PRELIMINARY STUDIES OF COEXISTING MICRON-SCALE ZIRCON AND BADDELEYITE IN SILICEOUS ROCKS FROM THE BASAL ROOIBERG GROUP, BUSHVELD COMPLEX, SOUTH AFRICA

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Abstract
Rhodes (1975) cited evidence that the 0.5 km aluminosilicate Baddeleyite Group of the ~2.0 Ga Bushveld Complex, widely accepted as an episiliclastic volcanic succession, originated as an impact melt. This proposal was widely rejected because French (1998) found no evidence for shock. This study revisits the impact hypothesis with focus on Zr-bearing phases in the basal ~130 m of the Rooiberg Group (for setting, see Elston and Tegtmeier, this session). The rocks contain ~75 wt % SiO₂ (in rhyolite range) and 200-360 ppm Zr (Schweizer, unpubl. Protteria PhD thesis, 1993), but lack optically resolvable and extractable zircon.

Characteristics which suggest quenching from abnormally high temperature include unusual quench textures and an absence of tochilinite.

WD data from zircon shows enrichments from (83-92) Zr, (4-18) Si, (1.8-3.0) Ti, (1.1-2) Fe, (0.8-1.8) Hf, and (0-0.3) U.

WDI 2Zr X-ray maps indicate that Zr is located in grains <10 μm in size scattered throughout the sample. The highest detection levels (yellow to white) indicate yellow colored zircons 7-10 μm in length or intermixed zircon-baddeleyite pairs 3-5 μm in length. The blue and green pixels indicate zircons that are 1-3 μm in length.

Electron Diffraction Patterns (TEM)
The electron diffraction patterns created for Fig. 4, D’ represent the monoclinic (101) zone axis of individual baddeleyite grains. The fact that variations in crystal orientation are very small is significant.

Fig. 4, F’ was slightly thicker, requiring tilting of the beam to acquire a measurable zone axis. Second order Laue patterns are visible in SAD region 1, while second and third are visible in SAD region 2.

The circular pattern of blurred dots in image P 3 is due to SAD overlapping with metamict baddeleyite, thus detecting and incorporating its amorphous signal.

Textural Observations (TEM)
Dark field images highlight the complicated textural relationship between zircon and baddeleyite. The baddeleyite shows evidence of pervasive embayment by zircon, as well as black regions and thickness variations (slight variances in brightness) which this reaction may have occurred, one of which is compatible with the impact hypothesis, while the other requires endogenic processes.

Discussion
Our current TEM data is limited to two grains of interzoned zircon and baddeleyite from a single thin section. Based on electron diffraction patterns and textural evidence from these two grains, it appears that baddeleyite existed as the primary phase and was later replaced by zircon. To our knowledge, the reaction ZrO₂ + SiO₂ → ZrSiO₃ taking place in a highly siliceous melt has not been documented and warrants further investigation. We have hypothesized two scenarios by which this reaction may have occurred, one of which is compatible with the impact hypothesis, while the other requires endogenic processes.

1. The impact interpretation of these grains asserts that the ZrO₂ crystalized from a superheated impact melt > 1686 °C. Upon cooling, baddeleyite reacted with the melt to form zircon. This scenario requires that all Zr-bearing phases in the target rock can be completely molten, before being incorporated into the Basal Rooiberg. The observation that all Zr-bearing phases in the samples lack zoning and are considerably smaller than 10 μm may provide evidence that supports this interpretation. Indirect support for the superheated impact melt can be interpreted from unusual quench textures found in the rock. If the quench textures are shown to have formed from temperatures beyond known terrestrial siliceous volcanic processes, the impact scenario for the origin of the zircon-baddeleyite pairs would be reinforced.

2. The second interpretation does not require impact conditions for the presence of baddeleyite. Instead, it is hypothesized that baddeleyite was entrained into the siliceous melt, reacting with it to form zircon. Possible pre-Bushveld sources of baddeleyte are the Pretoria Group, a marginal marine transgression/regression sequence which also includes the 2222 Ma mafic to andesitic Hekpoort Formation. It is important to note that baddeleyite may not be as rare as once thought in mafic rocks. Very small baddeleyte grains, similar in size to those observed in this study, may have been overlooked in mafic rocks when only using techniques such as optical microscopy. The possible evidence for physical weathering processes observed in the baddeleyites of this study may also support this interpretation (Fig. 3 C), though these features may also have been formed by resorption.

At present, there are two ways to determine which is the most likely interpretation for the observed coexistence of zircon and baddeleyte. One method requires a search of the Basal Rooiberg for a baddeleyite grain that is ~10 um in diameter, which can possibly be dated using a relatively new NanoSIMS techniqie (5). If the date attained is older than the Bushveld Complex, it would prove, however, that the baddeleyite was derived from a pre-Bushveld source. If, however, the baddeleyite is of Bushveld age, the entrapment of baddeleyite cannot explain the observed grains which would support the impact origin. Alternatively, Zr X-ray mapping of pre-Bushveld Complex siliciclastic and volcanic rocks such as the Hekpoort formation would reveal whether small (~10 um) baddeleyite grains are present. If small baddeleyites are discovered, it could be demonstrated that a population of small ZrO₂ grains were likely present and contained in a siliceous melt. If this search did not find baddeleyite present in significant amounts in any pre-Bushveld rocks the impact interpretation would be the more likely scenario.