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From Breakup of Rodinia to Global Glaciation: The Potential Role of Rifting and Passive Margin Formation

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The breakup of supercontinents reorganises plate boundaries, continental-scale topography, erosion and weathering, influencing the long-term carbon cycle. Drawing on a mechanistic understanding of continental rifting and passive margin formation developed for the dispersal of Gondwana [1], we explore how analogous processes during the fragmentation of Rodinia may have influenced weathering and climate in the late Precambrian. Continental rifting initiates steep rifted margin escarpments, while deeper mantle instabilities triggered by lithospheric thinning propagate cratonward, driving regional surface uplift and sustained denudation of continental interiors. Through this geodynamic mechanism, and under specific conditions, rifting can give rise to a migrating wave of exhumation that can persist for tens of millions of years [1], reorganising drainage networks and exposing large volumes of ancient crystalline basement to surface weathering. Such tectonically-forced denudation has the potential to enhance silicate weathering fluxes at continental scale, particularly where uplift coincides with humid climatic regimes and/or equatorial latitudes. Applied to the dispersal of Rodinia after 800 Ma, this framework predicts spatially highly variable but temporally coordinated erosion across rifted margins and craton interiors (for example, Laurentia). The resulting large-magnitude exhumation contributed to widespread unconformities: an important feature of the late Neoproterozoic geologic record. We propose that geodynamically driven uplift–erosion cycles during supercontinent breakup may have served as an important boundary condition on atmospheric CO2 levels, preconditioning the Earth system for profound climatic transitions in the late Neoproterozoic.

References

[1] Gernon, T.M., Hincks, T.K., Brune, S. et al. Coevolution of craton margins and interiors during continental break-up. Nature 632, 327–335 (2024). https://doi.org/10.1038/s41586-024-07717-1.