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Exploring crustal processes of the early Earth: Insights from mineral inclusions in Paleoarchean zircons from South Africa

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The Hadean eon remains an enigmatic chapter in Earth's evolution due to the absence of a rock record before 4.03 Ga. Detrital zircons from this period stand as the only direct record of our planet's initial half-billion-year history, making them indispensable for studies of early crustal composition and processes. During their formation, zircons entrap exotic phases, such as mineral inclusions, which offer insights into the source composition, formation conditions, and the oxidation state of the mantle during zircon crystallization.

To lay a robust foundation for future studies of Hadean detrital zircons, we focus our mineral inclusion study on zircons with known origins, specifically Paleoarchean zircons from the Barberton Greenstone-Granitoid Terrain (BGGT). Zircons in our dataset span a wide range of ages (major clusters at 3.23, 3.29, 3.45, and 3.55 Ga) and maturity (igneous to multi-generation detrital), representing the diversity of rocks in the BGGT. We characterize the primary zircon inclusion assemblage using energy dispersive x-ray spectrometry, with three primary objectives: First, we focus on igneous zircons with well-defined origins to evaluate the suitability of zircon mineral inclusions as tracers of crustal composition and processes. Second, we track possible variations in inclusion assemblages between source-rock igneous zircons and their detritus to identify biases that might affect detrital zircon studies. Lastly, we compare the abundance of various mineral phases within isolated (primary), crack-associated (primary or secondary), or crack-infilling (secondary) inclusion groups to assess the possible effects of metamorphism and metasomatism on inclusion assemblages.

The most abundant inclusion phase observed is quartz (30%). Other notable phases include apatite, biotite, muscovite, feldspar, rutile, xenotime, monazite, and Fe oxides. Isolated and crack-associated groups show similar modal mineralogies, while crack associated phases contain more common Fe oxides. Preliminary results hint at systematic differences between mineral inclusion assemblages of different age clusters, especially >3.5 Ga cluster zircons compared to all others, attesting to the possibility of preserving evidence of different source materials within zircon mineral inclusions. Additionally, we observe muscovite inclusions within zircons sourced from I-type granitoids, raising doubts about previous assumptions regarding the tie between muscovite inclusions and S-type sources.