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The role of deep subduction in supercontinent breakup

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The breakup of continents is a crucial stage of the episodic aggregation and dispersal of tectonic plates. In particular, the transition from a stable supercontinent to its rifting, breakup and subsequent drifting is one of the least understood aspects of plate tectonics. Over the last decades, several works have highlighted the potential role of pre-existing weaknesses or that of raising mantle plumes in assisting the localization of strain. However, to sustain large-scale divergent regime over geological time, extensional stresses are strictly required. Here we present results from 2-D thermo-mechanical numerical experiments and we show that rifting and drifting of continents result from lithospheric subduction at convergent margins, when this extends to lower mantle depths. We quantify the drag exerted by subduction-induced mantle flow along the basal surface of continental plates, comparing models where lithospheric slabs stagnate above the upper–lower mantle boundary with those where slabs penetrate into the lower mantle. When subduction is upper mantle-confined, divergent basal tractions localize at distances comparable to the effective upper mantle thickness ($\sim$500 km), causing the breakup of a microcontinent and opening of a marginal basin. Instead, when the descending lithosphere subducts deeper, extensional stresses localize at greater distances from the trench ($\geq$ 2900 km), are higher and are sustained over a longer time. Although relatively low, basal shear stresses integrated over large plates generate tension forces that may exceed the strength of the continental lithosphere, eventually leading to breakup and opening of an intervening distal basin. The models illustrate that the mechanism leading to the formation of back-arc basins above upper mantle-confined subduction provides a viable explanation for the opening of larger basins above deeper subduction. Examples include the Atlantic Ocean formation and the South and North American plates drifting during the Mesozoic-Cenozoic Farallon plate subduction. We suggest that the coupling of subduction to the whole mantle flow offers the key ingredient of supercontinental breakup and drifting.