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Roles of poro-elastic compressibility, rate-dependent strength and strain-stress dependent dilation for spontaneous generation of seismicity along fluid-bearing fault structures

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We present a newly developed marker in cell staggered finite difference poro-visco-elasto-plastic numerical model for spontaneous seismic cycle along fluid-bearing fault structures. The fully coupled hydro-mechanical multi-physics model includes poro-elastic compressibility of the solid matrix together with experimentally calibrated rate-dependent strength laws and strain-stress dependent dilation. Localised brittle/plastic deformation is treated accurately through global Picard iterations. To simulate deformation on both long- and short-time scale, an adaptive time stepping is used allowing the resolution of large seismic events with time steps on the order of milliseconds.

Our new numerical modelling tool allows to explore how the presence of pressurised fluids in the pore space of subduction interface and strike-slip zones triggers poro-elastic stress accumulation and release in form of various seismic cycles. The model is capable of simulating spontaneous quasi-periodic seismic events along self-consistently forming highly localized self-pressurised ruptures accommodating shear displacement between the plates. The generated elastic rebound events show slip velocities ranging from the order of Nm/s to m/s, covering the entire range of seismic and slow slip phenomena. The governing strength decrease along the propagating fracture is related mainly to the significant increase of fluid pressure generated by deformation induced plasto-elastic collapse of pores. The reduction of the effective pressure decreases the brittle/plastic strength of fluid-bearing rocks along the rupture, thus providing a dynamic feedback mechanism for the accumulated elastic stress release at the fault interface. It is remarkable that the seismic behaviours for both slow slip and ordinary earthquakes can be generated within the same self-consistent poro-visco-elasto-plastic rheological framework without any involvement of rate- and state-dependent friction commonly used for seismicity modelling. We furthermore analyse how this process and the seismic cycle are affected by poro-elastic, rate weakening and dilation parameters.