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Subduction initiation failure in numerical Wilson Cycle models

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The Wilson Cycle theory describes how closure of an ocean and formation of a new ocean tend to occur in similar locations. Its classic example is in the North Atlantic region where closure of the Iapetus Ocean led to continent-continent collision and the formation of the Caledonian mountain belt. After a long period with several rifting phases, the present-day North Atlantic Ocean opened nearby the Caledonian suture. A fundamental implied assumption in the Wilson Cycle theory is that subduction initiates at a rifted continental margin, thus allowing a full ocean to close.

Rifted margins may be preferred locations for subduction initiation, because inherited extension faults and areas of exhumed serpentinised mantle may weaken the margin enough to localise shortening. Numerical studies that specifically address subduction initiation have highlighted the roles of sediment loading, rheological strength contrasts, strain softening, and continental topographic gradients, among others. In many geodynamic subduction experiments, subduction is steered towards initiation at a rifted margin by prescribing inclined lithospheric weak zones, which represent inheritance from earlier deformation phases, and/or a short slab, which represents an initial phase of subduction. The assumed previous deformation histories are, however, usually not modelled.

I will discuss numerical experiments that explicitly consider structural and thermal inheritance caused by continental rifting, breakup and ocean spreading, before attempting subduction initiation. In my experiments, subduction preferentially initiates at the mid-ocean ridge, even when spreading has ceased and the mid-ocean ridge has thermally cooled, and strengthened, for many tens of millions of years. The rifted margins in the experiments are by themselves not weak enough to localise shortening. This failure to model the Wilson Cycle may well point to the necessity of including weakening processes, such as fluid-rock interaction or melting, in the experiments. But it also opens the discussion to considering additional complexities in the Wilson Cycle theory, such as the formation of microcontinents and their accretion, and subduction initiation at other locations than rifted continental margins.