Geophysical Research Abstracts
Vol. 20, EGU2018-19169, 2018
EGU General Assembly 2018

Rapid creep and simultaneous fracturing of modelled subduction melange at low stress

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Aseismic megathrust slip at tectonic rates or greater is thought to occur at differential stresses as low as 10MPa or less, and is commonly associated with low frequency seismic events. This slip must deform extremely weak material, though whether it is accommodated by localised frictional slip or distributed brittle-viscous behaviour is contentious. Exhumed megathrust rock assemblages typically indicate brittle-viscous processes within a melange, with a weak matrix of phyllosilicates deformed by variably distributed and localised strain at low stress, surrounding fractured clasts. We use outcrop-scale numerical models to explore the conditions where a melange with a high volumetric clast/matrix ratio can maintain a weak shear-zone at high strain. We also explore how clast stresses evolve in response to matrix flow, to compare clast strength to the low bulk strength of the melange. Melange modelled with equal proportions of matrix and clasts has a bulk strength dominated by the weak matrix, and can therefore plausibly accommodate the required strain-rates of $10^{-9}\ s^{-1}$ or higher. However, melange strength is strain-dependent and varies by at least an order of magnitude as clasts interact. This strain-dependence can be reduced by clast fracturing, or a reduction of the volumetric clast proportion to approximately 30%. A melange with 70% clasts becomes clast-supported after small amounts of strain. Clast stresses can be amplified by more than an order of magnitude in a melange with as little as 30% clasts, while the bulk material is steadily creeping. The failure of competent clasts is therefore not necessarily indicative of the bulk stress state of the melange, and clast failure can reduce the elastic strain and stress accumulation associated with the locking up of clasts. These results imply a melange model in which weak phyllosilicates allow steady and/or transient megathrust creep at low stresses, while embedded clasts simultaneously undergo elastic loading and episodic brittle deformation. The clasts may therefore introduce a time-dependence through their interaction. Scale invariance of both the models and typical fault rock geometries imply that the activation of low stress phyllosilicate deformation at the mineral scale can lead to low bulk strength, as well as transiently amplified stresses within enclosed high strength materials, up to the kilometre scale. This brittle-viscous deformation of melange material is compatible with both the rapid creep and high-stress fracturing responsible for slow slip events and associated tremor respectively.