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Subduction initiation (or not) due to absolute plate motion at STEP faults: The New Hebrides vs. the Tonga examples

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Subduction initiation remains one of the least understood global processes of plate tectonics. Prominent models have been cast in terms of two broad classes: “spontaneous” cases due to lithospheric gravitational instabilities and “induced” cases due to forced plate convergence. Yet gravitationally unstable lithosphere is old, strong, and difficult to begin to bend into a subduction zone and convergent forces necessary to begin subduction are often too large given the plates involved. These models also consider the asthenospheric mantle as passive, even though relative motion between slabs and the asthenosphere has long been regarded as a strong control on subduction dynamics. Here I propose that subduction-transform edge propagator (STEP) faults can initiate subduction depending on the absolute motion of the STEP fault with respect to the asthenosphere. STEP faults form where subduction zones end and the subducting plate tears forming a down flexed transcurrent plate boundary at the surface shearing against the adjacent rear arc lithospheric plate. However, STEP faults are not simple transcurrent boundaries. Absolute motion of the down flexed STEP fault edge with respect to the surrounding asthenosphere can produce a strong “sea anchor” force that either continues to bend the edge downward, initiating subduction, or opposes slab bending, inhibiting subduction. In the south Pacific, the southern end of the New Hebrides Trench and the northern end of the Tonga Trench are type-example STEP faults with opposite senses of dip but both moving northward with respect to the asthenosphere. The northward dipping New Hebrides STEP fault moves northward in a mantle reference frame creating a strong asthenospheric flow against the STEP fault edge, inducing active subduction at the Matthew-Hunter trench. In contrast, the Tonga STEP fault dips southward but also has a northward component of motion with respect to the mantle. Asthenosphere thus flows southward beneath the down flexed Tonga STEP fault edge opposing further bending. Subduction does not initiate at the Tonga STEP fault despite a ~100 Myr age contrast between the Pacific and north Fiji and Lau basin lithospheres. Since absolute plate motions reflect the sum of all forces acting on the entire lithospheric plate, a strong sea anchor mantle force may be generated at a STEP fault edge, initiating subduction (or inhibiting it), even where lithosphere is old, strong, and resists bending and without requiring large convergent forces between plates, overcoming these objections to previous models.