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Delayed lithosphere tearing along STEP Faults

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Tearing of the lithosphere at the lateral end of a subduction zone is a consequence of ongoing subduction. The location of active lithospheric tearing is known as a Subduction-Transform-Edge-Propagator (STEP). The transcurrent plate boundary system lengthens with time and is referred to as the STEP Fault. Lithospheric tearing was taken to start at the trench in the classical STEP model of Govers and Wortel (2005). They show that active STEPs and STEP Faults can be found alongside many subduction zones. However, recent seismicity studies show results near the active STEPs that are difficult to reconcile with the classical STEP model: there is significant and deep seismicity along the STEP Fault near to the west of Trinidad in the southeast Caribbean; a Wadati-Benioff zone perpendicular to the Pliny-Strabo trenches (the STEP Fault) in the eastern Mediterranean reaches 180 km depth; STEP Fault perpendicular earthquake slip vectors are observed along the northern termination of the South Sandwich trench. We seek to understand these discrepancies by studying the tearing process.

We show results of new physical analog lab models that aim to elucidate what controls lithospheric tearing and the resulting geometry of the lithospheric STEP. We study the ductile tearing in the process of STEP evolution, which is dynamically driven by the buoyancy of the subducting slab. In our experiments, the lithosphere as well as asthenosphere are viscoelastic media in a free subduction setup. A stress-dependent rheology plays a major role in localization of strain in tearing processes of lithosphere such as slab break-off.

We find that complete tearing of the lithosphere typically occurs later than in the classical model, at 100-150 km depth. The slab is consequently highly curved near the lateral end of the trench. However, not all STEPs show evidence for such delay, e.g., the north end of the Tonga trench. In our model experiments we therefore investigate the influence of age and integrated strength of the lithosphere and its contrasts across the passive margin, on the timing, depth, and the degree of localization of the tearing process. Furthermore, we relate the tearing at depth to deformation at the surface along and across the STEP fault and we discuss potential consequences for STEP evolution for a number of subduction zones worldwide. Delayed lithospheric tearing explains the observations qualitatively.