary science, sedimentology, geomorphology, mineralogy/crystallography, accessory mineral geochemistry, microstructural analysis, and geochronology, all with the goal of identifying and determining the provenance of shock metamorphosed sand grains. A wide range of high-pressure impact-generated microstructures are readily detectable on external grain surfaces using standard SEM backscattered electron imaging, which can identify features such as planar fractures, lamellar intergrowths, and granular texture, that when analyzed in polished section, can confirm an impact origin for a given detrital grain. Of readily available characterization methods, electron backscatter diffraction (EBSD) has emerged as a primary non-destructive tool for quantifying diagnostic shock microstructures in polished section, such as deformation twin lamellae and high pressure phases. Critical information provided by EBSD includes phase identification and orientation, which are routinely acquired at the 50 nm scale, and presented as maps of entire grains or regions of interest. Pole figures assist in describing crystallographic misorientation, and can be used to identify systematic disorientation relations. The list of shocked minerals identified in sedimentary detritus continues to grow, and includes quartz, zircon, monazite, apatite, and a host of other phases currently under study. So far, DSM have been documented originating from a number of impact sites, including the Vredefort Dome [1-5], Sudbury [6], Rock Elm [7], and Santa Fe [8] impact structures, as well as in a reworked ejecta deposit [9]. DSM have been identified in numerous sedimentary environments of different ages, including modern alluvium, colluvium, and beach sand, in Holocene [6] and Permian [10] glacial deposits, and in a reworked Precambrian ejecta deposit [9]. Shocked mineral inclusions have even been documented within other detrital shocked minerals, as was done recently for a suite of detrital shocked monazite eroded from Vredefort that contain shocked zircon inclusions [11, 12]. Two main factors are recognized that imply the global siliciclastic record contains DSM: they can survive extreme distal transport, and they can survive 'deep time' lithification. Studies of South African sediments have demonstrated that shocked minerals survive distal transport in alluvium, as they have been identified in the Vaal River >750 km downstream from the Vredefort impact [2], and more recently, nearly 2000 km from Vredefort at the mouth of the Orange River on the Atlantic coast passive margin [4,5]; SHRIMP U-Pb geochronology confirms the origin of detrital shocked zircon and monazite from shocked Vredefort bedrock. Deep time preservation is demonstrated through identification of Vredefort-derived shocked zircon and quartz in highly lithified Permian glacial diamictite from the 300 Myr-old Dwyka Group in South Africa; shocked minerals eroded from Vredefort were entrained and transported in Paleozoic ice sheets [10]. The oldest known occurrence of detrital shocked minerals are reidite-bearing zircon grains discovered in the ~1.2 Ga Stac Fada ejecta deposit in Scotland [9]. Impact craters can, therefore, be viewed as unique 'point sources' that contribute DSM to the sedimentary record, in some cases for billions of years [1,4]. DSM thus have a wide range of applications to studying impact processes, including providing evidence of eroded impact craters, sedimentary provenance, insight into geochronology of *ex situ* zircon in lunar breccia [13], landscape evolution, and long-term sediment transport processes throughout the geologic record.

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