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Numerical Investigation of a Novel Rheology-linked Origin for Seismic Tremor and Low-Frequency Earthquakes

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Subduction-linked seismic tremor has fascinated seismologists since its recognition near the turn of the century. Typical scenarios for its occurrence have focussed on the role of fluid-changes in modulating failure within a near-critically-stressed rock. An apparently significant problem for this mechanism is that it can naturally explain neither the near-constant size-threshold for tremor events in a given locale nor the spatial clustering typical of these events. Previously, researchers have mainly focussed on the typical matrix+block structure of the subduction melange complex that fills the region/channel between subducting and overriding plates to highlight that that stronger blocks could form asperities along the plate ‘interface’. Here we use numerical elasto-visco-plastic model experiments to explore a different hypothesis for the origin of tremor, one in which tremor can spontaneously initiate within a heterogeneous matrix+block ‘melange’ assemblage that fills a subduction channel once the formerly weaker matrix has been strengthened by well-known diagenetic processes to become stronger than its embedded formerly-stronger blocks (Vannucchi et al., AGU Fall Meeting, 2018). The 2-D numerical models that we explore here include elastic, Mohr-Coulomb-plastic, and viscous effects. Varying volume fractions (10-30%) and characteristic aspect ratios (3-10) of blocks were assessed. We document several characteristic deformation regimes that can occur within a heterogeneous melange which fills the interfacial subduction channel, only one of which can lead to tremor-like behaviour coupled with the generation of conditions that could also trigger the low-frequency earthquakes also known to occur in subduction-linked tremor systems. The first regime occurs when the matrix viscosity is low enough ($< 10^{17} - 10^{18}$ Pa-s for a 100m-thick subduction channel, $< 10^{16} - 10^{17}$ Pa-s for a 10m-thick channel) so that stresses are too low to initiate block or matrix failure. In this case the plate interface creeps aseismically. If the matrix viscosity exceeds this channel-width-dependent threshold, and the blocks have a higher yield stress than the matrix, then broadly-distributed brittle failure will occur within the matrix without a characteristic fault size typical to seismic tremor. In contrast, when the blocks have a lower yield stress than the matrix, then blocks will repeatedly fail in brittle tremor-like events with a characteristic magnitude that depends on the product of typical block size and yield stress. Due to repeated block failure events and associated deformation of the weaker blocks, the region of the matrix near block tips will become stressed enough for it too to yield in localized higher-stress-release events that we suggest as a possible origin for the low-frequency earthquakes often associated with regions of subduction tremor. Note that as this deformation proceeds the tremors and low-frequency earthquakes do not relieve the stress within the subduction channel, so that this region can still release stress during a megathrust event.