Earth's first stable continents did not form by subduction

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The geodynamic environment in which Earth's first stable continents formed remains controversial. Most exposed Archaean crust comprises tonalite–trondhjemite–granodiorite rocks (TTGs) that were formed from partial melting of a low magnesium mafic source and which have 'arc-like' trace element signatures resembling crust produced in modern subduction settings. In the East Pilbara Terrane, Western Australia, low magnesium basalts of the Coucal Formation at the base of the Pilbara Supergroup have trace element compositions consistent with them being the source rocks for TTGs. These basalts may be remnants of a ≥35 km-thick pre-3.5 Ga basaltic crust that is predicted if mantle temperatures were much hotter than today. Using phase equilibria modelling of the Coucal basalts, we confirm their suitability as TTG parents, and show that TTGs were produced by ~20–30% melting along high geothermal gradients (≥700 °C/GPa). Moreover, the trace element composition of the Coucal basalts indicates they were derived from an earlier generation of mafic rocks, suggesting the arc-like signature in Archaean TTGs was inherited from an ancestral source lineage. The protracted multistage process required for production and stabilisation of the first continents, coupled with the high geothermal gradients, are incompatible with modern-style subduction and favour a stagnant lid regime in the early Archaean.