A SEARCH FOR SHOCKED ZIRCONS IN IMPACT HORIZONS FROM THE BARBERTON GREENSTONE BELT, SOUTH AFRICA

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Introduction: Zircons from three spherule-bearing impact ejecta layers from Barberton, South Africa, were investigated for the presence of impact shock microstructures. Of 647 zircons imaged by SEM, no grains were found to contain shock microstructures. Most of the impact horizon zircons are euhedral, while others show clear evidence of sedimentary abrasion. The zircons examined are interpreted to originate from local sources, presumably washed into the basins in the energetic environment during or after deposition of the ejecta. The absence of shocked zircons, while not definitive, is consistent with the scenario that the ejecta (sensu strictu) did not contain zircon, and thus originated from a non-zircon bearing target rock on the early Earth. If shocked zircons are present, they are at abundances of < 1% of the zircon population.

Background: Unlike the Moon and other planetary bodies, the impact record of early Earth is not preserved due to erosional processes and crustal recycling [1]. To date, the oldest impact structures on Earth are the 2.02 Ga Vredefort Dome, and the 1.85 Ga Sudbury impact [2]. The oldest evidence of impact processes on Earth are spherule layers in the Barberton Greenstone Belt, South Africa, located in rocks dated between 3.47 and 3.24 Ga [3]. The spherule layers display meteoritic geochemistry, including anomalous PGE [3], Ni-spinels [4], and Cr-isotopes [5] and are thus well established as impact ejecta. Shocked zircons have been found in other well known ejecta, including at K-T boundary sites [6], however to date, no shocked minerals have been reported from Barberton ejecta deposits.

Samples: For this study, zircons from three spherule layers and one sandstone were studied. These include two samples from the Onverwacht Group- ejecta layers from the Mendon Fm (SA22) and the Kromberg Fm (SA836) [7]; and ejecta layer 'S2' (SA555) from the Fig Tree Group. In addition to ejecta layers, detrital zircons from a quartzose sandstone in the Fig Tree Group (SA612) were also examined. Grains were imaged using backscattered electrons (BSE) to search for shock microstructres in zircons. Shock microstructures are the hallmark of impact processes. The most common microstructure in zircon is planar fractures (PFs), which are crystallographically controlled sets of parallel fractures [8]. PFs in zircon form at shock pressures from 20-50 GPa [9].

Methodology: Zircons from the three impact horizons and Fig Tree sandstone were hand picked and placed onto SEM stubs. Backscattered electron (BSE) and secondary electrons (SE) imaging of grain surfaces were carefully studied for identification of microstuctures as well as grain morphology.

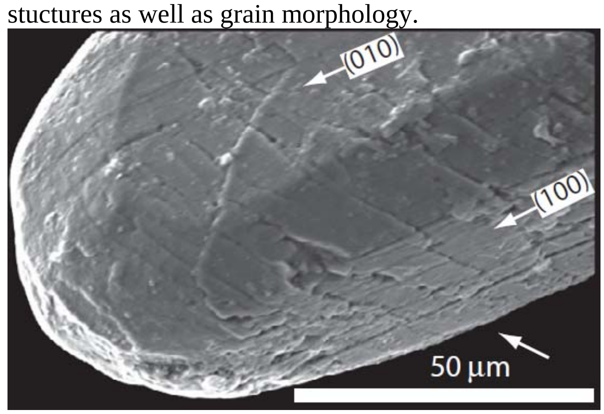

Figure 1. Example of planar fractures (PFs) in zircon. The grain is a detrital shocked zircon from the Vaal River at the Vredefort Dome, South Africa [6].

Results: For each sample, 100 to 225 zircons were studied; a total of 647 zircons were imaged with an SEM. No zircons were found to contain shock microstructures. However, a wide range of crystal morphologies were observed that help to qualitatively constrain the origin of the impact horizon zircons.

(1) Mendon Fm ejecta layer (SA22): 220 zircons imaged. Most zircons are euhedral, but conspicuous severely rounded zircons are present (Fig. 2). Subhedral zircons show evidence of sedimentary abrasion.

(2) Kromberg Fm eject layer (SA836): 110 zircons imaged. Most zircons are euhedral, with no evidence of sedimentary abrasion. A few modestly rounded grains are present. Euhedral 'soccer ball' zircons are conspicuous (Fig. 3).

(3) "S2" ejecta layer (SA555): 220 zircons imaged. Most zircons are euhedral, however conspicuous rounded zircons are present.

(4) Quartzite, Fig Tree Group (SA612): 97 zircons imaged. All zircons are surprisingly euhedral, with little evidence of sedimentary abrasion (Fig. 4).

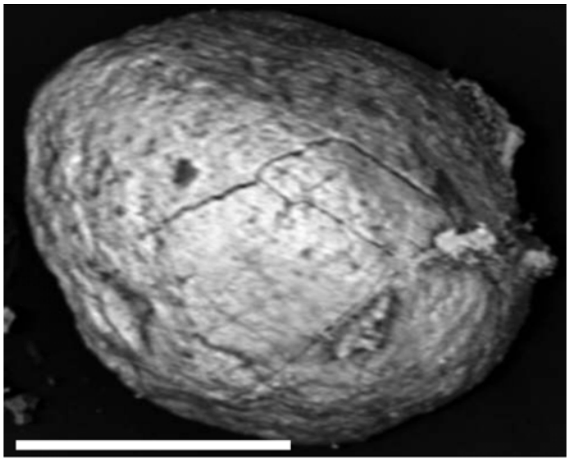

Figure 2. Rounded zircon from the Mendon Fm. ejecta layer (SA22). Scale is 50 µm.

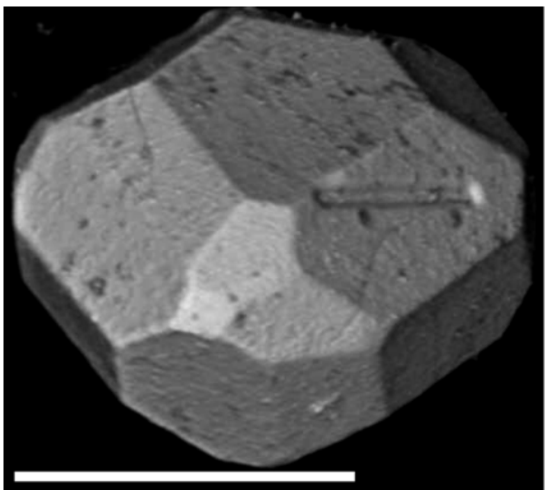

Figure 3. Euhedral 'soccer ball' zircon from the Kromberg Fm. ejecta layer (SA836). Scale is 50 µm.

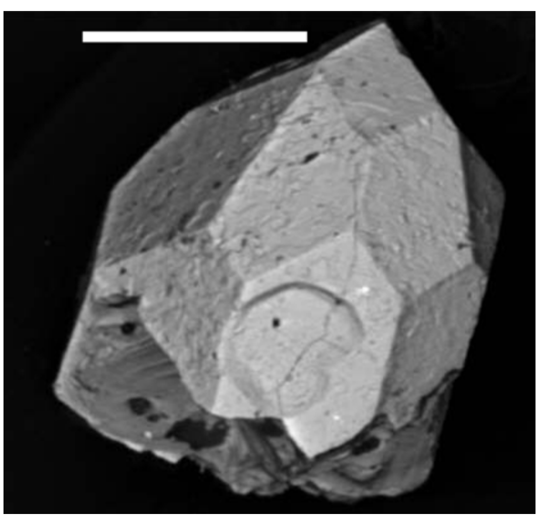

Figure 4. Euhedral zircon from a Fig Tree Group quartzose sandstone (SA612). Scale is 50 µm.

Discussion: Two conclusions can be made from these results: (1) speculation on the origin of zircons in Barberton ejecta layers, and (2) constraints on the composition of the target rocks.

The morphologies and lack of impact microstructures allow constraints to be placed on the origin of the ejecta layer zircons. The absence of impact microstructures suggests that the zircons are locally derived, being deposited either during or after deposition of the ejecta by highly energetic and erosive waves produced by the impact [3]. It is, however, possible that they were contained within the original ejecta and originated from target rocks that experienced <20 GPa shock wave, however this is viewed as unlikely. The presence of both rounded (Fig. 2) and euhedral (Fig. 3) morphologies is consistent with a local source. The rounded zircons were likely detrital zircons at the time of ejecta deposition. Euhedral zircons with no evidence of sedimentary abrasion likely originated as loose sediment on hillslopes that experienced little transport, but that was washed into the basin during the energetic environment of ejecta deposition.

The lack of shocked zircons that can be confirmed as originating in the primary ejecta layers through the identification of shock microstructures suggests that zircons were not present in the ejecta, and therefore not present in the target rocks. If this model is correct, it constrains the mineralogical composition of the target rocks to non-zircon bearing rocks. While granitoids were present on the early Earth [9], the target rock source of the Barberton ejecta horizons appears to have been mafic or ultramafic, consistent with previous interpretations based on geochemistry of the impact layers [3,4].

References: [1] French and Koeberl (2010) Earth-Sci. Rev. [2] Koeberl (2006) GSA Sp. Pap. 405. [3] Lowe et al. (2003) Astrobiol. [4] Byerly and Lowe (1994) GCA [5] Kyte et al. (2003) Geology. [6] Bohor et al. (1993) *EPSL*. [7] Byerly and Lowe (2010) GCA. [8] Cavosie et al. (2010) GSA Bulletin. [9] Wittman et al. (2006) *MAPS*. [10] Cavosie et al. (2006) GCA.