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The stepwise growth of tectonic plates across Earth's evolving supercontinent cycle

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Plate tectonics both creates and recycles crust, but the rate of continental growth over Earth history remains contentious: some believe it formed fast and early, others more gradually and, perhaps, episodically, through the supercontinent cycle. Time constrained analysis of both oxygen and hafnium isotopes in zircon grains and incompatible elements (Zr, Th) from magmatic rocks confirms the importance of Earth's supercontinent cycle not only on the degree of crustal recycling rates that arises from the aggregation and dispersal of supercontinents, but also on mantle temperatures, crustal growth rates, and climatic conditions. These changes are used to infer a conditioned duality of the Earth system between alternating periods of hot and cold mantle that arise in response to the supercontinent cycle. Hot mantle periods that accompany supercontinent aggregation events are characterised by mantle superplume events, increased crustal recycling and warm, reducing climatic conditions. Cool mantle periods during supercontinent rifting result from core insulation by slab graveyards and are characterised by low rates of crust production and cool, more oxidizing conditions. Changes in the intensity of the orogenic cycle through time since its inception at c. 3.2 Ga are ascribed to self-reorganisation of progressively larger tectonic plates (tessellation of a sphere) that accommodate the secular decrease in planetary heat. Bursts of crust extraction during Neoarchean and Mesoproterozoic supercontinent assembly led to overstep periods of large plates on subduction-cooled, melt-depleted mantle, accompanied by global ice ages. Optimal packing (pentagonal dodecahedron) of the plates was attained on dispersal of Nuna at 1.4 Ga, leading to a peak in geochemical and isotopic proxies of orogenic intensity during c. 1.2 Ga assembly of Rodinia (large plates on warmer Earth), with declining intensity thereafter as a function of decreasing heat with same-size plates.