EGU21-10396
https://doi.org/10.5194/egusphere-egu21-10396
EGU General Assembly 2021

Effective rheology of a two-phase subduction shear zone: insights from numerical simple shear experiments and implications for subduction zone interfaces

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Exhumed subduction shear zones often exhibit block-in-matrix structures comprising strong clasts within a weak matrix (mélanges). Inspired by such observations, we create synthetic models with different proportions of strong clasts and compare them to natural mélange outcrops. We use 2D Finite Element visco-plastic numerical simulations in simple shear kinematic conditions and we determine the effective rheology of a mélange with basaltic blocks embedded within a wet quartzitic matrix. Our models and their structures are scale-independent; this allows for upscaling published field geometries to km-scale models, compatible with large-scale far-field observations. By varying confining pressure, temperature and strain rate we evaluate effective rheological estimates for a natural subduction interface. Deformation and strain localization are affected by the block-in-matrix ratio. In models where both materials deform viscously, the effective dislocation creep parameters (A, n, and Q) vary between the values of the strong and the weak phase. Approaching the frictional-viscous transition, the mélange bulk rheology is effectively viscous creep but in the small scale parts of the blocks are frictional, leading to higher stresses. This results in an effective value of the stress exponent, n, greater than that of both pure phases, as well as an effective viscosity lower than the weak phase. Our effective rheology parameters may be used in large scale geodynamic models, as a proxy for a heterogeneous subduction interface, if an appropriate evolution law for the block concentration of a mélange is given.