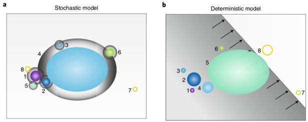

Article: Preseismic Fault Slip and Earthquake Prediction

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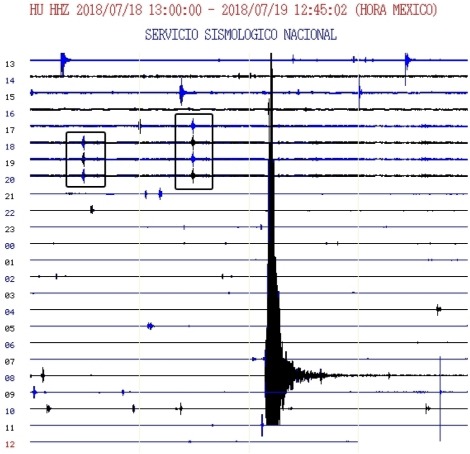
Introduction

Weird isn't it?



A bug? antropogenic? coinsidence?

Most attempts to determine this mechanism have concentrated on observations of the ratio of compressional to shear velocity, V_p/V_s prior to earthquakes.

One of the most widely reported earthquake precursors, indicate that V_p/V_s first decreases to anomalously low values in advance of an earthquake and then recovers to approximately the normal values shortly prior to the earthquake.

Dilatancy would predict a progressive decrease in V_p/V_s but not the recovery.

Diffusion+Dilatancy = fluid migration would better explain both:
fits the observed precursor time VS magnitude data.

Other mechanism+Dilatancy explaining Velocity recovery without fluid diffusion in the focal

Several authors cite evidence which suggests that preseismic fault slip has occurred before at least some earthquake.

- At Cienega Winery (San Andreas fault), fault creep rates accelerated from 12 to 20 mm/yr 18 months prior to two earthquakes (Mw=5.5 and 5.6).
- Before M=5.5 June 27 1966 Parkfield unusual ground cracking was observed that could exceeds the dilational strain rates.
- Others ...

This paper has two purposes:

- Laboratory evidence for preseismic slip in artificially faulted samples.
- Mechanisms involving premonitory fault slip are compatible with the slope of the $\log t$ vs M data.

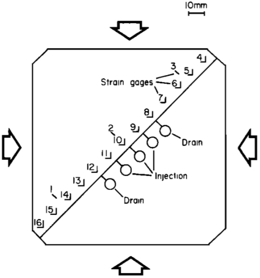


Fig. 1. Sample configuration showing locations of strain gages. Gages 1–3 give normal strains, and gages 4–16 give shear strains parallel to the fault.

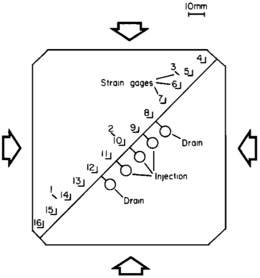
Two processes:

- Stable sliding: aseismic creep ... smooth displacement on the fault surfaces without sudden changes in the displacement rate
- Stick slip: earthquakes ... relative long period with no slip and the shear stress increases, punctuated by the abrupt onset of rapid slip accompanied by a stress drop
- Mixtures

Scholz et al. and Byerlee and Summers experiments have suggested that stable fault slip may precede earthquakes.

Hence preseismic slip displacements could be of similar magnitude for laboratory specimens and large faults.
Would make difficult to observe premonitory slip. Bad scenario.

Premonitory displacements may be proportional to slip-induced stress or strain changes on the fault. **Good scenario.**



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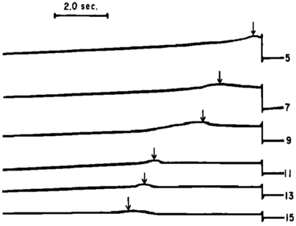
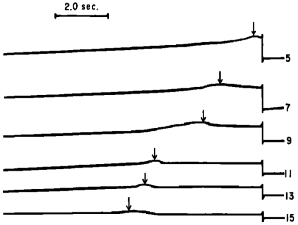


Fig. 2. Slow-speed oscillograph record of stick-slip event showing large amounts of slowly propagating preseismic slip. Numbers refer to gage locations. Arrows mark the time at which fault slip began at each strain gage.

Experiments were conducted at low normal stresses 4-18 MPa. Stick slip was observed throughout this range. Of more than 150 stick slip events recorded in detail, premonitory slip was observed in all but two cases.



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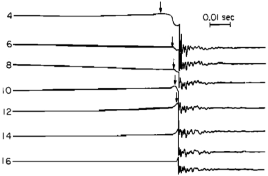

Fig. 3. High-speed oscillograph record of stick slip event. Not shown on this record because of the short time scale is the initial slowly propagating slip event that has already transversed the sample from bottom to top. Arrows mark the propagation of the second, more rapidly propagating preseismic slip event. Note that at gages 10 and 12 the seismic slip is transitional with preseismic slip. Oscillations following the stress drop are caused by vibration of the loading frame.

Stage I is the slow propagation of slip across the sample, with slip rates controlled by the externally applied.

Stage ii consists of a much shorter interval (¡ $10^{-2}s$) after the initial slip event reaches the sample edge. The shear stress decreases. Consists of a slip velocity perturbation triggered when the stage i slip breaks out at the end of the sample.

Stage III is the resulting unstable (seismic) slip that is driven by a sharp drop in frictional force.

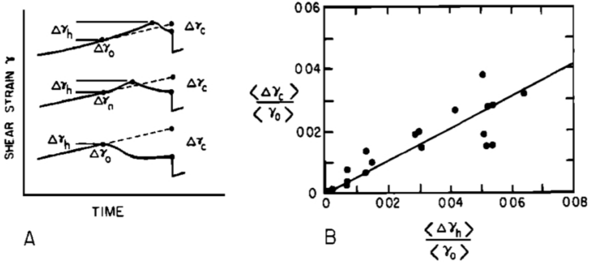

Fig. 4. Effect of heterogeneity on stage I slip. (*a*) Schematic diagram of shear strains recorded by the strain gages plotted against time. Slip first begins at time t_0, when the local strains are γ_0. Illustrated for each gage are $\Delta\gamma_c$, the strain caused by preseismic slip, and $\Delta\gamma_h$, the critical strain required to initiate slip measured in relation to γ_0. (*b*) Data for the amount of preseismic slip against heterogeneity; $\langle\Delta\gamma_c\rangle$ and $\langle\Delta\gamma_h\rangle$ are the average values of $\Delta\gamma_c$ and $\Delta\gamma_h$ from all gages showing stage I slip. The data are normalized by $\langle\gamma_0\rangle$, the average shear strain at the time that slip begins.

Seismic slip in the absence of premonitory creep occurred only when the barriers, i.e., stress, were very small. In the usual situation, where seismic slip occurs following fault creep, the heterogeneity in the fault at the time of unstable slip is also effectively zero.

Two questions relevant to the application of preseismic slip to earthquake faults may be asked:

- what is the magnitude of the average change in shear stress required to overcome the fault friction measured in relation to the shear stress when slip first begin for faults?
- Is it possible that preslip occurs on very limited portions of a fault and that seismic slip propagates well beyond the preslip zones?

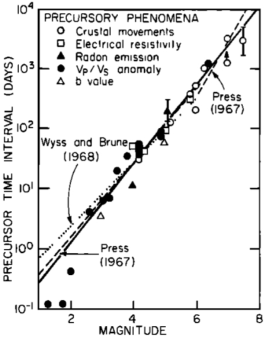

Fig. 5. Earthquake precursor time versus magnitude [from *Scholz et al.*, 1973]. Solid line is the *Scholz et al.* [1973] fit to the data, and dashed and dotted curves are fits to these data based on (19), using the magnitude–fault length relationships of *Press* [1967] and *Wyss and Brune* [1968], respectively.

A number of investigators have reported a correlation between M and duration of the anomalous period t.

$$M = \alpha + \beta \log t \qquad (1)$$

TIme dependence argues a dilatancy/diffusion behaviour.

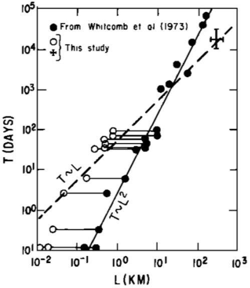

Fig. 6. Earthquake precursor time versus fault length (data modified after *Whitcomb et al.* [1973]). Solid circles are from *Whitcomb et al.* [1973]. Open circles give length determinations based on the *Press* [1967] *M-L* relationship for intermediate and small earthquakes instead of the *Wyss and Brune* [1968] relationship employed by *Whitcomb et al.* [1973]. The cross represents possible range of t and L for $M = 8$ (see text).

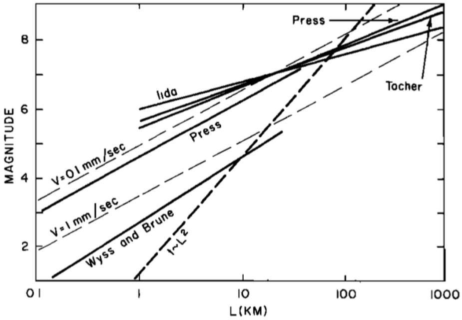

Fig. 7. Magnitude-length relationship from *Press* [1967], *Wyss and Brune* [1968], *Tocher* [1958], and *Iida* [1965]. Dashed curves are magnitude-length relationships and stage I propagation velocities that exactly satisfy the *Scholz et al.* [1973] fit to the *M-t* data (Figure 6), under the assumption that $t \sim L^1$ in (17)–(20). The heavy dashed curve is an exact fit assuming $t \sim L^2$ instead of (17).

Summary

1. there is evidence that suggests significant amounts of preseismic slip for a few earthquakes
2. preseismic slip on laboratory faults is an intrinsic part of the process of homogenization of stress along a fault leading to unstable (seismic) slip
3. a precursor time scaling relationship of $t \sim L$ is indicated by empirical magnitude-length and magnitude-precursor time relationships.

TABLE 1. Predicted Values of β and Propagation Velocities From Magnitude-Length Scaling Equation

$\beta = B$	V,* cm/s	Magnitude-Length Relationship
	$M < 6$	
1.6	2.1×10^{-2}	*Press* [1967]
1.9	1.9×10^{-2}	*Wyss and Brune* [1968]
	$M \geq 6$	
0.98	1.2×10^{-2}	*Tocher* [1958]
0.76	8.6×10^{-3}	*Iida* [1965]
1.06	1.3×10^{-2}	*Press* [1967]

*Velocities are obtained from the best fit to Scholz et al. M-t data.

TABLE 2. Predicted Values for β From Magnitude-Energy Scaling (Equations (20) and (21))

$\beta = 3d$	Magnitude-Energy Relationship
1.4	*King and Knopoff* [1969]
1.5	*Thatcher and Hanks* [1973]
1.6	*DeNoyer* [1959]
1.7	*Benioff* [1955]
2.0	*Gutenberg and Richter* [1956]
2.1	*Bath* [1958]

For further reading on MCMC, SMCMC, HMCMC: