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A simple thermo-mechanical crustal-scale shear zone model applied to the Morcles nappe (Switzerland)

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We present a one-dimensional mathematical shear zone model which considers a power-law flow law and a temperature dependent viscosity. The analytical solution for the velocity profile across the shear zone depends only on a single dimensionless parameter β. β depends on the activation energy of the applied flow law, the temperature at the base of the shear zone and the temperature difference across the shear zone. The solution can describe three fundamental types of deformation: (1) homogeneous simple shear for β«1, (2) thrust-sheet emplacement on a thin ductile shear zone for β»1 and (3) fold nappe emplacement by heterogeneous simple shear for $\beta \sim$1-10. We apply the shear zone model to deform a passive model line which is initially straight and oblique to the shear zone. With a systematic parameter search we determine the parameters which provide the best fit between the deformed model line and a reference line representing the first-order geometry of the Morcles nappe. We also apply a more elaborated pressure-driven shear zone model to test whether realistic flow laws and pressure gradients provide realistic shear velocities for the Morcles nappe. We estimate β with three methods: (1) applying physical parameters to the analytical formula for β, (2) geometrically fitting the model and reference line and (3) comparing results of the velocity-driven and pressure-driven shear zone model. Estimates of β from all three methods are consistent and between 5 and 12. Results of our thermo-mechanical model indicate that the first-order deformation mechanism generating the Morcles fold nappe, in particular the strongly sheared overturned limb, was heterogeneous ductile simple shear.