THE CENOZOIC DETRITAL SHOCKED MINERAL RECORD OF SOUTHERN AFRICA

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Introduction: Detrital shocked minerals, including zircon, monazite, and quartz have been documented in a range of different siliciclastic deposits produced from the erosion of the two largest impact basins on Earth, the Vredefort Dome and the Sudbury Basin [1-3]. Here we review results of ongoing detrital shocked mineral studies in the Orange River basin of southern Africa. The emerging paradigm is that: (1) detrital shocked minerals survive continental-scale transport, by rivers, wind, ice, and coastal processes. (2) a sedimentary record of shocked minerals over a large stratigraphic interval will be created during the erosion of any impact structure where they occur in bedrock, and (3) this record can aid in the identification of ancient, eroded, or unidentified impact structures.

Shock microstructures: Shock microstructures in detrital minerals are documented on grain surfaces and in polished section using transmitted light microscopy and SEM imaging techniques (BSE, CL, EBSD). In the Vaal River, detrital shocked quartz from the Vredefort Dome preserves decorated PDFs that are conspicuous in polished section in transmitted light and CL [1]. On grain surfaces and polished interiors, detrital shocked monazites preserve planar fractures (PFs) in up to 4 cyrstallographic orientations, and less commonly granular texture [1,4]. Similar to monazite, shocked zircons preserve PFs in multiple crystallographic orientations and also granular texture [1,2,5,6]. PFs in detrital shocked minerals are often naturally etched and thus require no chemical treatment. Crystallographic modeling combined with surface imaging and EBSD analysis of natural samples has confirmed up to 8 distinct crystallographic orientations of planar fractures in zircon, including (010), (100), (011), (001), and four {112} orientations [5]. In addition, impact microtwins [7] have also been documented by EBSD in detrital shocked zircons as thin (<1 μm) lamellae in two different {112} orientations [5].

Vredefort Dome: The Vredefort Dome is located in the Vaal River basin, which is a tributary to the Orange River, the largest drainage in southern Africa. We have documented detrital shocked zircon, quartz, and monazite eroded from the Vredefort Dome in 14 samples of modern fluvial sediments of the Vaal River at proximal [1] and distal locations up to 750 km downriver from the impact structure [2]. The same shocked minerals have also been found in 13 samples of Pleistocene (1.6 Myr) to Miocene terrace deposits [8,9] along the length of the Vaal River at sites up to 750 km from the Vredefort Dome [10]. Detrital shocked zircons have also been documented in Pliocene fluvial terraces of the Orange River at a distance of 800 km from the Vredefort structure [10]. U-Th-Pb geochronology was used to source distally transported shocked zircon and monazite in the Vaal River to the Vredefort Dome [2,4,6,11]. Grains with PFs yield crystallization ages from ca. 2.7 to 3.1 Ga and record Pb-loss at ca. 1100 Ma, which has been documented in bedrock [7,12]. Detrital zircons with granular texture experienced total Pb-loss and yield the age of impact [6]. The distal detrital shocked mineral record represents the most far-travelled, Vredefort derived deposits thus far documented.

Morokweng: The only other known impact structure in the Orange River basin is Morokweng, a buried Jurassic age structure where shocked minerals have been reported in drill core [13] and in limited surface exposures [14]. We have searched for detrital shocked minerals eroded from Morokweng in samples of modern sediment from the Molopo River and the Phepane, a tributary within the basin, and have not identified any shocked grains. The buried Morokweng structure is not actively eroding, and thus will not contribute detrital shocked minerals to the Orange basin until it is again exposed to subaerial weathering.

Other impact structures: Three other small, young impact structures occur in southern Africa outside the Orange River basin, including Roter Kamm (4 Myr, 2.5 km) [15], Tswaing (225 kyr, 1 km) [16], and Kalkkop (250 kyr, 0.6 km) [17]. The extent of the detrital shocked mineral record from these small impact structures is still being assessed, but will likely not be as regionally extensive as the volume of shocked bedrock is relatively small.

A continental record of impacts: The Orange River drains a large portion of southern Africa with an area of nearly 1,000,000 km^2, half of which is on the Kaapvaal craton. Shocked zircon and monazite with PFs have recently been identified in beach sand on the Atlantic coast near the mouth of the Orange River, >100 km from the closest known impact structure [18]. A shocked zircon yields a Kaapvaal age of 3034 Ma, and thus originated from either the Vredefort or Morokweng structures, which are 2000 and 1200 km upriver, respectively. Shocked monazites yield ages from 1100-980 Ma which are consistent with an origin from Roter Kamm, the only impact structure located in similar age (Namaqua) bedrock in southern Africa. An origin from Roter Kamm would require a combined eolian and fluvial transport history [18].

The occurrence of detrial shocked minerals from muliple impact structures in mature sands at the Orange River mouth shows that a record of the erosion of continental impact basins will be widely dispersed and preserved over time in siliciclastic sediments.

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