A 3.0 GYR GEOLOGIC HISTORY OF THE VREDEFORT IMPACT BASIN RECORDED IN A SINGLE GRAIN OF SAND.

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Introduction: The recent recogition that shock microstructures in zircon, quartz, and monazite survive post-impact heating, uplift and erosion of the target rocks, and subsequent distal transport in siliciclastic sediments has opened up new avenues for investigating records of eroded impact structures. Detrital shocked minerals have now been found in modern sediments and sedimentary rocks at two Precambrian impact sites, the 2.0 Ga Vredefort Dome [1,2,3,4] and the 1.85 Ga Sudbury [5] impact structures. Here we describe a single detrital shocked zircon from modern sand that records a 3 Gyr history of the evolution of the giant Vredefort Dome impact basin. This result highlights the importance of detrital mineral records for reconstructing ancient impact events.

Detrital shocked zircon at the Vredefort Dome: Cavosie et al. [1] reported the presence of detrital shocked zircons from the channel and tributaries of the Vaal River at the Vredefort Dome, South Africa. Shock microstructures were documented from SEM imaging of grain surfaces and polished interiors using SE, BSE, and CL imaging techniques. The most common shock microstructure observed were planar fractures (PFs), a shock microstructure that records shock pressures of 20-50 GPa [6]. In addition to PFs, a single zircon (grain 07VD07-3) from a Vaal tributary that drains the core of the structure, contained a domain consisting of granular texture, a shock microstructure associated with shock pressures >50 GPa [1,6]. Here we present the results of in-situ U-Th-Pb and trace element analyses, and electron backscatter diffraction (EBSD) analysis to constrain the geologic and impact history recorded in grain 07VD07-3.

SEM imaging: SEM imaging of the grain surface shows a rounded crystal with no identifiable crystal faces, typical of transported sediment. BSE imaging reveals a set of parallel planar fractures (PFs) prominently exposed on the grain surface (Fig. 1). In this grain, and many other detrital shocked zircons [1], the surface expression of PFs is discontinuous; local areas of grains are often preferentially etched in the fluvial system. The granular domain of this grain is subtly expressed in the central area of Figure 1a as a group of circular depressions, but in general is not a conspicuous shock microstructure as exposed on the grain surface.

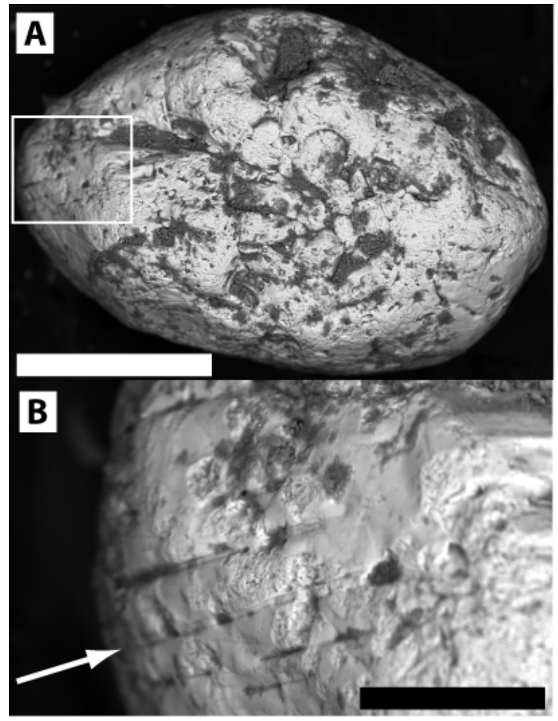

Figure 1. Backscattered electron image (BSE) showing expression of planar fractures on the grain surface. Scale bar in A = 200 µm; B = 50 µm.

In polished seciton, CL imaging reveals two distinct domains (Fig. 2a). Domain 1 is comprised of the outer ~100 µm of the grain, and preserves oscillatory and sector zoning, both typical growth textures of igneous zircon. Domain 2 comprises a region of recrystallized 'granules' located in the central area of the grain, and also extends to the rim (Fig. 2a). The 'granules' range from 10-100 µm in diameter, and are distinctly brighter in CL than the igneous growth zoning in domain 1.

U-Th-Pb analysis: Six age determinations were made by SHRIMP RG ion microprobe at Stanford University (Fig. 2). Three analyses were made in each domain. The three analyses in Domain 1 (PFs) are all discordant. A discordia regressed through the previously determined age of impact at 2020 Ma [7,8] yields an upper concordia intercept of 3161±74 Ma (Fig. 2) for two of three analyses. This age is interepreted to date the host rock. The three analyses from Domain 2 (granular) fall on a discordia with upper intercept of 1974±71 Ma and lower intercept of 1100 Ma. The age of 1974±71 Ma overlaps with the impact age of 2020 Ma [7,8].

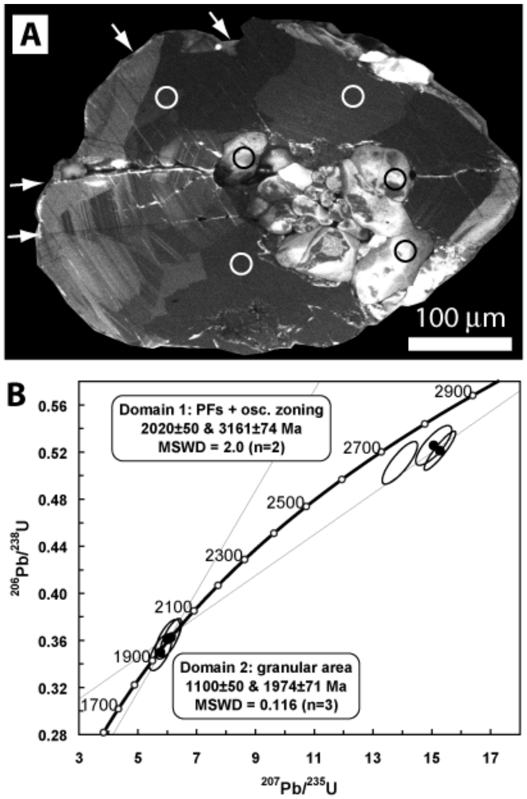

Figure 2. **A.** Cathodoluminescence (CL) image of polished grain. Circles indicate location of SHIRMP analyses. Arrows indicate orientations of PFs **B.** U-Pb condordia diagram showing results of 6 analyses; 3 from oscillatory zoned area and 3 from granular domain.

Trace elements: Trace element data for the six spots analyzed for U-Th-Pb yield similar normalized REE patterns, and are typical for igneous, crustal zircon. In detail, analyses in Domain 2 (granular), yield lower values for Y, Ce, Eu, Th, and U.

EBSD: EBSD analyses were made at the ZAP lab at the Univ. of West. Ontario using a Hitachi SU-6600 analytical VP-FEG SEM. EBSPs were collected at 0.5 µm spacing, resulting in whole grain high resolution mapping of grain 07VD07-3. EBSD mapping reveals that Domain 1 is a homogenous orientation. Two other conspicuous features are present: (1) narrow (<1 um) zones of high angle (>60°) misorientation (red in Fig. 3, indicated by arrows), interpreted to be twinned zircon [e.g., 9], and (2) the granules of Domain 2 show a variety of orientations, most different than Domain 1 (Fig. 3a).

Discussion: The detrital zircon described above preserves a remarkable 3.0 Gyr record of the pre-, syn-, and post-impact geologic history of the Vredefort Dome continental impact basin.

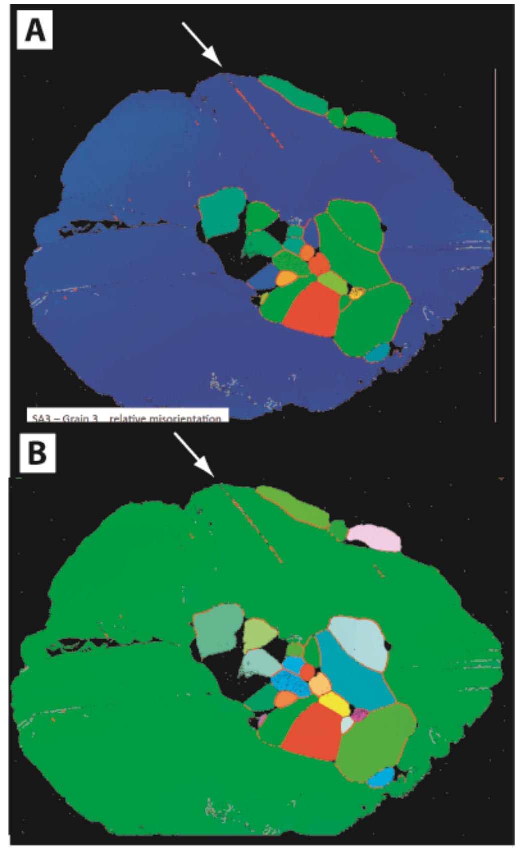

Figure 3. Color EBSD maps. A. local misorientation map B. Inverse pole figure. In both images, the arrow indicates the location of twin planes.

Domain 1 records the pre-impact igneous history of the basin; oscillatory and sector zoning, U-Th-Pb age, and trace elements are evidence of a ca. 3150 Ma continental granitoid terrane. Domains 1 and 2 record different stages of the syn-impact history. PFs and twinning in Domain 1 record shock pressures of 20-50 GPa; granular texture in Domain 2 indicates pressures >50 GPa, constraining the location of the host rock for this zircon to the central region of the structure. A U-Pb age of 1974±71 Ma in the granules records impact triggered recrystallization and loss of trace elements. The rounded morphology and occurrence as detritus in modern sediment record the final stages in the evolution of the Vredefort impact basin, which is currently being transported and deposited 100s to 1000s of km across southern Africa as detrital shocked sand [2,4].

References: [1] Cavosie et al. (2010a) GSA Bulletin. [2] Erickson et al. (2010) GCA. [3] Cavosie et al. (2010b) GCA. [4] Erickson et al. (2011) LPSC. [5] Thomson et al. (2011) LPSC. [6] Wittmann et al. (2006) MAPS. [7] Kamo et al. (1996) EPSL. [8] Moser (1997) Geology. [9] Moser et al. (2011) Can J Earth Sci.