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Detrital Zircon: From Earth's Earliest Crust to Today's Critical Metals

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Zircon's exceptional physical and chemical resilience, combined with its capacity to incorporate a diverse suite of elements, makes it one of the most powerful archives of Earth's history. Beyond its role as the 'gold standard' geochronometer, the isotopic variability of its major constituents (Zr, Si, O, Hf, U) provides valuable insights into magmatic processes, while its ability to host numerous trace elements underpins a growing array of proxies for magma source and conditions of crystallisation. These include indices for temperature, oxygen fugacity, water content, pressure of crystallisation, and crustal thickness, as well as empirical discriminators of both geochemical affinity (e.g. I-, S-, and A-type suites) and tectono-magmatic settings. Increasingly, melt/zircon partitioning relationships are also being exploited to reconstruct melt compositions directly from zircon chemistry.

When applied to large detrital datasets, zircon compositional proxies offer a means to investigate secular changes in magmatism and geodynamics at terrane to global scales. However, this approach carries several important caveats, including uncertainties associated with zircon fertility, differential erosion, sampling bias, and preservation bias.

This contribution will critically assess the application of compositional proxies in detrital zircon within the context of three overarching questions:

1. What were the active tectonic settings of the Hadean and Archean?
2. Was the Proterozoic characterised by thin crust, low elevations, and hot orogenesis?
3. Can zircon chemistry be reliably applied as a vector in mineral exploration?

Beyond zircon, minerals such as apatite and rutile provide an expanding suite of complementary trace-element proxies. Whilst they share many of the same caveats as zircon, the integration of multiple mineral records has the potential to yield greater resolving power for reconstructing secular changes in Earth's evolution.