DISCOVERY OF MAFIC IMPACT MELT IN THE CENTRAL UPLIFT OF THE VREDEFORT BASIN.

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Introduction: The large (~250-300 km diameter [1]) Vredefort impact structure in the Archean crust of southern Africa provides us with an analogue for studying the crust-crater dynamics of impact modification of ancient lithosphere. No evidence of the impact melt layer expected for a Vredefort-scale event has been recognized, presumably due to 2.02 Ga of post-impact erosion [2]. Impact modeling, however, predicts that the Vredefort structure was overlain by a melt sheet several kilometers thick [3], similar to that of the Sudbury structure. A previous report of a 0.5 m-wide impact-age norite dyke [4] was subsequently reinterpreted as 'pseudotachyllite' that was locally derived [5].

Methods: We have tested the impact origin of the 'type' norite dyke at Vredefort and conducted additional detailed mapping in the region in search of similar mafic rocks. Tests included the examinination of contact relationships, shock microstructural state of accessory phases (e.g. EBSD of zircon) and host minerals, U-Pb and Hf isotopic analysis of unshocked and shocked zircons, and Ti-in-zircon thermometry.

Detailed mapping at 10 m grid spacing was initially carried out in the area of the 'type' gabbro-norite dyke [4]. Geochronology mineral separation was conducted at the Jack Satterly Geochronology lab at the University of Toronto and SIMS U-Pb isotopic analysis and Ti-thermometry were conducted at the Stanford/ U.S.G.S. SHRIMP-RG facility according to previously published procedures [6]. Electron nanobeam techniques including cathodoluminescence (CL) , electron diffraction (EBSD) and Energy Dispersive Spectroscopy (EDS) were performed with a Hitachi SU6600 VP-FEG-SEM at the University of Western Ontario Zircon and Accessory Phase Laboratory (ZAPLab) with internal protocols [7]. Hf Laser Ablation ICPMS isotopic analyses were conducted at the University of Bristol, UK. according to previously published procedures [8,9].

Results and Discussion: Outcrops of gabbronorite as much 10 m across were located within Archean Inlandsee Leucogranofels (ILG) gneiss at two locations. Unlike the polydeformed gneissosity of the ILG, the texture of the gabbronorite is massive to weakly foliated, exhibiting a strong foliation at one margin in a zone containing cm-scale inclusions of ILG. The form of the gabbronorite bodies, and their mineral textures, are consistent with an origin as dm-scale dykes and lenses that experienced minor recrystallization during solidification. Pyroxene and plagioclase are unshocked, the former exhibiting exsolution lamellae. Unshocked grains of igneous zircon and baddeleyite are intergrown with pyroxene, ilmenite and plagioclase. In contrast, shock microstructures in accessory phases of the ILG are abundant despite local impact melting and recrystallization. A subpopulation of similar shocked and recrystallized zircons, interpreted as xenocrysts, occurs in some samples of the gabbronorite. Zircon U-Pb SHRIMP ages for the unshocked gabbronorite zircon overlaps the ID-TIMS age for the impact of 2019±2 Ma. The εHf values of igneous grains are consistent with gabbronorite derivation by melting of a crustal reservoir with an Archean model age (e.g. the Witwatersrand basin). Ti-in-zircon temperatures are well-above average for endogenic crustal melts, ranging from 790˚C to 900˚C like those from the mafic base of the Sudbury impact melt sheet [10].

Our mapping, textural, microstructural, isotopic and thermometry data prove an impact origin for these mafic meta-igneous rocks, wheras historically an impact origin has not been accepted due to recrystallized textures and a local mineral fabric. We propose that these characteristics were acquired during post-impact crater modification and cooling, due to, for instance isostatic adjustment following central crater excavation and rebound. Other deeply eroded remnants of early cratering in Archean crust could appear similar, with the geochemical and textural signatures of the Vredefort bodies serving as a benchmark in the search for Early Earth impact melt residua.

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