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Mechanical basis for slip along low-angle normal faults

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The existence of active low-angle normal faults is much debated because (1) shallow dipping normal faults do not produce large earthquakes (M>5.5) and (2) the classical theory of fault mechanics implies that faults are locked for a dip lower than 30°. However, field observations suggest that brittle deformation occurs on low-angle normal faults at very shallow dip. Field evidences and theory can be reconciled using an alternative mechanical model of fault reactivation including a thick elasto-plastic frictional fault gouge. This model allows the dilation angle ψ in the fault gouge to be lower than the friction angle ϕ, contrary to the classical model which implies that the two angles are equals. Within this formulation, it is possible to consider that the fault may keep a constant thickness (incompressibility, ψ=0), thicken (dilation, $\psi >0$) or thin (compaction, $\psi <0$) with shear. 2D mechanical models of fault zones were performed at upper crustal scale obeying to this rheological model. We show that plastic compaction allows reducing the effective friction of the faults sufficiently for low-angle normal faults to be active at dip of 20°. As the model predicts that these faults must be active in a slip-hardening regime, it prevents the occurrence of large earthquakes. However, we also evidence the neoformation of Riedel shear bands within the thick fault zone when the numerical resolution of the mechanical models is sufficient. Contrary to the main fault zone which behaves at large scale in a hardening regime, these Riedel shear bands form in a softening regime, dynamically instable. We propose that such a model could be applied to the behaviour of the Western Gulf of Corinth, where most of the extension is accommodated on a creeping shallow detachment. Repeated microseismic activity observed within this detachment produces multiplets that we interpret as the Riedel shear bands produced in our high resolution 2D models.