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Conditions of subduction initiation at transform faults

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Subduction initiation (SI) takes place in various geodynamic environments. One of the most observed concerns initiation at a transform fault or a fracture zone. In such context, there is debate whether subduction dynamics is induced by external forces or originate spontaneously. In this last case, the process of spontaneous subduction (SS) corresponds to the gravitational instability of the more negatively buoyant plate leading to subduction, without convergent motions. SS was suggested for the initiation of the Izu-Bonin-Mariana subduction zone, based on the occurrence of a specific magmatic sequence including “forearc basalts” and boninites. Some thermo-mechanical models of lithosphere gravitational instability have been tuned to help the triggering of the sinking of the older and colder plate, restricting the study of conditions yielding subduction. We perform a more general 2D parametric study, by combining pseudo-brittle and ductile rheologies to decipher the conditions of SI, and by imposing or not an external forcing. We investigate large ranges of age contrast across the transform fault but also the role of the mechanical structure of the fault, assumed to be made of a weak layer.
Our results first show that SS can be modelled only if the transform fault, but also a relatively wide crustal or lithospheric domain on both sides of the fault are weak enough. Furthermore, simulations suggest that SS is restricted to a limited range of lithosphere age pairs, the thinner plate having to be younger than 15 Myr. In any cases, SS yields an instantaneous slab rollback associated with an extremely fast trench retreat, resulting in upper plate extension and asthenosphere upwelling along the slab top, up to the surface. We conclude that the set of conditions necessary to trigger SS is not observed nowadays in nature, so that this process appears very unlikely in a cold Earth. Furthermore, as when triggered, SS initiation is close to catastrophic, the typical magmatic sequence including boninites should erupt within a brief amount of time, which disagrees with geological records of subduction infancy in Izu-Bonin, $\sim$52-50 Myr ago, attesting for boninitic eruptions during $\sim$20 Myr.
Moreover, our study shows that if plate convergence is imposed by kinematic conditions far away from the transform fault, subduction of the younger lithosphere beneath the older one may occur for a large range of conditions, providing that the plate age offset remains moderate, following a behavior and kinetics in agreement with what is observed for subduction initiation for several incipient subductions such as Puysegur and Hjort, south of New-Zealand.