Fault Slip in C Sharp Minor: Fault Slip Resonance as a Mechanism for Slow Slip

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GPS measurements in various different tectonic environments have recorded fault movements that are similar to earthquakes but much slower, occurring over timescales of ~1 week to ~1 year. These "slow slip events" have been observed in Japan, Cascadia, Mexico, Alaska, Hawaii, and New Zealand. The phenomenon is poorly understood, but several observations hint at the processes underlying slow slip. Modeling of GPS data and estimates of associated tremor location indicate that slip focuses near the transition from unstable ("stick-slip") to stable friction at the deep limit of the seismogenic zone. Perhaps most intriguingly, slow slip is quasi-periodic at several locations, with recurrence varying from 6 to 25 months depending on which fault (or even fault segment) is examined. Periodic slow fault slip may be a resonant response to climate-driven stress perturbations. Fault slip in southern Mexico recurs annually, and as shown in the figure, stress perturbations on the fault surface include an annual signal caused by surface hydrologic loading. The annual stress variation is only of order a few hundred Pa, which is a small fraction of the annual tectonic stress accumulation, so this stress would not be expected to produce a robust slip response unless the fault's response to stress was somehow amplified at that period. Physical relations for rate- and state-dependent friction actually predict an amplified or "resonant" response at periods of order months to years, depending on frictional properties. Fault slip resonance helps to explain why slip events are periodic, why periods differ from place to place, and why slip focuses near the base of the seismogenic zone. Resonant slip should initiate within the rupture zone of future great earthquakes, suggesting that slow slip may illuminate fault properties that control earthquake slip.

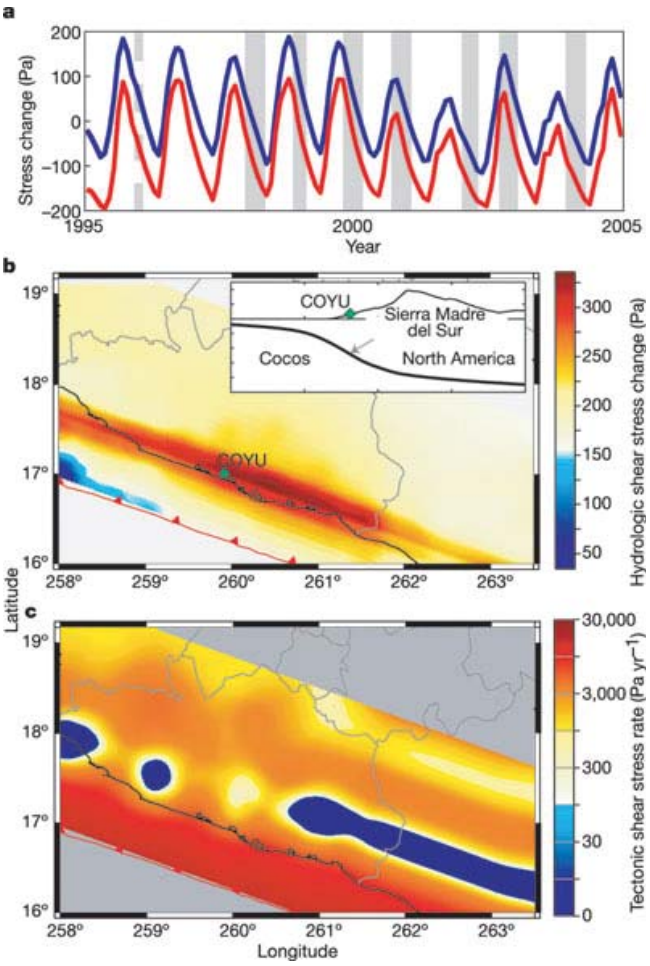

Figure 1. Stress variations on the plate boundary interface in southern Mexico. (A) Time series of normal stress (blue; positive indicates fault compression) and shear stress (red; positive favors thrust slip) at a point beneath GPS site COYU. Grey bars denote periods of deep slow slip; peak slip occurs at the center of the bar. (B) Map view of peak-to-peak shear stress perturbation, projected from the plate interface to the surface. Inset shows plate geometry and strike-averaged topography versus distance from the trench; arrow indicates location of time series sampled in A. (C) Rate of accumulation of tectonic shear stress.

References

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