The strength inversion origin of non-volcanic tremor: models and observations

Jason P. Morgan¹, Albert de Montserrat Navarro², Paola Vannucchi³, Alexander Peter Clarke⁴, Audrey Ougier-Simonin⁵, and Luca Aldega⁶

¹SUSTech, Shenzhen, CN (jason@sustech.edu.cn)
²University of Padova, Padua, Italy
³University of Florence, Florence, Italy
⁴Royal Holloway University of London, Egham, United Kingdom
⁵British Geological Survey Keyworth, Nottinghamshire, United Kingdom
⁶University of Rome “La Sapienza”, Rome, Italy

Non-volcanic tremor remains a poorly understood form of seismic activity. In its most common subduction zone setting, tremor typically occurs within the plate interface at or near the shallow and deep edges of the interseismically locked zone. Detailed seismic observations have shown that tremor is composed of repeating small low-frequency earthquakes (LFE), often accompanied by very-low-frequency earthquakes (VLF), all involving shear failure and slip. However, LFEs and VLFs within each cluster show nearly constant source durations for all observed magnitudes. This implies asperities of near-constant size, with recent seismic observations hinting that the failure size is of order ~200m.

We propose that geological observations and geomechanical lab measurements on heterogeneous rock assemblages representative of the shallow tremor region are most consistent with LFEs and VLFs involving the seismic failure of relatively weaker blocks within a stronger matrix. Furthermore, in the shallow subducting rocks within a subduction shear channel, hydrothermal fluids and diagenesis have led to a strength inversion from the initial weak matrix with relatively stronger blocks to a stronger matrix with embedded relatively weaker blocks. In this case, tremor will naturally occur as the now-weaker blocks fail seismically while their more competent surrounding matrix has not yet reached a state of general seismic failure, and instead only fails at local stress-concentrations around the tremorgenic blocks.

Here we use the recently developed code LaCoDe (de Monserrat et al., 2019) to create and explore a wide range of numerical experiments. These experiments are designed to characterize the likely stress and strain accumulations that can develop in a heterogeneous subduction shear channel, and their implications for the genesis of tremor and its spatially associated seismic events. In our previous modeling efforts we did not strongly vary either the block volume-fraction or the initial block and matrix geometry. Here we do both, and also explore a range of rock compressibilities ranging from seismically-inferred values to nearly incompressible behavior. We also explore
models with irregular 'quasi-geological' initial block/matrix geometries. Drucker-Prager plasticity is used to characterize a fault-like mode of shear failure. This suite of experiments demonstrate that, for a wide range of block and matrix conditions, the proposed strength-inversion mechanism can generate a mode of shallow tectonic tremor that clusters in spatially discontinuous swarms along the plate interface. At the deeper edge of the interseismically locked zone, channelised dehydration associated with subduction along a plate interface could induce a similar relative strength inversion, and thereby generate deep seated tremor.