IMPLICATIONS OF DETRITAL SHOCKED MINERALS AT THE MOUTH OF THE ORANGE RIVER: CONTINENTAL SCALE TRANSPORT BY FLUVIAL, EOLIAN, AND COASTAL PROCESSES

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Introduction: The longevity of detrital shocked minerals in sedimentary systems has been documented in the Vaal River in South Africa, where shocked minerals can be traced >750 km downriver from their source at the Vredefort Dome [1,2]. Here we extend this record with a report of detrital shocked minerals from multiple impact structures at the mouth of the Orange River on the Atlantic coast. A shocked zircon yields a U-Pb crystallizaton age of 3034 Ma, and two shocked monazites yield ages of 1100 and 980 Ma. The 3034 Ma zircon originated from the Kaapvaal craton. The 2020 Ma Vredefort and 145 Ma Morokweng are the only known impact structures in the Orange basin; for either of these to be the source of the shocked zircon at the Orange mouth requires extraordinary fluvial transport distances of 2000 and 1200 km, respectively. The shocked monazites originated from Namaqua age (1200-960 Ma) rocks. The ~4 Ma Roter Kamm impact structure in SW Namibia is located in Namaqua bedrock, and may be the source of the shocked monazites. An origin from Roter Kamm requires eolian transport from the Namib desert east to the Fish River, and alluvial transport south to the Orange. An alternate interpretation is that the shocked minerals eroded from an unidentified <1 Ga impact structure located in Archean and Namaqua age bedrock within the Orange basin.

Shock microstructures: A total of 574 zircons and 104 monazites from the Atlantic coastline at the mouth of the Orange River (Fig. 1) were surveyed for shock microstructures using back scattered electron (BSE) imaging. One shocked zircon and two shocked monazites were identified. The grains are subhedral to anhedral and range from 250 to 450 µm in length. The shocked zircon shows two sets of planar fractures (PFs) on the exterior surface (Fig. 2a). Cathodolumenescence imaging of the zircon interior reveals two PF orientations. One shocked monazite, imaged with BSE, shows one PF orientation on the surface and contains a large anhedral zircon inclusion (Fig. 2b); two PF orientations are visible on the interior of the monazite, and the zircon inclusion contains one orientation of PFs. The other monazite is an elongate grain that contains one PF orientation on the exterior and two PF orientations visible on the interior (Fig. 2c).

U-Th-Pb geochronology: U-Th-Pb analyses of the 3 grains by SHRIMP-RG were made at the Stanford USGS Microanalysis Center. Four spot analyses on the large shocked zircon were concordant to 8% discordant and yield a concordia upper intercept age of 3034±36 Ma (Fig 3a, b). The shocked monazite with a large zircon inclusion was analyzed 5 times. Three analyses of the host monazite are reverse discordant, possibly due to incorporation of excess ^{230}Th during crystallization [4], and yield a ^{206}Pb/^{238}U age of 1104±34 Ma. Two analyses of the zircon inclusion are concordant and yield an age of 1109±10 Ma (Fig. 3a, c). Three concordant analyses on the second shocked monazite yield a ^{206}Pb/^{238}U age of 978±16 Ma (Fig. 3a, c).

Summary: The 3.0 Ga zircon is consistent with derivation from either the Vredefort Dome located 2000 km upriver [5,6], or Morokweng, located 1200 km upriver. Morokweng is an unlikely source to contribute shocked minerals to modern sediments, as it is buried, and the Molopo river is dry and cut-off from the Orange River by a long lived dune system [7,8]. This interpretation is supported by the results of a search by us for shocked minerals in modern sediment samples from rivers within the Morokweng structure that yielded no shocked grains.

The shocked monazites are consistent with derivation from the 2.5 km Roter Kamm structure, as it is the only known crater in southern Africa that is located in Namaqua age bedrock [9]. Shocked minerals eroded from Roter Kamm may have been transported east by eolian processes and entered the Fish River basin [10,11], the closest tributary to the mouth of the Orange River, ~90 km to the south.

If the shocked zircon and monazites originated from a one source, this would require an unidentified impact structure on the western Kaapvaal craton.

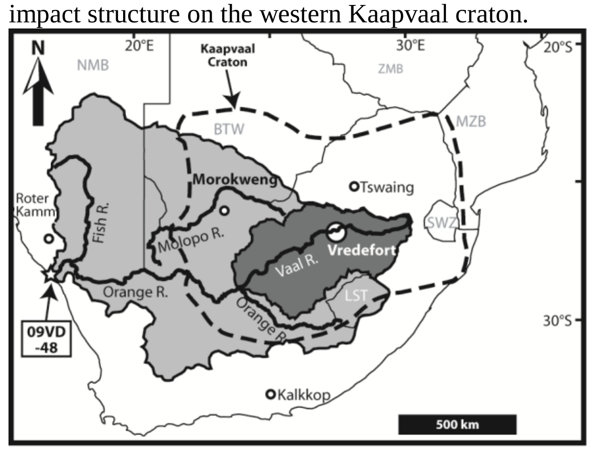

Figure 1. The location of the Orange River basin and the 5 known impact structures in southern Africa. The detrital shocked minerals are from sample 09VD48.

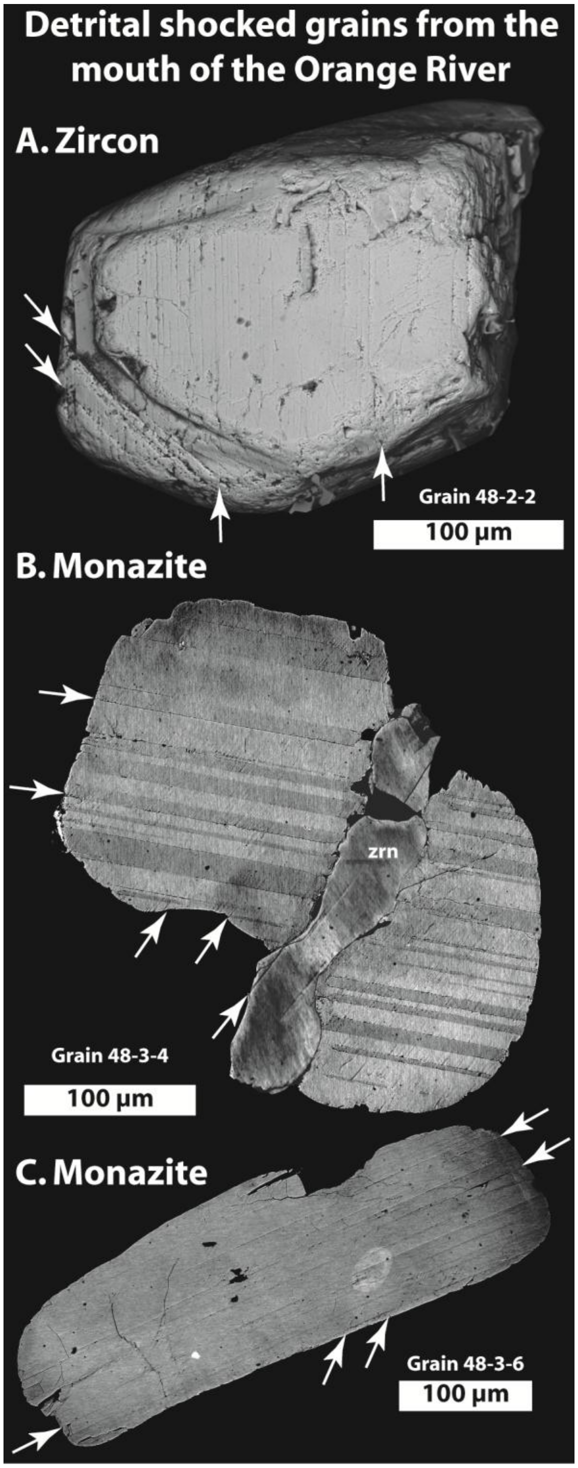

Figure 2. Detrital shocked grains from the mouth of the Orange River. **A.** Exterior BSE image of shocked zircon 48-2-2, displaying 2 PF sets. **B.** Interior composit BSE image of shocked monazite, 48-3-4, displaying 2 PF sets and large zircon inclusion with one set of PFs. **C.** Interior BSE image of shocked monazite 48-3-6, displaying 2 set of PFs.

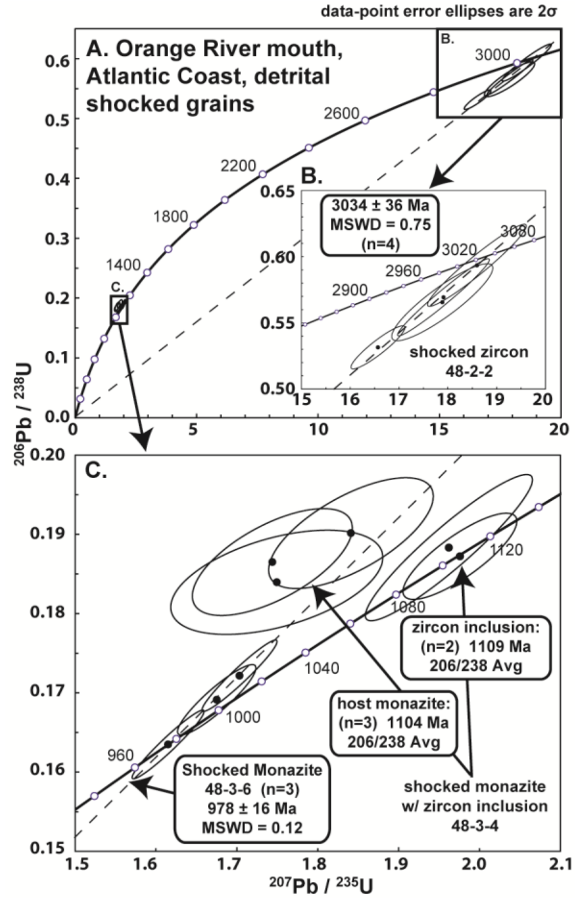

Figure 3. U-Pb concordia diagram of detrital shocked grains from the mouth of the Orange River. **A.** Data for all three grains. **B.** Close-up of data for detrital shocked zircon 48-2-2. **C.** Close-up of data for the two detrital shocked monazites, which includes the data for the shocked zircon inclusion.

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