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Conditioned duality of the Earth system via the supercontinent cycle

Van Kranendonk, M.J.[1,2], and Kirkland, C.L.[2,3]

[1]School of Biological, Earth and Environmental Sciences, and Australian Centre for Astrobiology, University of New South Wales Australia, Kensington, NSW 2052 Australia: m.vankranendonk@unsw.edu.au
[2]Australian Research council Centre of Excellence for Core to Crust Fluid Systems, Macquarie University
[3]Department of Applied Geology, Curtin University, Bentley, WA 6845, Australia

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The balance between constructive versus destructive processes in the formation and recycling of continental crust over Earth history - or crustal growth - remains contentious; whereas some advocate continuous continental growth, others suggest episodic growth predominantly during periods of supercontinent assembly. In this paper, we review the geological record and present an analysis of time constrained hafnium and oxygen isotopes in dated zircon crystals, and of incompatible elements (Zr, Th) in dated magmatic rocks, to confirm the operation of Earth's supercontinent cycle. This analysis reveals the importance of the supercontinent cycle to continental growth by demonstrating a link between periods of enhanced crustal recycling and elevated geochemical proxies of subduction flux.

The temporal fluxes in subduction rate suggest a conditioned duality of the Earth system between alternating periods of hot, volatile-rich and cold, volatile-depleted mantle relative to an idealised power decrease curve. Hot mantle periods accompany supercontinent dispersion events and are characterised by mantle superplumes and increased crustal recycling during rapid global subduction. Cool mantle periods during supercontinent aggregation are interpreted to arise from the widespread subduction of cold oceanic lithosphere and core insulation by the slab graveyards that accompanied formation of the supercontinent: these periods are characterised by enhanced mantle influence on magmas but low rates of continental crust production.

Pulses of rapid continental growth that accompanied supercontinent assembly led to crustal overste ps – essentially periods when too much crust had formed relative to the thermal state of the mantle at that time. When combined with the anomalous mantle cooling that accompanied these pulses of rapid crust formation, we postulate that supercontinent assembly led to a stepwise increase in plate size via changes in tessellation during supercontinent dispersal (Fig. 1).

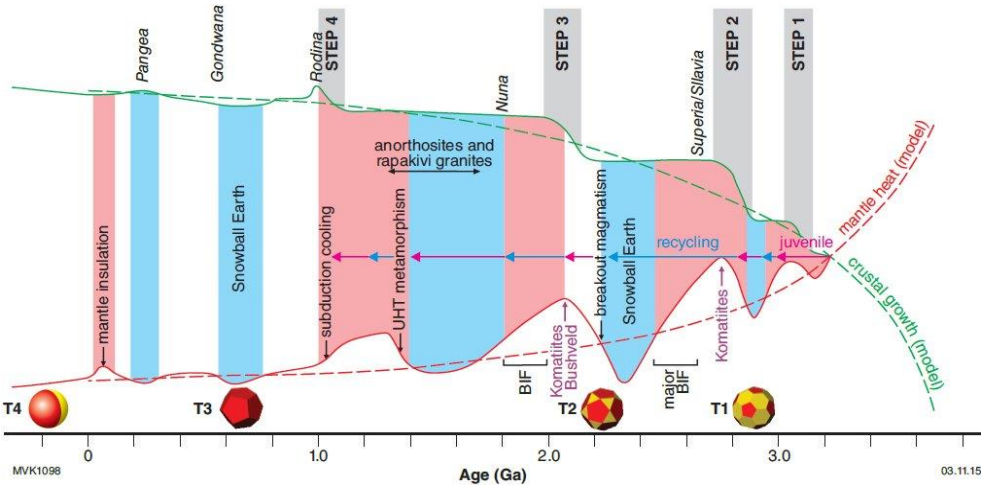

Figure 1: Schematic model of Earth evolution, showing modelled (dashed red curve) and inferred (smooth red curve) heat loss, idealised and inferred crust formation (dashed and smooth green curves, respectively) and inferred tessellation states (T1 to T4).