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Variability in forearc deformation during subduction: Insight from geodynamic models and application to the Calabria subduction zone

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In nature subducting slabs and overriding plate segments bordering subduction zones are generally embedded within larger plates. Such large plates can impose far-field boundary conditions that impact the style of subduction and overriding plate deformation. Here we present 3D dynamic analogue models of subduction, in which the far-field boundary conditions at the trailing edges of the subducting plate (SP) and overriding plate (OP) are varied. Four configurations are presented: Free (both plates free), SP-Fixed, OP-Fixed and SP-OP-Fixed. We investigate their impact on the kinematics and dynamics of subduction, with a special focus on overriding plate deformation. Our models indicate that in natural (narrow) subduction zones, assuming a homogeneous overriding plate, the formation of backarc basins (e.g., Tyrrhenian Sea, Aegean Sea, Scotia Sea) is generally expected to occur at a comparable location (300-500 km from the trench), irrespective of the boundary condition. Furthermore, our models indicate that the style of forearc deformation (shortening or extension) is determined by the mobility of the overriding plate through controlling the force normal to the subduction zone interface (trench suction). Our geodynamic model that uses the SP-OP-Fixed set-up is comparable to the Calabria subduction zone with respect to subduction kinematics, slab geometry, trench curvature and accretionary wedge configuration. Furthermore, it provides explanation for the natural observations of both backarc extension in the Tyrrhenian Sea and forearc extension in the Calabria region, which have been active since the Miocene. We explain the observations as a consequence of subduction of the narrow Calabrian slab and the immobility of the subducting African plate and overriding Eurasian plate. This setting forced subduction to be accommodated almost entirely by slab rollback (not trenchward overriding plate motion), while trench retreat was accommodated almost entirely by backarc and forearc extension (not trenchward overriding plate motion), similarly to our SP-OP-Fixed model. This tectonic setting induced strong trench suction, which caused the forearc extension in Calabria.