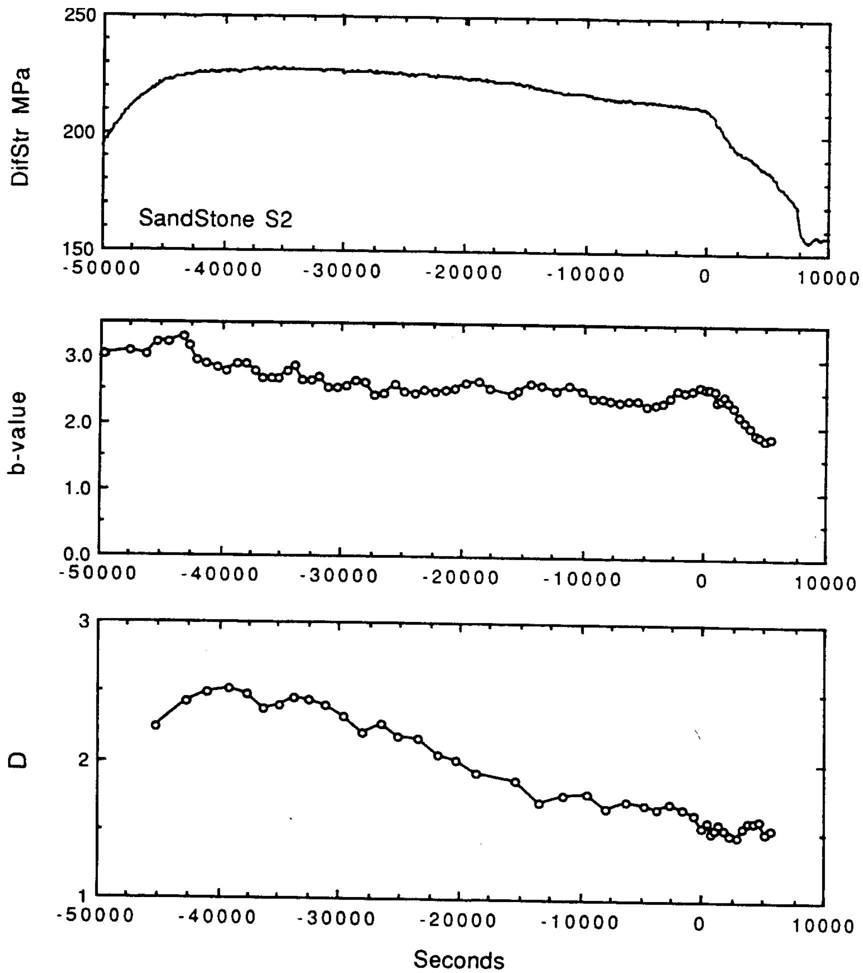
Physics of Earthquake Prediction – a Laboratory Perspective



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USGS
science for a changing world

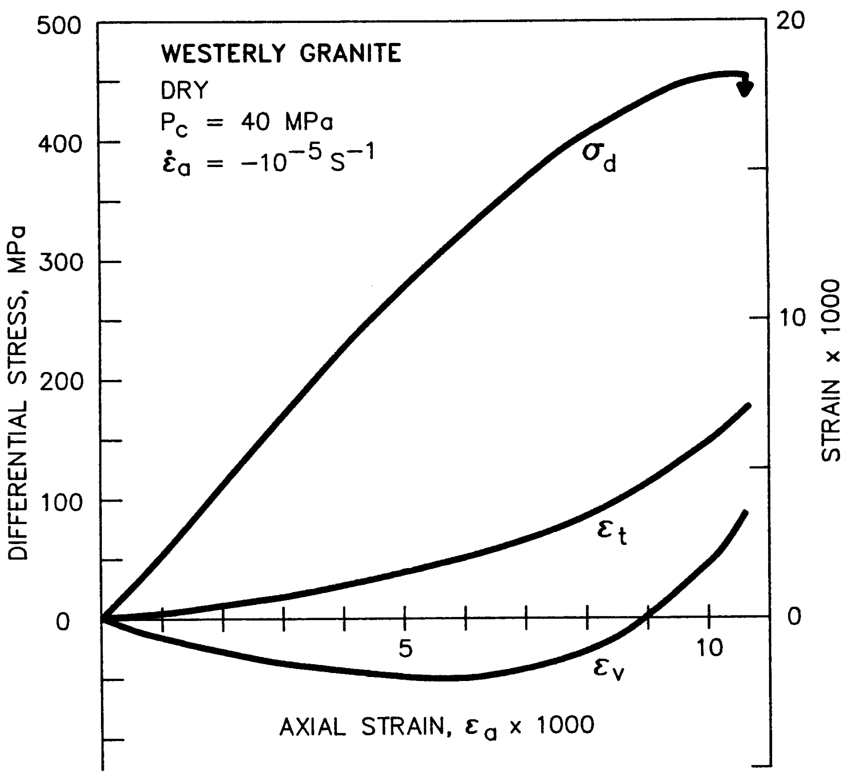
D-D

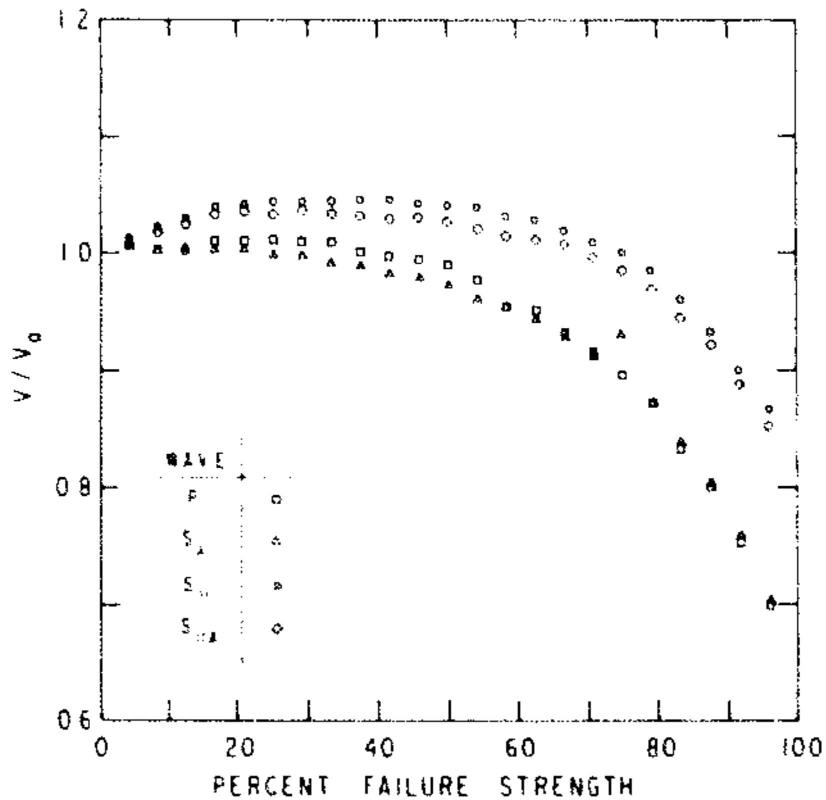
Dilatancy-Diffusion

- For Coulomb material, failure is preceded by microcrack growth and volume increase
- Leads to pore fluid pressure decrease
- Followed by diffusion of pore water and pressure recovery

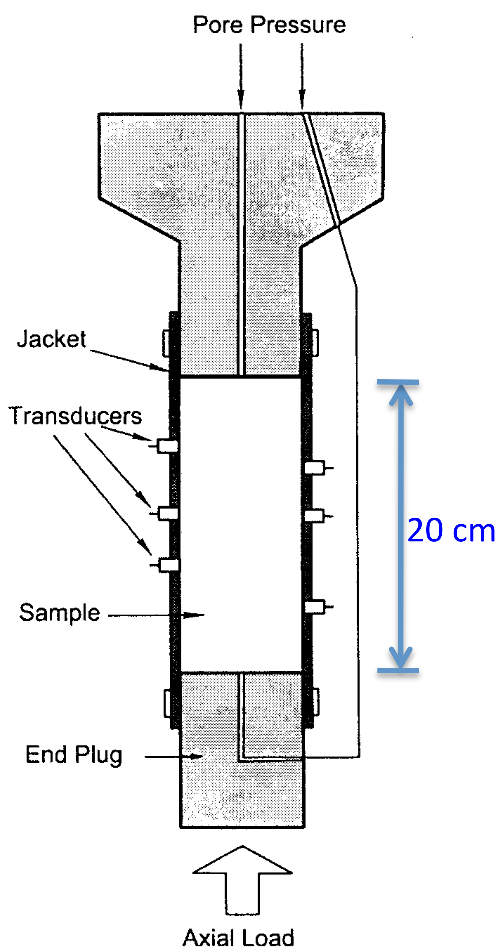
Typical stress-strain plot
For granite

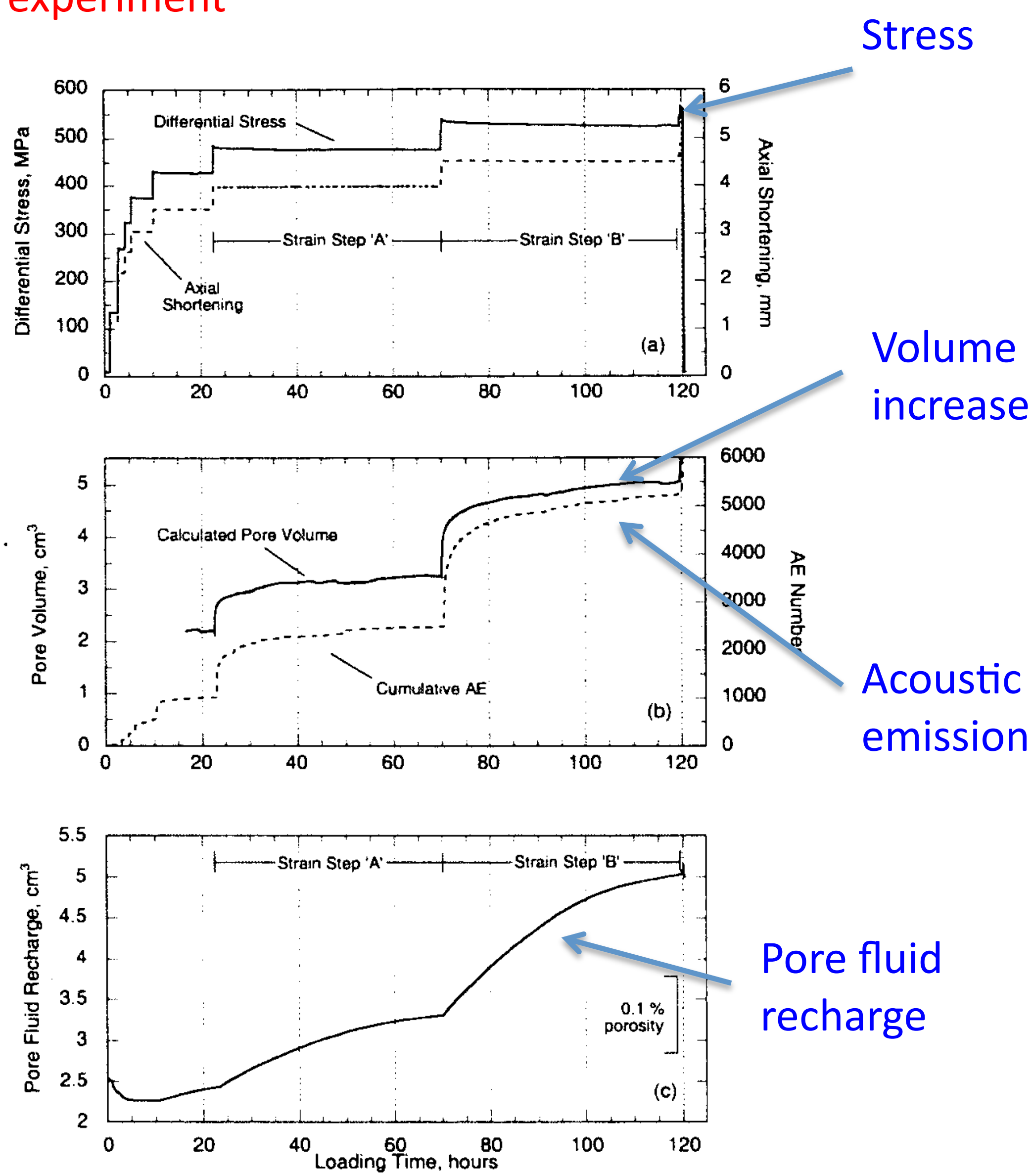
Relative change in P and S velocity
During loading to failure in granite





A Dilatancy-diffusion-like experiment





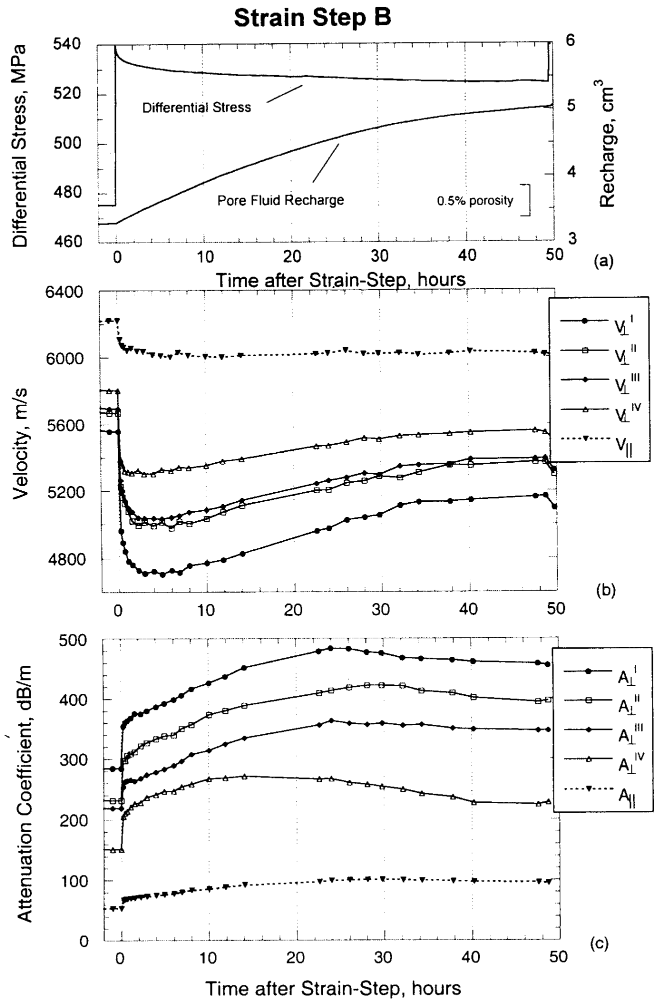


Figure 7. Time histories of strain step B: (a) mechanical parameters, (b) calculated *P*-wave velocities of five-element model, (c) calculated *P*-wave attenuation of five-element model. The timing of the velocity and attenuation response was much like the response to strain step A.

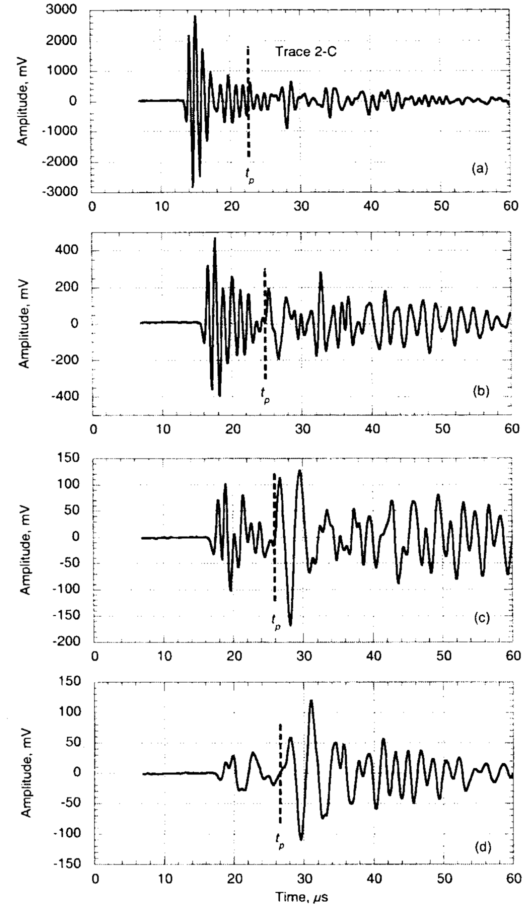


Figure 9. Waveforms recorded for trace 2-C at different loading times (see loading history in Fig. 2). The end of the *P*-wave packet used to evaluate frequency content is indicated by t_p. The loading times are (a) 0.4 hr, (b) 24.4 hr, (c) 73 hr, and (d) 120.4 hr.

Clustering of AE (microcracking) before and after fracture of Intact granite

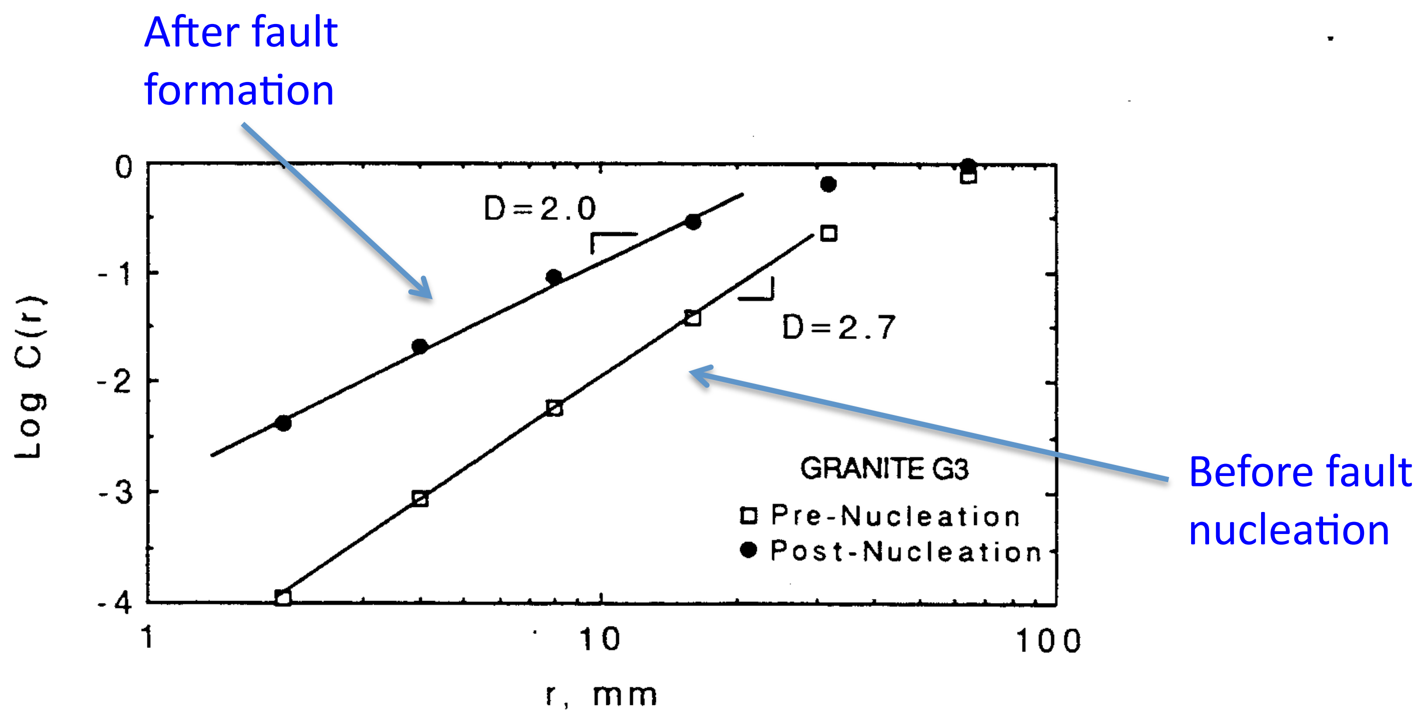
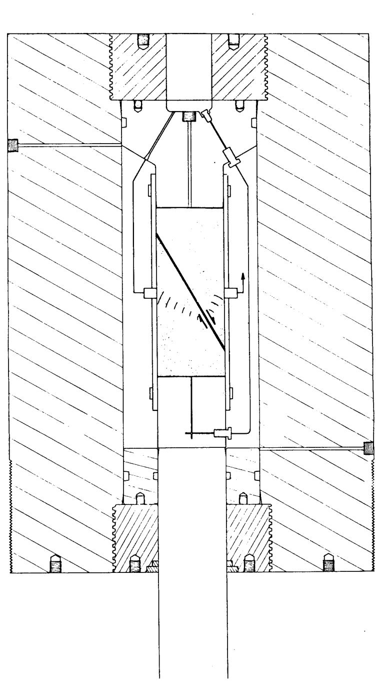
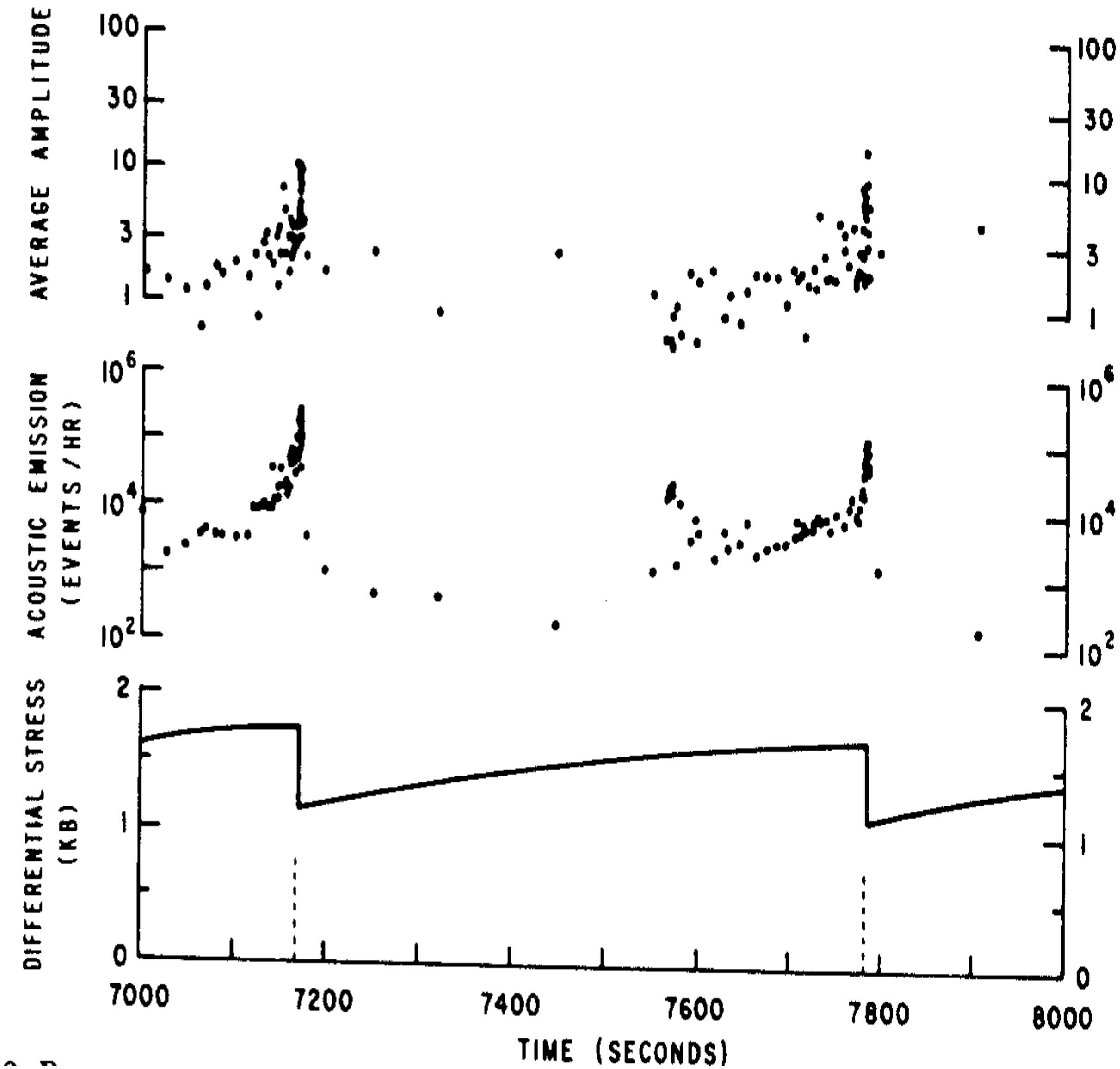


Fig. 1 Correlation integral C(r) is shown for pre- and post-nucleation stages of Westerly granite deformation at 50 MPa confining pressure. C(r) provides a measure of the distribution of interevent distances. AE events occurring randomly within a fault plane (post-nucleation) will have a slope D = 2. Events occurring randomly within a volume (pre-nucleation) would have a slope D = 3. The observed value of D = 2.7 indicates a tendency for events to cluster spatially somewhat more than would be expected for a purely uncorrelated population.

Change in b-value
For stick-slip
on granite sawcut





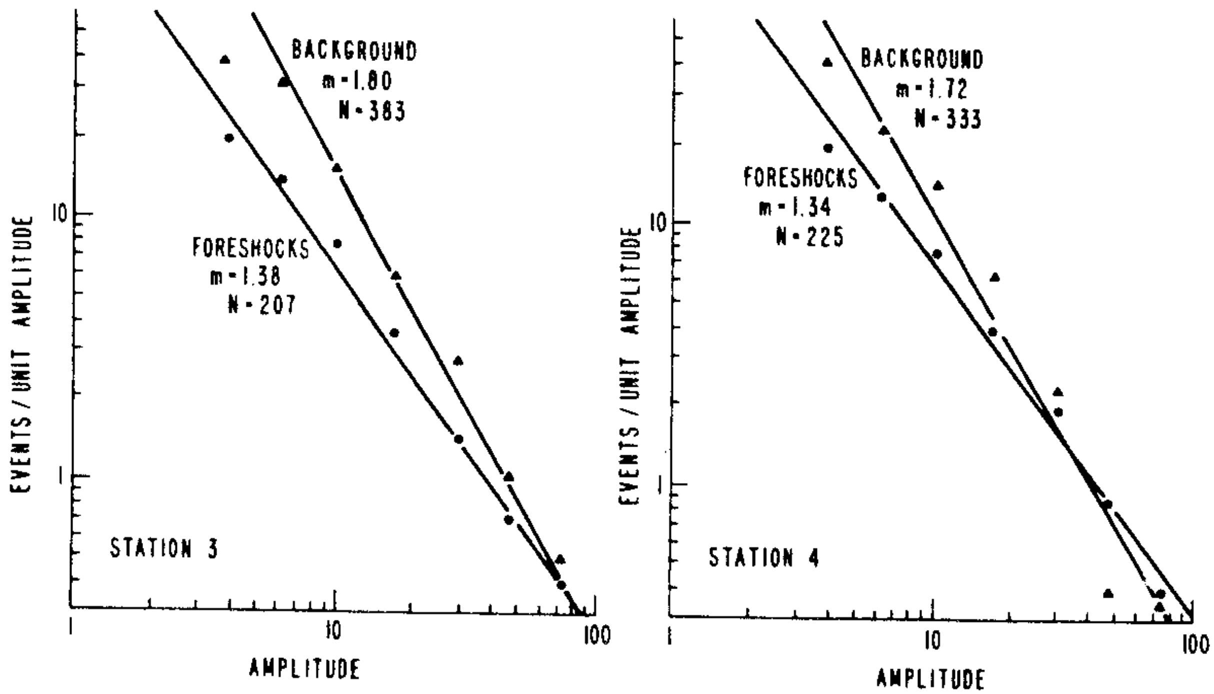
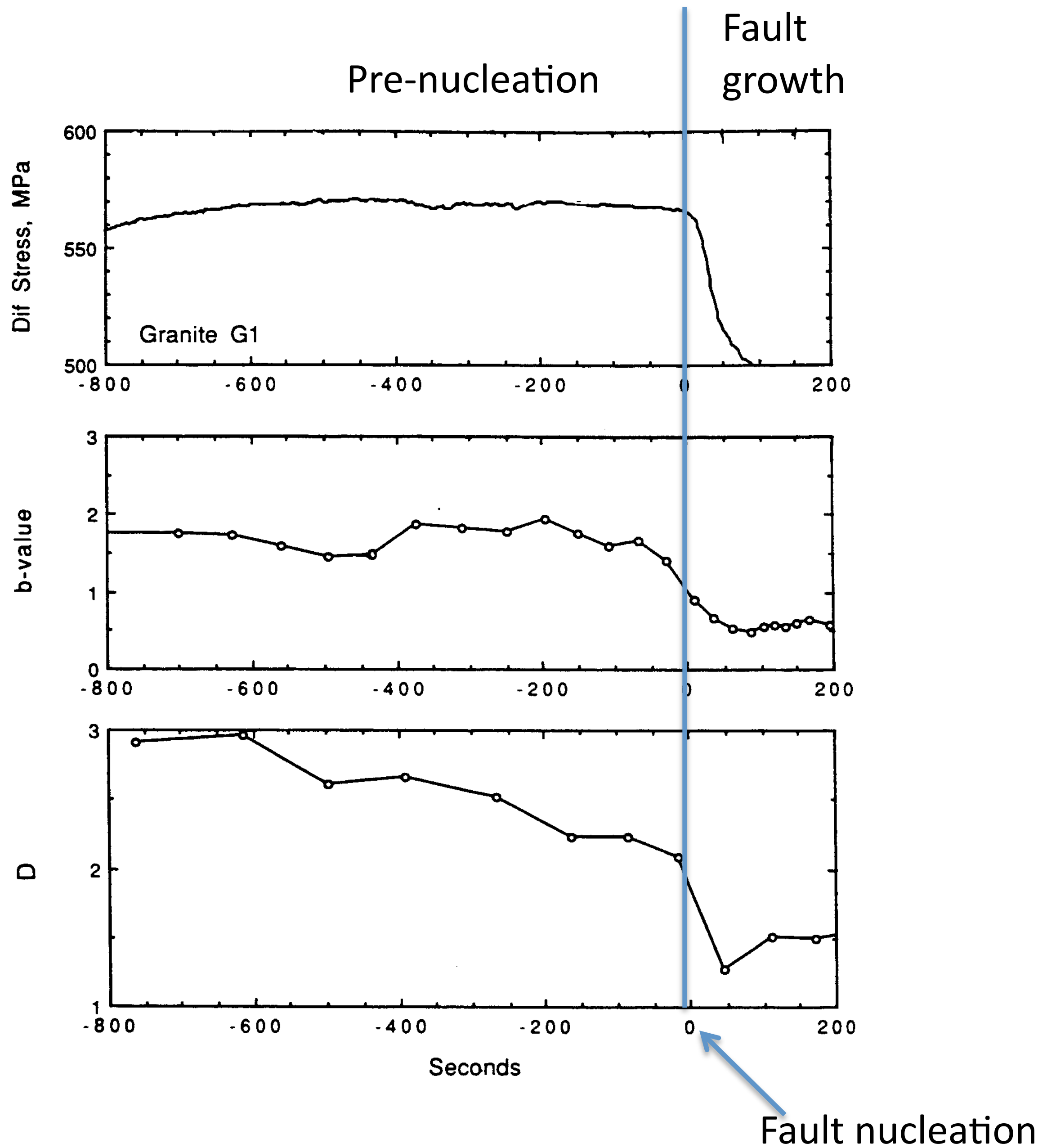
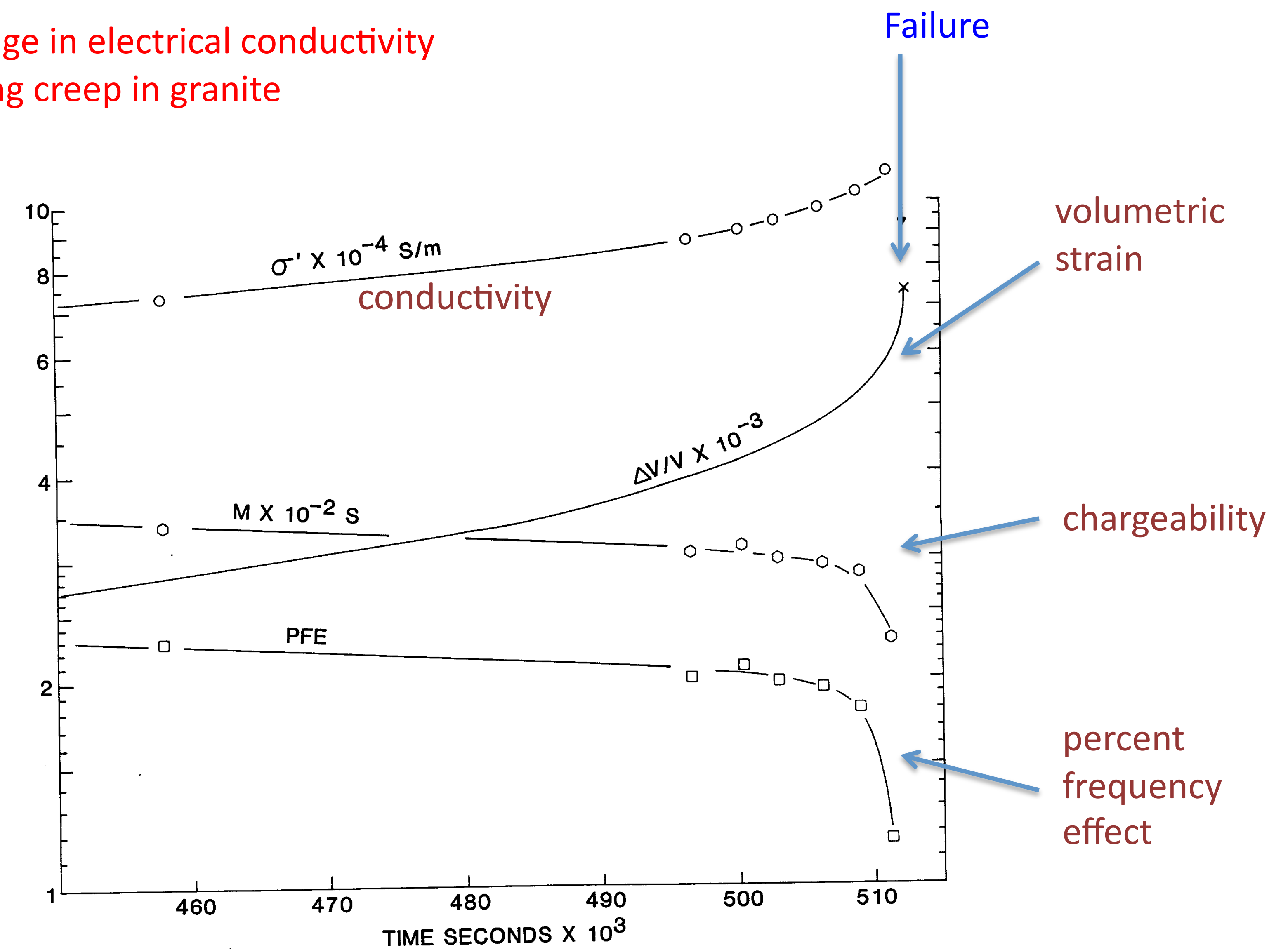


FIG. 3. The change in m-slope between background and foreshock microfractures prior to the first four stick-slip events is illustrated. Slopes are calculated by a least-squares fit. Stations 3 and 4 are the two transducers located at the center of the sample.

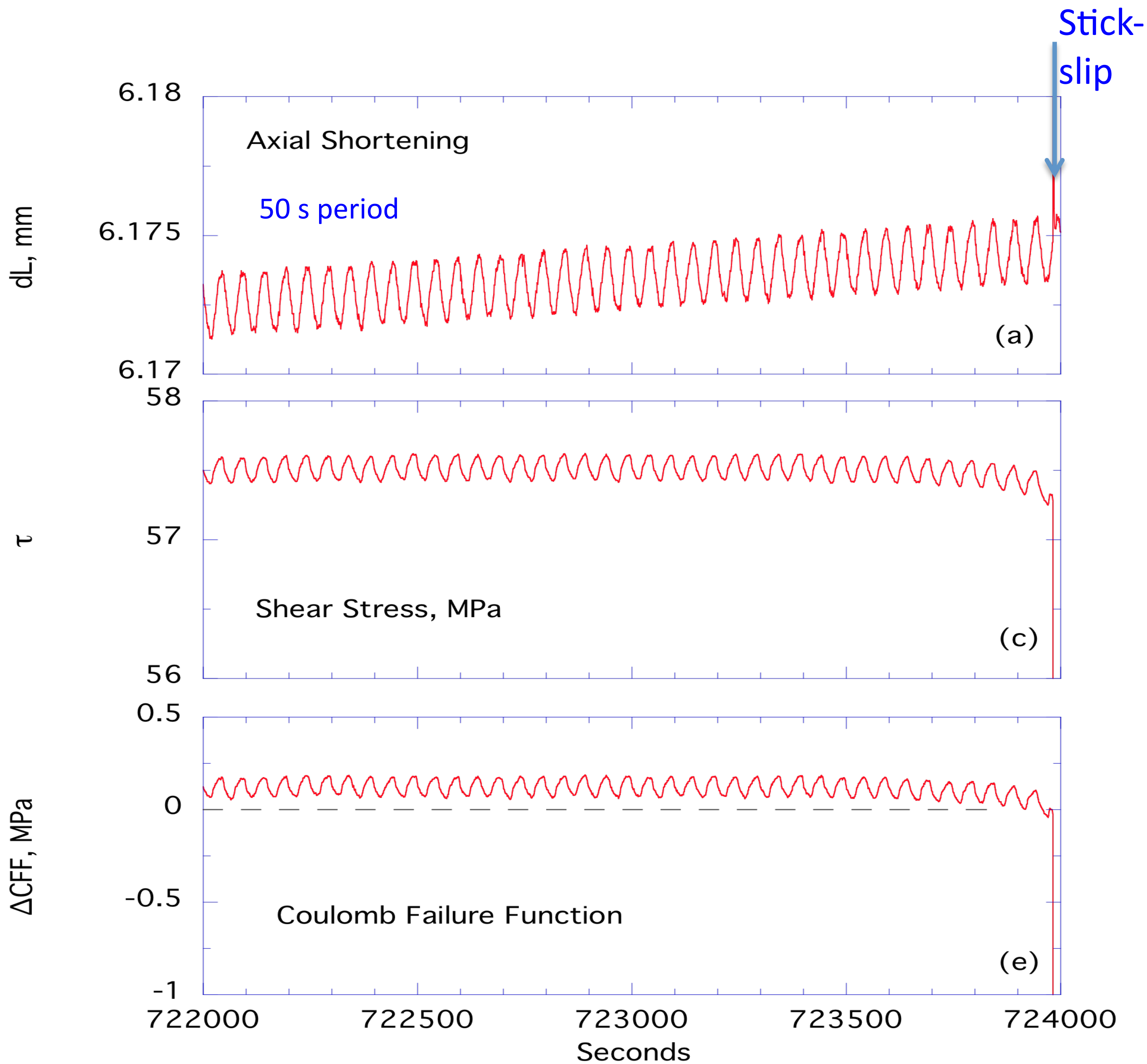
Fault Nucleation In Granite



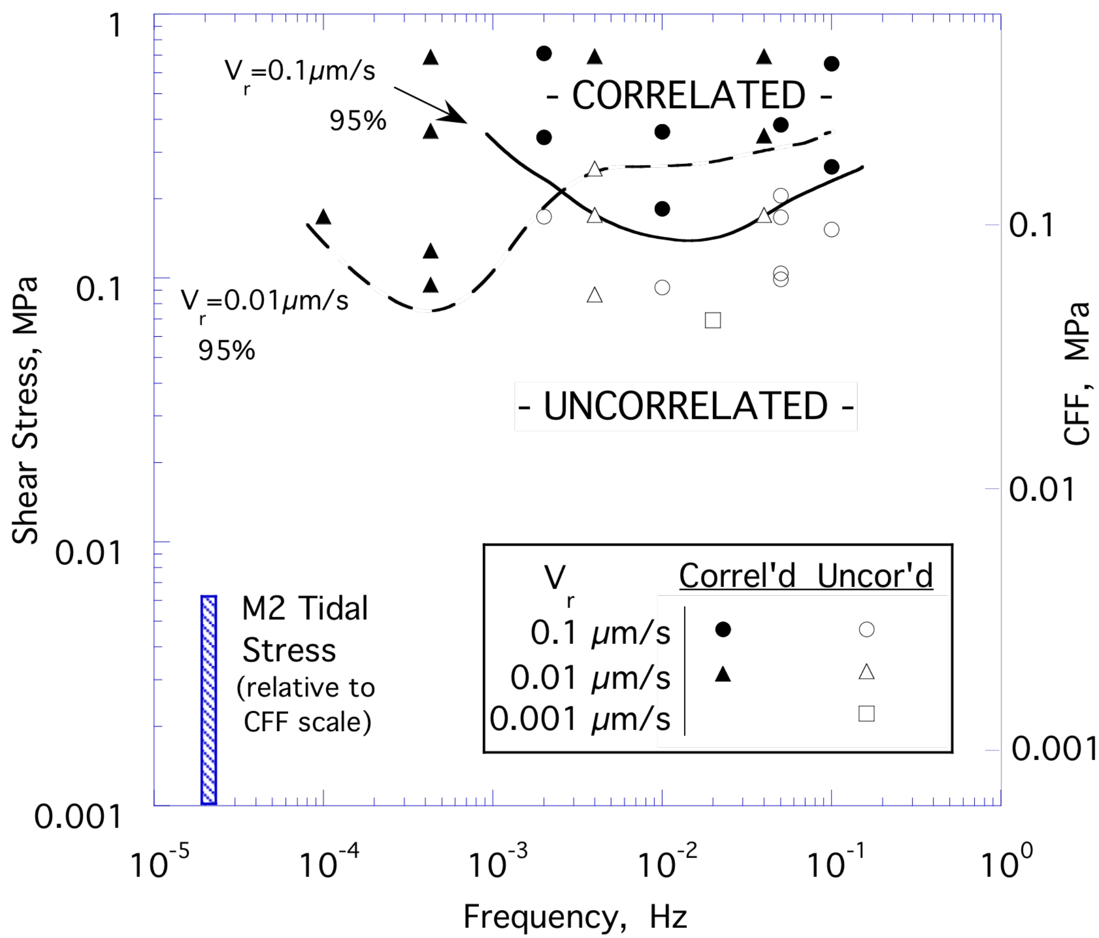
Change in electrical conductivity during creep in granite



Stick-slip during oscillating stress on granite sawcut sample (simulated tidal loading)



Strong influence of stress oscillations on timing of stick-slip occurs above about 0.1 MPa amplitude



CONCLUSIONS

Most of the measureable effects shown are either directly or indirectly the result of strain – generally dilatancy and crack growth

This fact has a number of implications, including:

•Strain changes that are large enough to produce measureable effects are likely to also produce microseismicity, and measureable velocity changes

•Coseismic changes should be larger and more easily observable than precursory changes

•Slowly evolving precursory signals should be modulated by tidal strains

Rupture nucleation is likely to involve a small volume that is deep in the (wet) crust and is likely to be very difficult to detect or distinguish from background.