GEOCHRONOLOGY OF DETRITAL SHOCKED ZIRCONS IN A PLEISTOCENE (CA. 1.6 Ma) FLUVIAL DEPOSIT 500 KM DOWNRIVER FROM THE VREDEFORT DOME, SOUTH AFRICA.

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Introduction: Recent studies have documented the occurrence of detrital shocked zircon, quartz, and monazite in modern sediments eroded from the 2.0 Ga Vredefort Dome impact structure [1,2,3]. These minerals have further been shown to survive sedimentary transport to distal locations (>750 km) in the modern channel of the Vaal River [4,5]. Here, we present U-Th-Pb age determinations for detrital shocked zircons found in Pleistocene (ca. 1.6 Ma) fluvial terrace deposits near Windsorton South Africa, 500 km downriver from the Vredefort Dome. The geochronology results confirm the Vredefort Dome impact structure as the source of these far travelled grains. This the first report of detrital shocked minerals that have been transported to distal locations from a known impact structure and that were subsequently buried in ancient sedimentary deposits. These results demonstrate the utility of detrital shocked minerals in siliciclastic sedimentary rocks for reconstructing ancient or eroded impact events.

Background: The 2.02 Ga Vredefort Dome in South Africa is the oldest known impact structure on Earth, with an original diameter of 250-300 km [6]. Approximately 8-10 km of impact structure has been removed by erosion. Impact shocked minerals have been described in many rocks from the Vredefort Dome [6]. The Vaal River flows across the impact structure in an east-to-west direction, before joining the Orange River near Douglas. Cenozoic paleochannel deposits (fluvial terraces) are preserved along the length of the Vaal and are well exposed due to fluvial diamond mining. This study is focused on the Rietputs Fm., a 7m thick coarse gravel to cobble conglomerate terrace deposit that occurs throughout the Vaal River valley at a height of 12-14 m above the modern channel [7]. Cosmogenic nuclide burial dating shows the deposition of the coarse Rietputs gravels occurred ca. 1.6 Myr ago [7].

Samples: Six samples of the Rietputs Fm. were analyzed in this study. The samples were collected at Windsorton, South Africa, a site on the Vaal ~500 km downstream from the Vredefort Dome. Four Rietputs sediment samples from the east side of the Vaal (Sec - 01C, -02F, -02H, -03D) were previously used in the burial dating study [7]; two additional samples (09VD-29, -31) were collected from the west side of the Vaal. Detrital grains of shocked zircon, monazite [8] and quartz were found in each sample. Detrital shocked zircons were imaged using optical light microscopy and an SEM to image external grain surfaces. Cathodoluminescence (CL) images of polished surfaces and in-situ U-Th-Pb age determinations were made at the SHRIMP-RG laboratory at Stanford Univ.

Results: A total of 470 detrital zircons were analyzed from the 6 Rietputs samples. Of these, 104 grains (22%) were found to contain planar fractures (PFs), a shock microstructure that forms in zircon between 20-50 GPa [9] (Fig. 1).

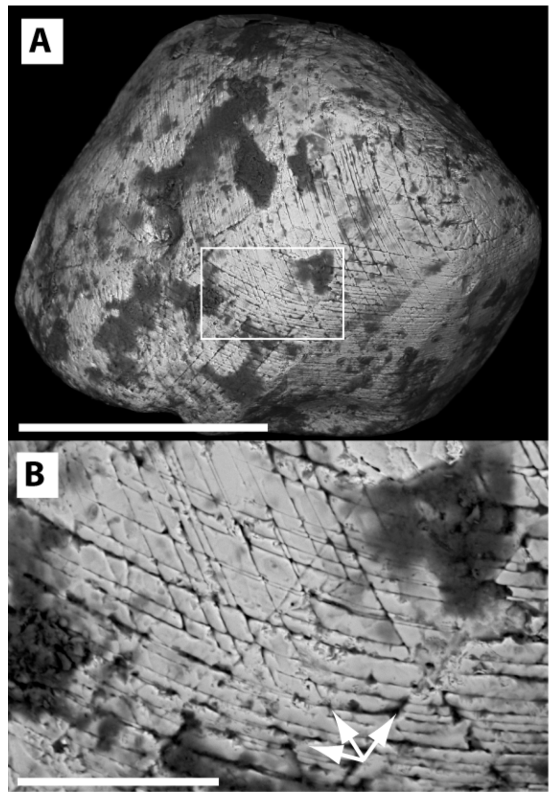

Figure 1. Detrital shocked zircon from sample Sec-02F, grain 44. Scale in A = 200 µm; B = 40 µm. White arrows in B indicate three orientations of PFs.

U-Th-Pb analyses were made on 18 detrital shocked zircons from the Rietputs Fm. Most grains are concordant or near concordant. Two main age populations are evident; one at ca. 3075 and the other at ca. 2725 Ma. Three grains with multiple spot analyses yield concordia ages of 3081±18, 3079±11, and 3040±39 Ma. A population of single spots on 8 grains yield an upper concordia intercept of 3069±9 Ma (Fig. 2). A group of single spots on 3 grains yields a concordia age of 2725±25 Ma (Fig. 3).

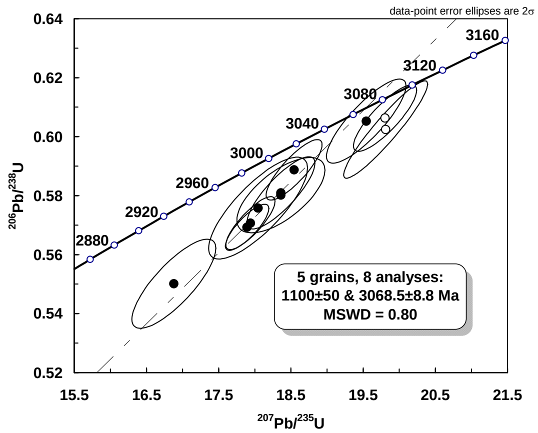

Figure 2. U-Pb concordia diagram of detrital shocked zircons from the Rietputs Fm. that yield ca. 3069 Ma ages.

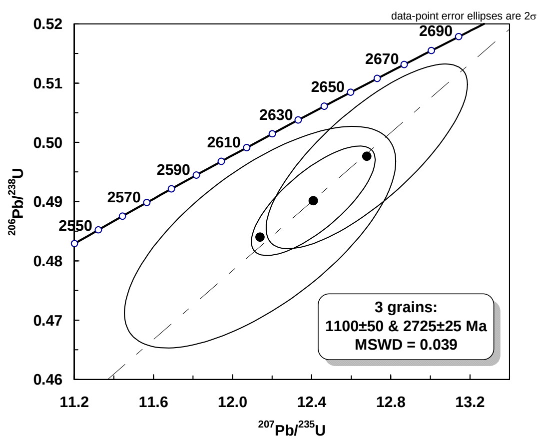

Figure 2. U-Pb concordia diagram of detrital shocked zircons from the Rietputs Fm. that yield ca. 2725 Ma ages. Each data point is a single analysis from three different grains.

For all grains, Pb-loss trajectories are consistent with a disturbance at ca. 1100 Ma; no impact age (i.e., 2020 Ma, [6]) Pb loss is recorded in these grains. The 1100 Ma Pb loss recorded in these detrital grains has also been reported in rocks from the 'core' [10] and collar [11,12] of the Vredefort Dome.

Discussion: The PF microstructures in the Rietputs Fm. detrital zircons are the same as that recorded in bedrock [11,12,13] and sediment [1] at the structure, as well as in modern sediment in the Vaal River [4,5]. The main age population of ca. 3075 Ma recorded in Rietputs shocked zircons is a common zircon age reported for bedrock in the Archean granitoid 'core' of the Vredefort Dome [6]. However, the 2725 Ma age has not been documented in rocks thus far from the core area; we thus interpret that these grains originated from supracrustal rocks in the 'collar' of the structure, where relatively fewer zircon geochronology studies have been made.

These results demonstrate that detrital shocked zircons eroded from large impact basins survive distal transport in siliciclastic sediments (500 km), and burial over geologic time (ca. 1.6 Myr), and still retain microstructural and isotopic information that can be used to reconstruct aspects of the impact event.

References: [1] Cavosie et al. (2010a) GSA Bulletin. [2] Cavosie et al. (2010b) GCA. [3] Cavosie et al. (2011) LPSC. [4] Erickson et al. (2010) GCA. [5] Erickson et al. (2011) LPSC. [6] Gibson and Reimold (2008) Coun. Geosci. Mem. 97. [7] Gibbon et al. (2009) J. Human Evol. [8] Cintron et al. (2011) LPSC. [9] Wittmann et al. (2006) MAPS. [10] Armstrong et al. (2006) GSA Sp. Paper 405. [11] Moser et al. (2010) GCA. [12] Moser et al. (2011) Can J Earth Sci. [13] Kamo et al. (1996) EPSL.