Influence of detachment faults on intra-oceanic subduction initiation: 3D thermomechanical modeling

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Extensional detachment faults have been widely documented in slow-spreading ridges on Earth and due to their weakness can effectively localize deformation. It has been proposed that these weak detachments provide ideal conditions for the nucleation of a subduction zone parallel to the ridge axis when ridge-perpendicular compressional forces are applied, i.e. like in the western Neotethys in Jurassic times (Maffione et al., 2015, figure 1). However, only 2D numerical models were carried out to support this theory, whereas the geometry of detachment faults is intrinsically 3D. To explore the concept of intra-oceanic subduction initiation along detachment faults, we conducted 3D numerical modelling experiments with the I3ELVIS code (Gerya and Yuen, 2007) in order to investigate both the formation of detachment faults in slow oceanic spreading systems and their response upon inversion from oceanic spreading to convergence.

According to the numerical experiments, the formation of detachment faults strongly depends on the magnitude of the healing rate of faulted rocks in oceanic lithosphere. The detachment faults formed in our numerical models deviate from the simple conceptual model of oceanic detachment faulting where fault footwalls are rotated, leading to the formation of oceanic core complexes (Escartín et al., 2015). The controlling parameters for oceanic core complexes are not necessarily similar to those for detachment faults, and the formation of detachment faults is therefore less strongly coupled with the formation of oceanic core complexes than formerly proposed.

Upon compression, an asymmetric spreading pattern is prone to asymmetric inversion, where underthrusting of one oceanic plate under the other occurs. The detachment faults localize extensive deformation, but the conceptual model for the direct inversion of a single detachment fault into an incipient subduction zone has not been supported numerically. Our results show instead a widespread interaction of multiple detachment faults when convergence is being applied. The nascent subduction zone cuts through the base of several detachment faults, thereby forming an initial accretionary wedge in the incipient fore-arc.

Our results therefore call for further research on three-dimensional modelling of the interplay between detachment faults and oceanic core complexes and on the initiation of a self-sustaining subduction zone adjacent to a pre-existing oceanic ridge.

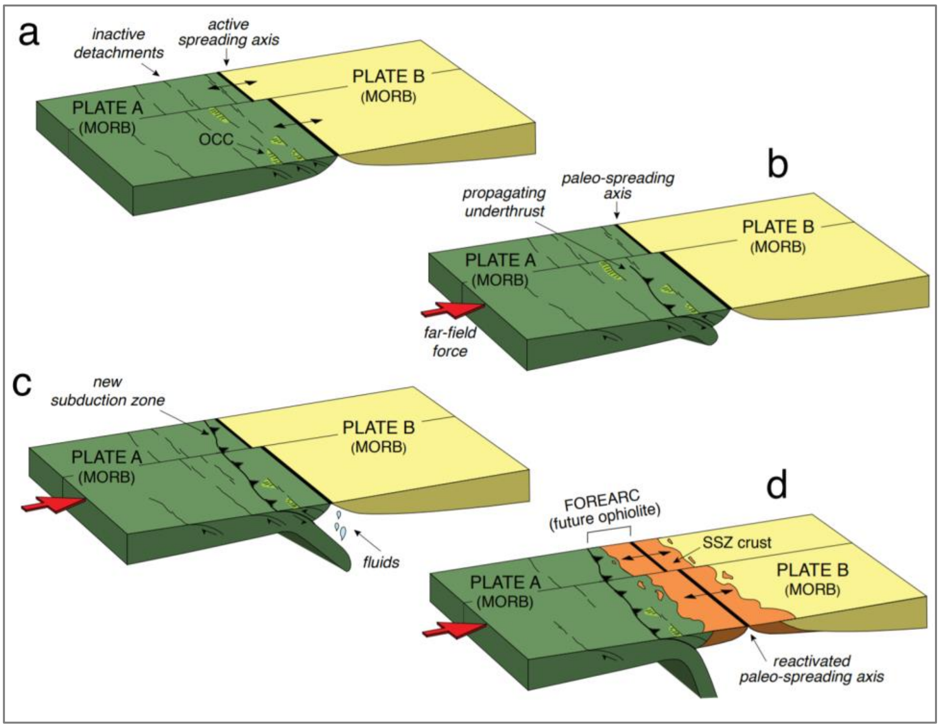

Figure 1. The proposed evolutionary tectonic model of intra-oceanic subduction initiation at detachment faults, thought to have occurred in the western Neotethys in the Middle Jurrasic **(a)** (Ultra-)slow spreading ridge with detachment faults yielding local oceanic core complexes (OCC's) **(b)** Upon ridge-orthogonal compression, detachment faults localize deformation **(c)** Lateral propagation of underthrust resulting in a extensive subduction zone **(d)** Reactivated paleo-spreading axis where magmatic activity generates SSZ-crust (from (Maffione et al., 2015))

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