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Décollement controls on strain distribution in mountain belts: insights from numerical models.

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Doubly vergent orogens have a pro-wedge (lower plate) and a retro-wedge (upper plate). Most shortening is accommodated in the pro-wedge while retro-wedge shortening is typically limited. For example, the Eastern Pyrenees have experienced about 145 km of convergence, of which about 125 km (86%) was accommodated in the pro-wedge and about 20 km (14%) in the retro-wedge. Strain partitioning between pro- and retro-wedge is influenced by several factors, some of which have been identified in past work: Extensional inheritance and syn-orogenic sedimentation can help to increase the percentage of total shortening accommodated in the retro-wedge while erosion promotes pro-wedge shortening. We use high-resolution 2D numerical models to investigate factors that control pro- versus retro-wedge shortening. For a total convergence similar to the Eastern Pyrenees, our models predict that variations in extensional inheritance and syn-orogenic sedimentation will result in a maximum of 10% of total shortening being accommodated in the retro-wedge. Here, we investigate the role of 1) the rheology and 2) distribution of a décollement layer.

Our models show that: 1) Décollement rheology has a first order control on strain distribution between the pro- and the retro-wedge. After 145 km of total convergence, a model with a weak frictional (φ=2, shale-like) décollement will only accommodate 10% of total shortening in the retro-wedge. In contrast, in models with a weak viscous (μ=10^{18}, salt-like) décollement retro-wedge shortening amounts to 18% and a stronger, but still weak, viscous décollement (μ=10^{19}) leads to 21%. 2) Décollement distribution influences the timing of the first outward propagation of thick-skinned deformation in the retro-wedge. In the Eastern Pyrenees, thick-skinned deformation propagated out into the retro-wedge within 145 km of total convergence. In models with a décollement on both sides of the orogen this only occurred after 240 km. If, as in the Eastern Pyrenees, the décollement is missing in the model's retro-wedge, the required convergence would be reduced to 180 km.

Assuming deformation localizes along the path of least resistance, meaning a force balance exists between the pro- and retro-wedge, anything that changes the force required to deform one side of the orogen will have direct consequences for the other side as the strain distribution adjusts. In our models a viscous décollement enables the sedimentary cover of the pro-wedge to be transported into the pro-foredeep, increasing the force required for pro-wedge frontal accretion and thus promoting shortening in the retro-wedge. In models with no décollement in the retro-wedge, higher friction along existing crustal shear zones will accelerate formation of a new, more external shear zone. This mechanism alone cannot explain frontal accretion in the retro-wedge after only 145 km of convergence, meaning other factors such as more pre-existing extensional shear zones may also play a role in the Eastern Pyrenees.