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Formation and chemical evolution of zircon in mafic and felsic rocks of the Bushveld Complex

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Zircon within the Bushveld Complex (BC) shows a wide range of morphologies, trace element compositions and zoning trends, with clear differences between the mafic rocks of the Rustenburg Layered Suite (RLS) and felsic rocks (Lebowa Granite and Rashoop Granophyre Suites). These differences result from distinct physicochemical conditions and fractionation processes. Results of thermodynamic modelling [1, 2] and Ti-in-zircon thermometry [3] indicate that parental felsic magmas of the BC became Zr oversaturated at 851-881 °C, i.e. after <30 % fractional crystallization of Pl+Ilm+Ap. This lead to rapid crystallization of euhedral, elongated zircon dominated by {100} prism faces, high aspect ratios and distinctly low Th/U and high REE contents [4]. Uranium-rich, CL-dark zircon rims further indicate that U enrichment in the residual melt was not compensated by coeval zircon growth.

In contrast, zircon grains in mafic rocks of the Critical Zone (RLS), were formed from highly differentiated intercumulus melts (having >71 wt.% SiO_2, based on melt inclusion studies [5]) after significant fractional crystallization of mainly Opx+Cpx+Pl+Chr+Ol, at residual melt fractions of «15%. These grains crystallized within intercumulus domains over a wide temperature range (Ti-in-zircon: 667-938 °C), and acquired highly variable trace element compositions and ratios (Th/U: 0.2-25; Nb/Ta: 0.1-18), and two distinct zoning trends. A first high-T trend (from 938 to 840 °C) is characterized by decreasing U (300 to 3 ppm) at increasing Th/U (0.5 to >25), and can be explained by Rayleigh fractionation by zircon growth together with rutile. A second low-T trend (from 840 to 670°C) shows exactly the opposite zoning and most likely results from zircon growth in assemblage with abundant biotite, which caused assimilation of previously formed rutile. This interpretation is supported by results of thermodynamic and AFC modelling.

[1] Gualda et al. (2012) J. Petrol. 53, 875-890; [2] Connolly (2009) Geochem. Geophys. Geosys. 10; [3] Ferry & Watson (2007) Contrib. Mineral. Petrol. 154, 426-437; [4] Kirkland et al. (2015) Lithos 212-215, 397-414. [5] Gudelius et al. (2017) Goldschmidt Abstracts 2017:1454.