# Constraints on friction, dilatancy, hydraulic diffusivity, and effective stress from low-frequency earthquake rates on the deep San Andreas Fault

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Similar to their behavior on the deep extent of some subduction zones, families of recurring low-frequency earthquakes (LFE) within zones of non-volcanic tremor on the San Andreas fault in central California show strong sensitivity to stresses induced by the tides. Taking all of the LFE families collectively, LFEs occur at all levels of the daily tidal stress, and are in phase with the very small, ≤~200 Pa, shear stress amplitudes while being uncorrelated with the ~2 kPa tidal normal stresses. Following previous work we assume LFE sources are small, persistent regions that repeatedly fail during shear within a much larger scale, otherwise aseismically slipping fault zone and consider the constraints on two different models of the fault slip: 1) that the correlation of LFE occurrence reflects modulation of the fault creep rate by the tidal stresses, and 2) that creep occurs episodically, triggered by the tides. With these models we examine the predictions of laboratory-observed rate-dependent dilatancy associated with frictional slip. The effect of dilatancy hardening is to damp the slip rate, so high dilatancy under undrained pore pressure reduces triggering of slip and modulation of slip rate by the tides. The undrained end-member models produce: 1) no sensitivity to the tidal normal stress, as first suggested in this context by *Hawthorne and Rubin* [2010], and 2) fault creep rate or earthquake rate in phase with the tidal shear stress. For these models, the observed tidal correlation constrains the hydraulic diffusivity to be less than about 1 x $10^{-6}$ /s and the product of the friction and dilatancy coefficients to be at most 5 x $10^{-7}$ in the LFE source region. The product is more than an order of magnitude smaller than observed at room temperature for talc, an extremely weak and weakly dilatant material. This may reflect a temperature dependence of the dilatancy and friction coefficients, both of which are expected to tend towards zero at elevated temperatures at the brittle-ductile transition. Alternatively, in the absence of dilatancy the ambient effective normal stress would be no more than about 50 kPa. In summary, for friction models that have both rate-dependent strength and dilatancy rate-dependence, the observations require intrinsic weakness, low dilatancy, and lithostatic pore fluid pressures.

Keywords: low frequency earthquake, friction, tremor

 