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Proterozoic lithosphere delamination triggered global modern cold subduction

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Earth's Mesoproterozoic era (1.6–1.0 Ga) was characterized by anomalous thermal conditions and diminished subduction flux[1-3], yet the mechanism driving the subsequent transition to widespread cold subduction remains elusive. Here, we integrate multiple thermometric proxies (i.e. detrital zircon Ti thermometry, whole-rock Zr saturation temperatures, and metamorphic thermobaric ratios) to document a thermal climax at 1.6–1.1 Ga followed by rapid cooling at 1.1–0.9 Ga. This cooling interval coincides with synchronous thinning of continental crust, oceanic crust, and lithosphere, alongside the formation and collapse of the Grenvillian orogenic plateau. We propose that large-scale lithospheric delamination beneath the Rodinia supercontinent drove this transition. To test this hypothesis, we conducted 2D geodynamic modelling assuming an end-member scenario with halted subduction following Rodinia assembly. Results demonstrate that delamination triggers asthenospheric upwelling, rapidly heating the overlying crust while simultaneously cooling the mantle through replacement by colder material. Subsequent processes include conductive cooling of the rejuvenated lithosphere, continental spreading, and the onset of sustained cold subduction. This model accounts for the peak in crustal thermal conditions and subsequent cooling, notably the occurrence of UHT metamorphism followed by protracted post-peak cooling in Grenvillian orogens[4]. Although delamination may have been diachronous across different orogens, the 1.1–0.9 Ga window represents a pivotal episode during which both crust and mantle cooling enabled the global stabilization of cold subduction. Our findings provide a novel mechanistic framework linking lithospheric thermal evolution to a fundamental transition in plate tectonic style.

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