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Analytical two-wedge corner flow model for tectonic nappe evolution in collisional orogens

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Many collisional orogens are made of tectonic nappes and are characterized by doubly-vergent wedge kinematics, but the mechanical conditions for nappe evolution remain contentious. The Western Alps are a prominent example of such and their kinematic evolution is described by two main phases: 1) nappe formation by top-to-foreland shearing with extrusion and 2) subsequent backfolding of the ordered nappe stack. However, the mechanical conditions for nappe formation and for the subsequent switch to backfolding are still unclear. Here we apply a new analytical corner-flow model exhibiting two wedges of different viscosity, and show that nappe formation by forced return flow in the lower wedge, with acute angle, requires an upper wedge with a viscosity that is at least three orders of magnitude larger. In contrast, the switch to backfolding only takes place when the viscosity ratio between the two wedges decreases to approximately one. The exhumation path and corresponding velocities for nappe formation and backfolding, which are based on geological data for the prominent Monte Rosa nappe in the Western Alps, are reproduced by our model suggesting that nappe formation took place by forced flow and not by buoyancy-driven flow. We show that during nappe formation collisional orogens are mechanically characterised by two tectonic wedges with significantly different strength whereas during subsequent backfolding the orogens are characterised by essentially one wedge. Our two-wedge model elaborates the doubly-vergent wedge model and allows investigating a much wider variety of nappe geometries.