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Mantle waves and the organised destabilisation of craton surfaces

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Many cratonic continental fragments dispersed during the rifting and break-up of Gondwana are bound by steep topographic landforms known as 'great escarpments', which rim elevated plateaus in the craton interior. In terms of formation, escarpments and plateaus are traditionally considered distinct owing to their spatial separation, occasionally spanning more than a thousand kilometres. We integrate geological observations, statistical analysis, geodynamic simulations, and landscape-evolution models to develop a physical model that mechanistically links both phenomena to continental rifting (Gernon et al., 2023, 2024). Escarpments primarily initiate at rift-border faults and slowly retreat at about 1 km Myr^{-1} through headward erosion. Simultaneously, rifting generates convective instabilities in the mantle—a 'mantle wave'—that migrates cratonward at a faster rate of about 15–20 km Myr^{-1} along the lithospheric root, progressively removing cratonic keels, driving isostatic uplift of craton interiors and forming a stable, elevated plateau. This process forces a synchronized wave of denudation, documented in thermochronology studies, which persists for tens of millions of years and migrates across the craton at a comparable or slower pace. We interpret the observed sequence of rifting, escarpment formation and exhumation of craton interiors as an evolving record of geodynamic mantle processes tied to continental break-up, upending the prevailing notion of cratons as geologically stable terrains.

References

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