Role of grain size reduction in formation and inversion of oceanic detachment faults

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Oceanic detachment faults are large and long-lived (1-2 Myr), forming at slow- and ultraslow- mid-ocean ridges. They can expose lower crustal gabbroic rocks and mantle peridotite in the seafloor, recognized as oceanic core complexes (OCCs). Mechanical models proposed that detachment faults originate at high angle and, as fault offset increases, are rotated flexurally to an inactive low-angle configuration. Previous studies showed that long-lived detachment faults need a rheological boundary for the offset: (1) an alteration front; (2) the brittle-plastic transition (BPT); (3) the boundary between gabbro intrusions and weakened hydrated peridotite; or (4) low magma supply. In order to better understand the rheological behavior of oceanic detachments, we investigate numerically potential effects of ductile weakening controlled by grain size reduction on the oceanic detachment faults formation as well as on their subsequent inversion during the Wilson cycle. We employ 3D thermomechanical numerical models with a composite rheology consisting of diffusion and dislocation creep. In our model, oceanic crust deforms in a brittle manner and its strength is controlled by fracture-related strain weakening and healing. In contrast, the lithospheric mantle deforms according to the dry olivine flow law, as a mixture of grain size-dependent diffusion and dislocation creep. Numerical results show that ductile weakening induced by grain size reduction could indeed notably influence both the style of detachment faulting and the fault dipping angles in the depth of the BPT. Grain size has a great effect on the offset of detachment faults and the formation of megamullions and controls the place of new subduction initiation below the BPT. We systematically investigate the influence of the thermal structure, initial grain size and spreading rate on the characteristic oceanic detachment fault pattern. In addition, we also study effects of these parameters on the final inversion of detachment faults during induced intra-oceanic subduction initiation.