Geophysical Research Abstracts
Vol. 17, EGU2015-6499-1, 2015
EGU General Assembly 2015

Geodynamic models of the Wilson Cycle: From rifts to mountains to rifts

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The Wilson Cycle theory that oceans close and reopen along the former suture is a fundamental concept in plate tectonics. The theory suggests that subduction initiates at a passive margin, closing the ocean, and that future continental extension localises at the ensuing collision zone. Each stage of the Wilson Cycle will therefore be characterised by inherited structural and thermal heterogeneities. Here we investigate the role of Wilson Cycle inheritance by considering the influence of (1) passive margin structure on continental collision and (2) collision zones on passive margin formation.

Passive margins may be preferred locations for subduction initiation because inherited faults and areas of exhumed serpentinized mantle may weaken a margin enough to localise shortening. If subduction initiates at a passive margin, the shape and structure of the passive margins will affect future continental collision. Our review of present-day passive margins along the Atlantic and Indian Oceans reveals that most passive margins are located on former collision zones. Continental break-up occurs on relatively young sutures, such as Morocco–Nova Scotia, and on very old sutures, such as the Greenland–Labrador and East Antarctica–Australia systems. This implies that it is not always post-collisional collapse that initiates the extensional phase of a Wilson Cycle.

We highlight the impact of collision zone inheritance on continental extension and rifted margin architecture. We show numerical experiments of one Wilson Cycle of subduction, collision, and extension. Subduction initiates at a tapered passive margin. Closure of a 60 Ma ocean leads to continental collision and slab break-off, followed by some tens of kilometres of slab eduction. Mantle flow above the sinking detached slab enhances deformation in the rift area. The resulting rift exposes not only continental crust, but also subduction-related sediments and oceanic crust remnants. Renewed subduction in the post-collision phase is enabled by lithosphere delamination and slab rollback, leading to back-arc extension in a style similar to the Tyrrhenian Sea.