# Brittle and Ductile Friction and the Physics of Tectonic Tremor

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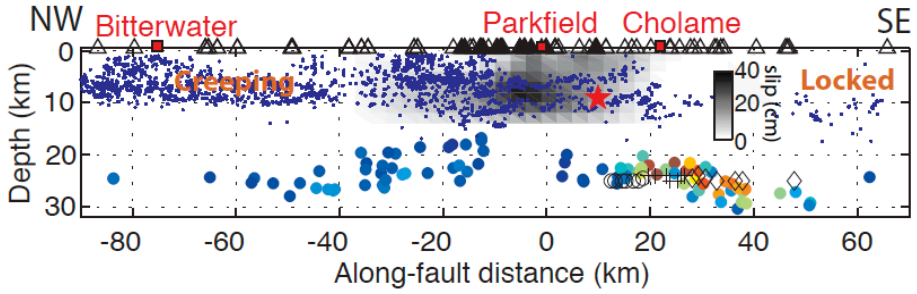
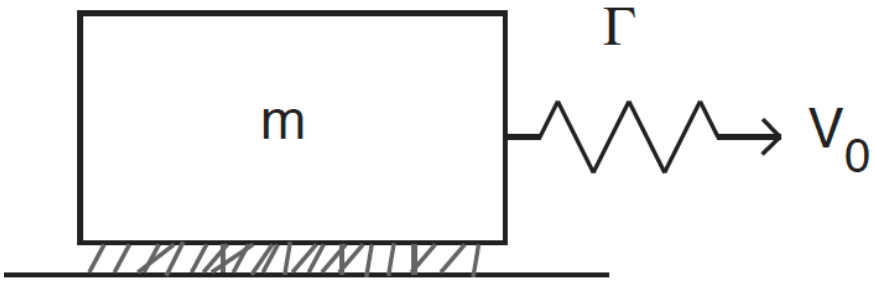
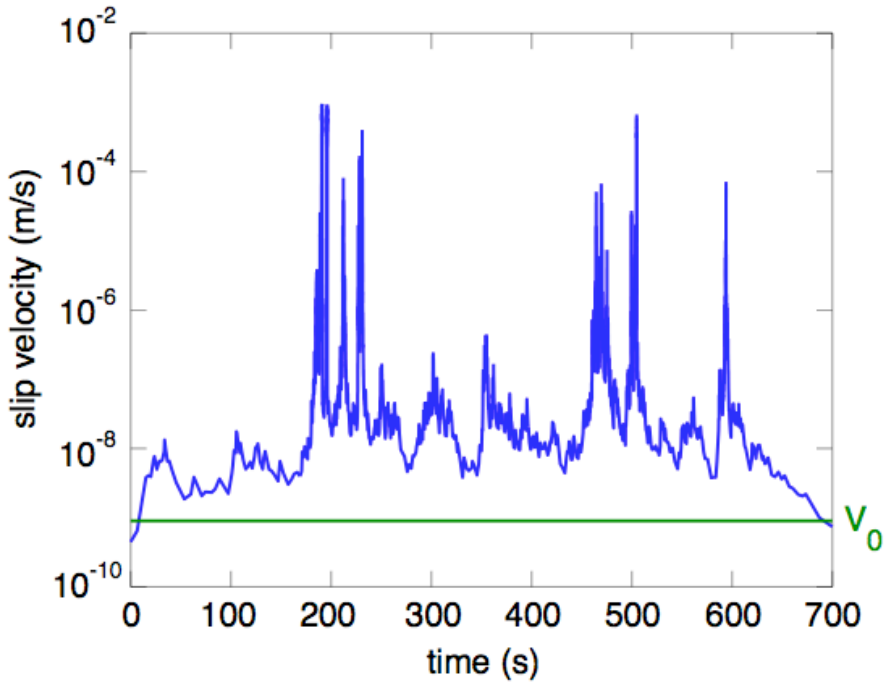
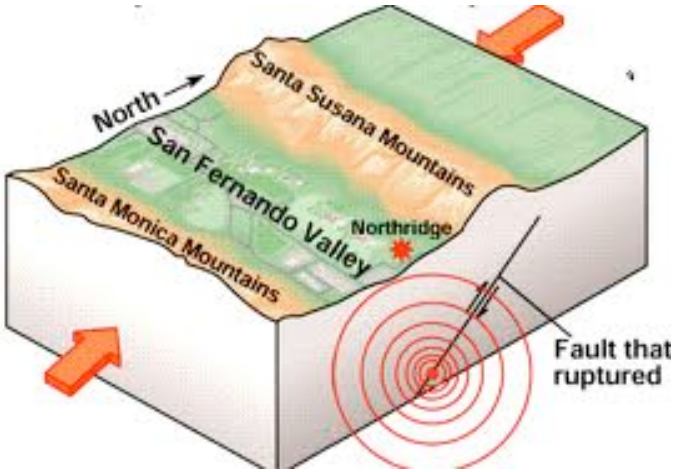
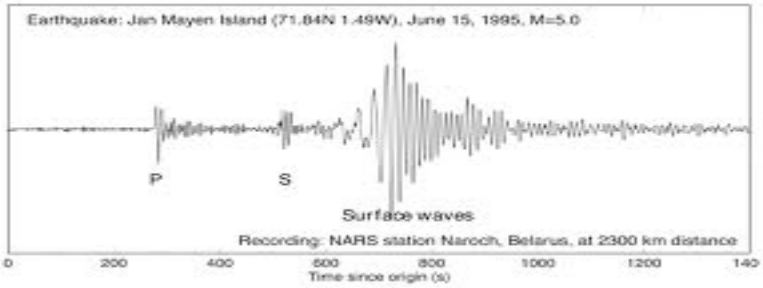


# Physics of Earthquakes




Goal: improve our understanding of the physics of earthquakes.

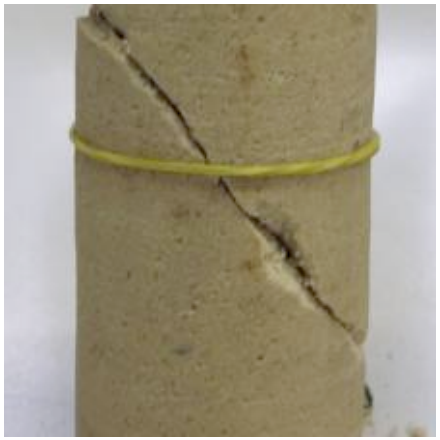
Challenging problem:

• Earthquakes occur deep in the crust, can't be observed directly

• Happen infrequently, so we have limited data on their occurrence

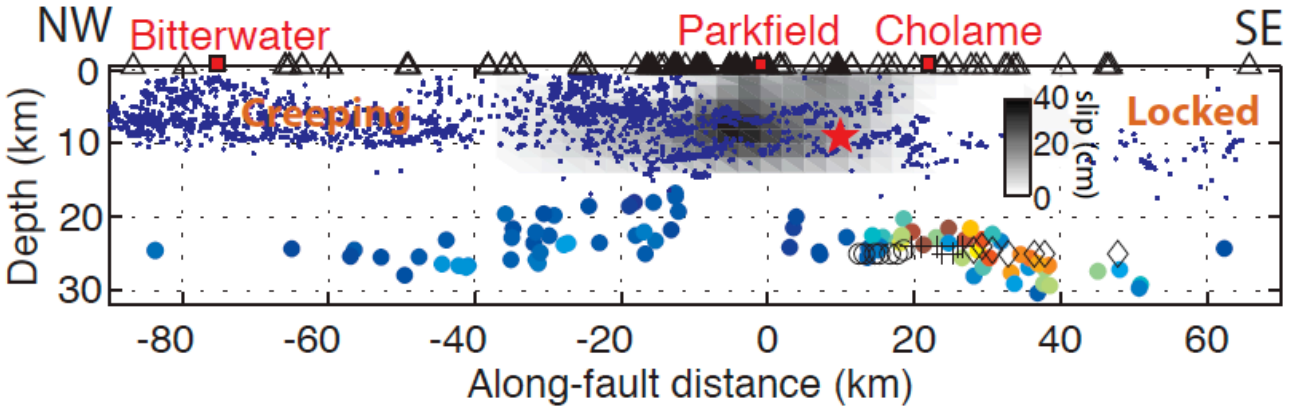
• Occur at extreme physical conditions, hard to replicate in lab

Difficult to constrain physical models!



# Physics of Earthquakes

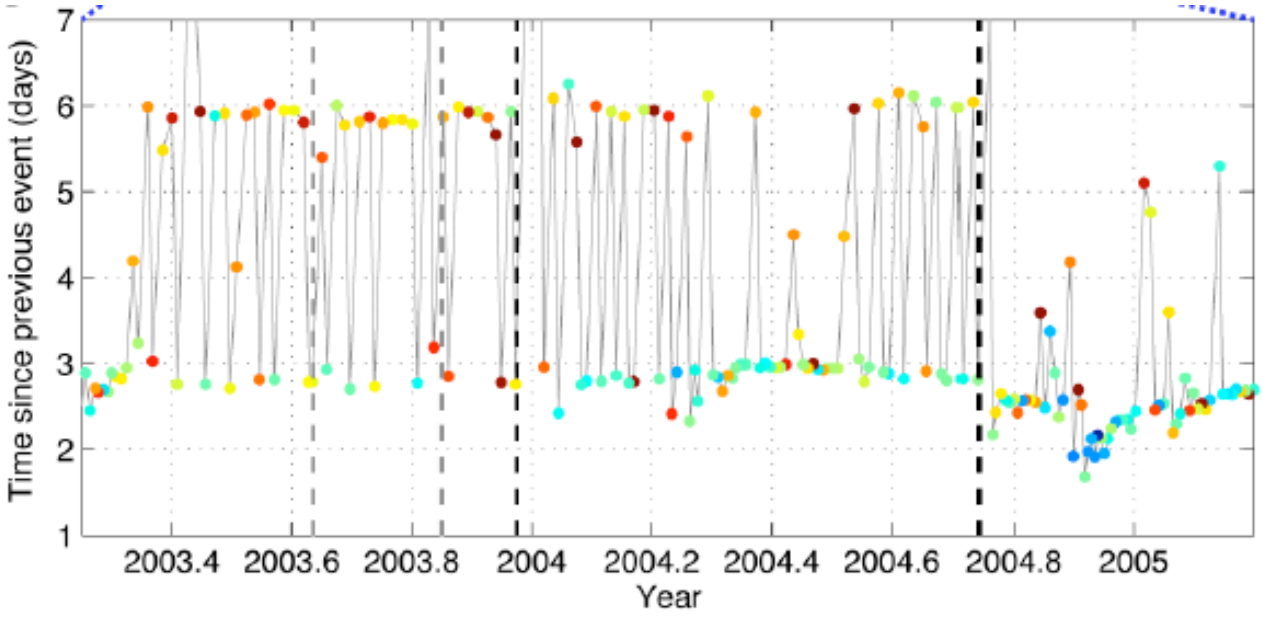

Shelly and Hardebeck, GRL, 2010



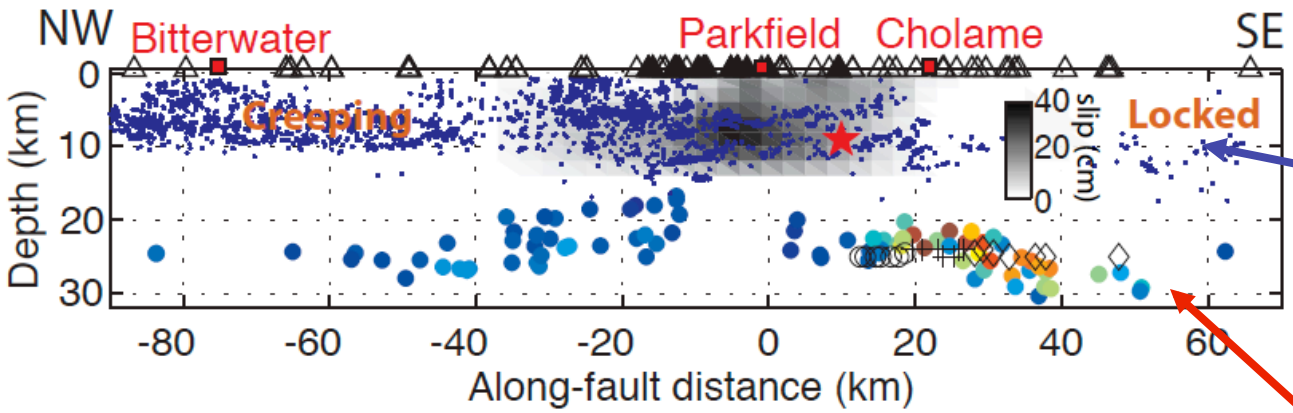

However, there are tiny earthquakes that occur deep in the crust – "Nonvolcanic Tremor"

Occur frequently (days between events instead of years), so we have better data on their occurrence.

Shelly, Science, 2010



# Modeling Tremor



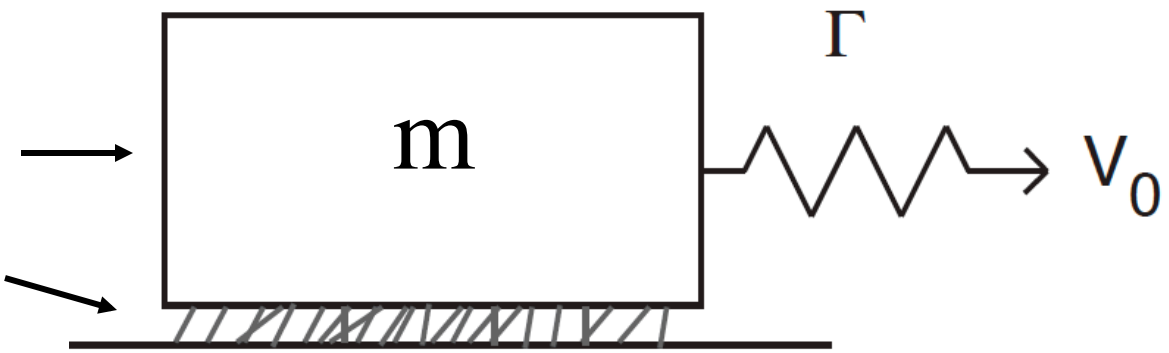

Earthquakes occur in the brittle upper ~15 km of crust.

Friction gradually changes from brittle to ductile in lower crust, where tremor occurs

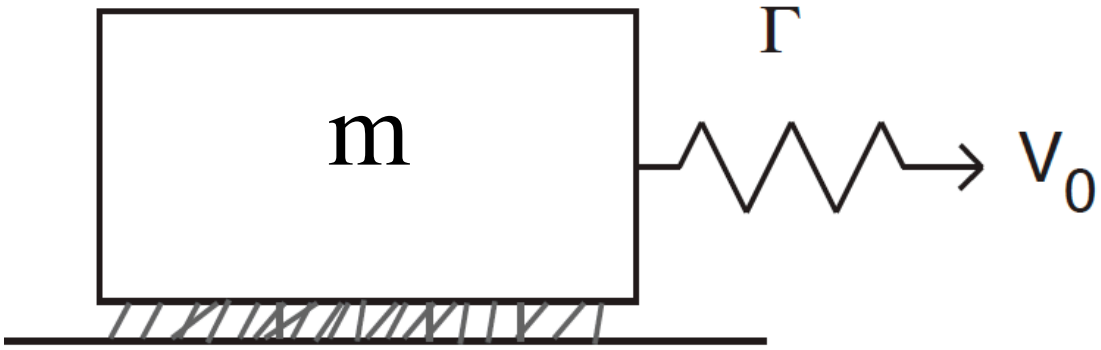
Idea: friction at depth is both brittle and ductile. Develop a simple model for this, and use observations to determine frictional properties at depth.

Model tremor at a single location as a block slider

(Top view of fault plane)



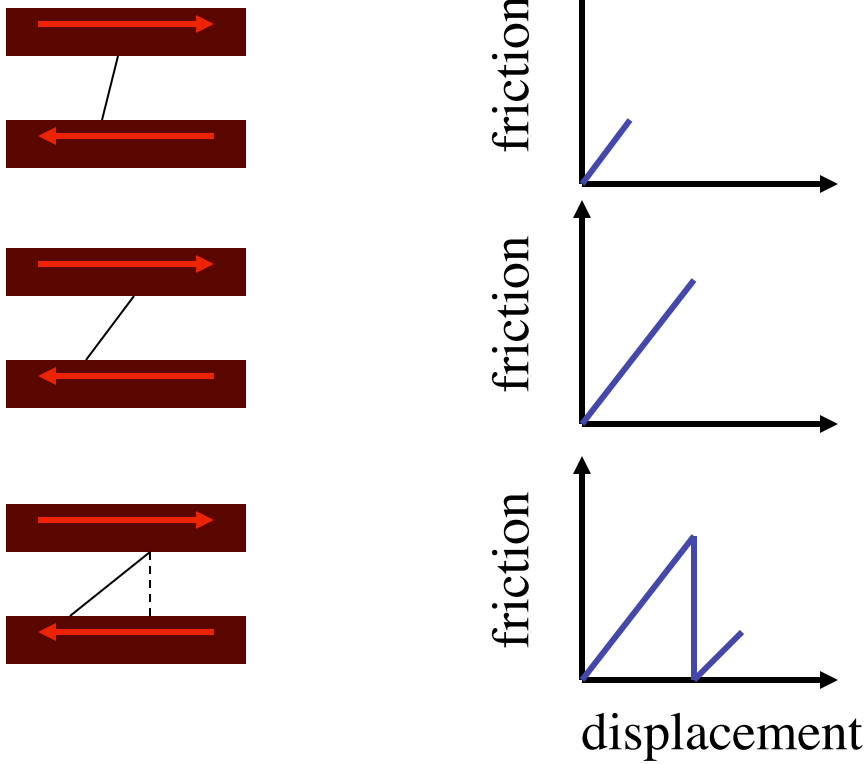
# Brittle-Ductile Friction Model



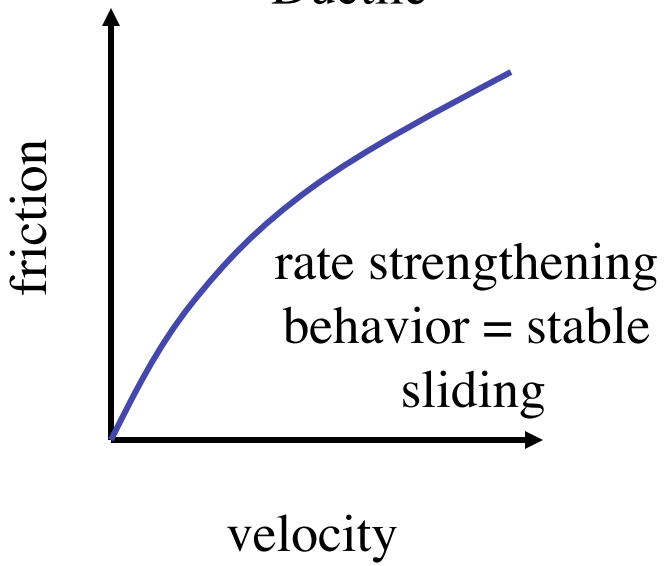

Idea: bristles represent brittle fault patches (resist motion, then fail). Other patches behave in a ductile manner (slide stably).

Friction is the sum of brittle and ductile parts.

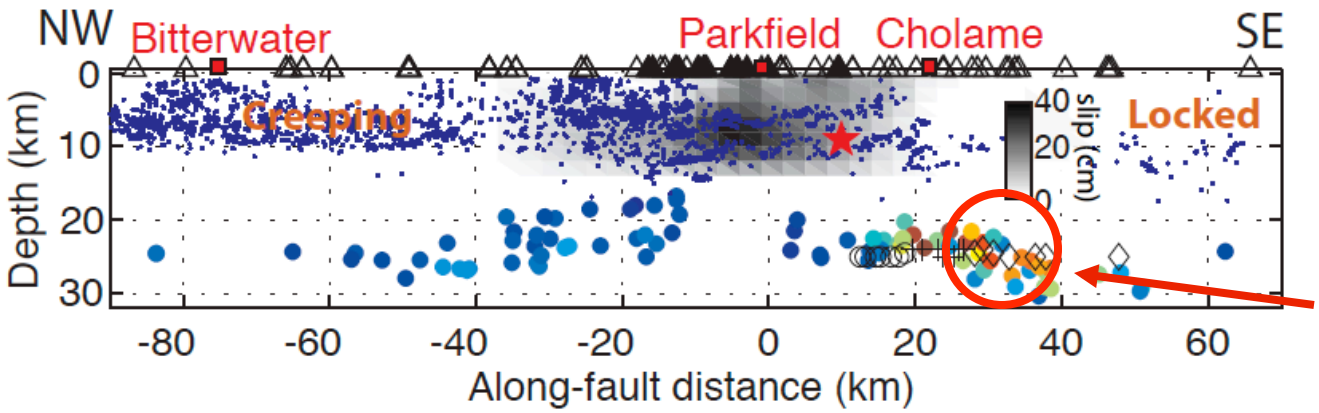
Brittle




Ductile



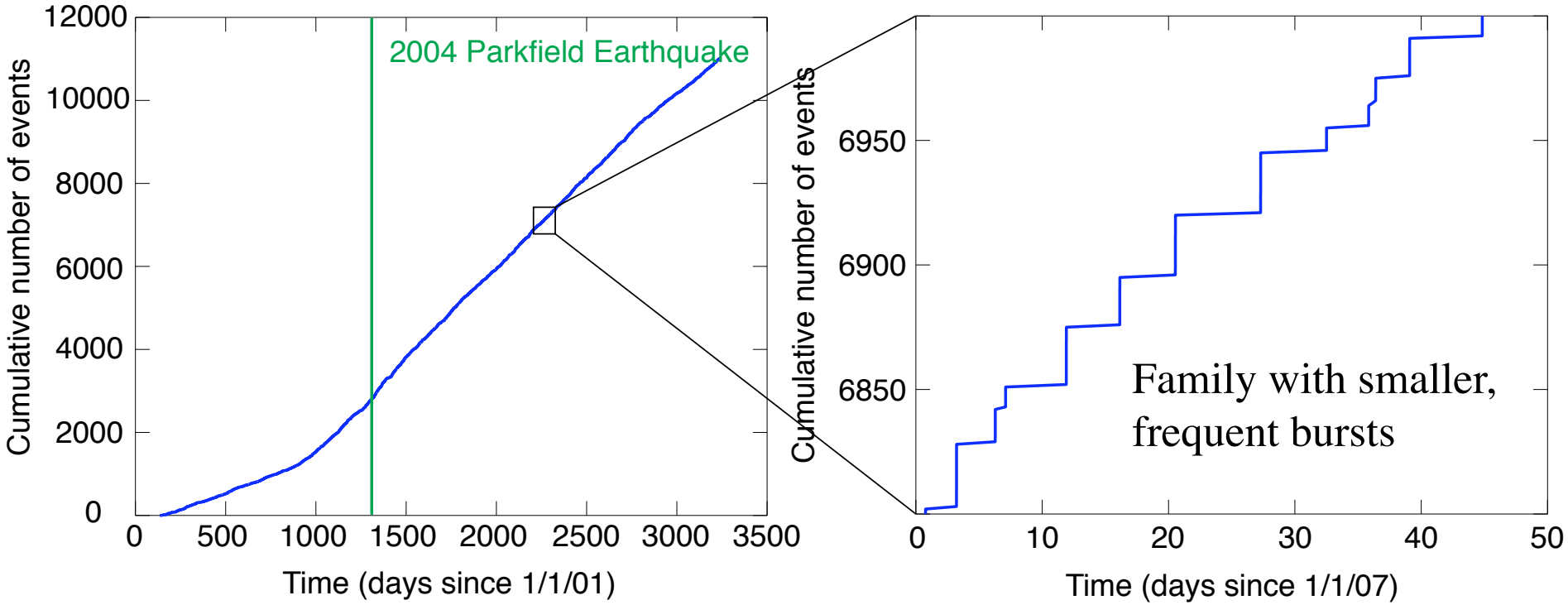
# Constraining Model Parameters




Look at an example tremor family.

Located in this patch of tremor, one of the deeper examples.

Family 19165 (27.5 km depth)



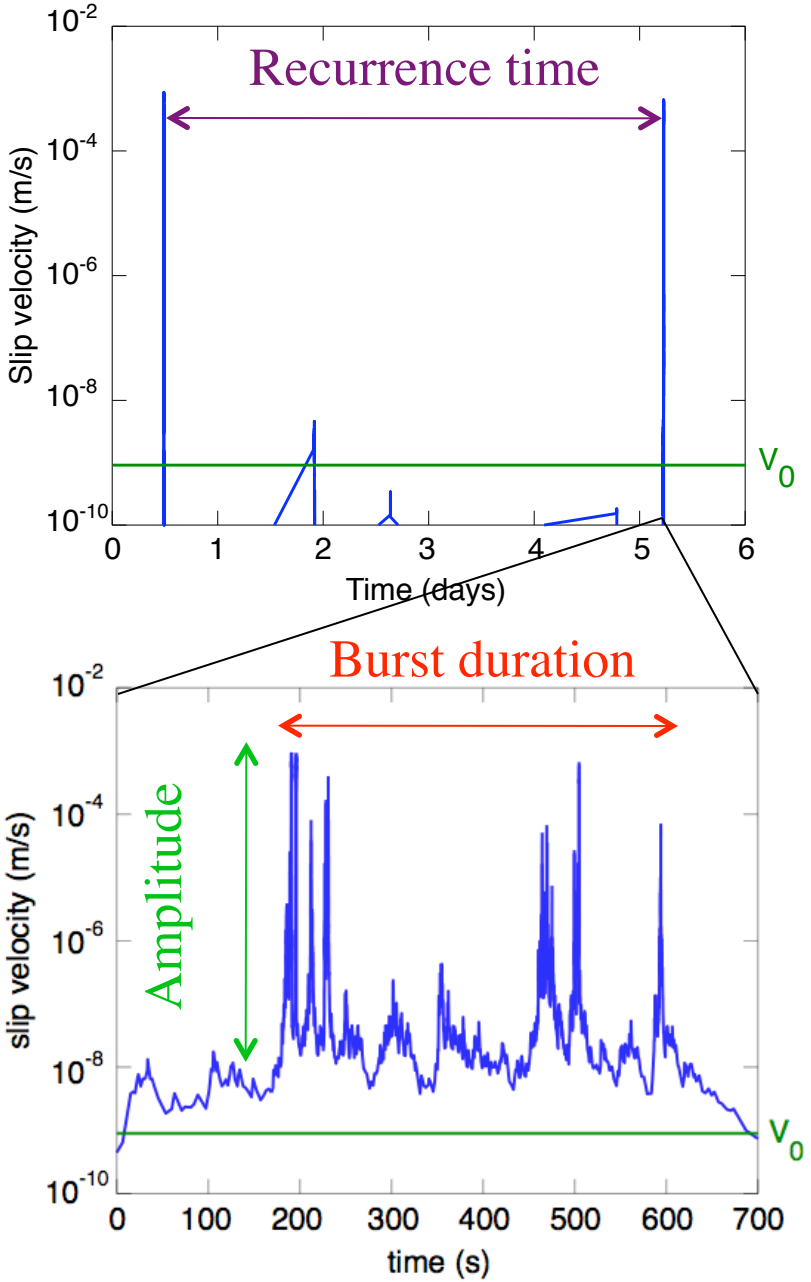
# How to Compare Data and Model?

Compare 3 aspects of data and model quantitatively:

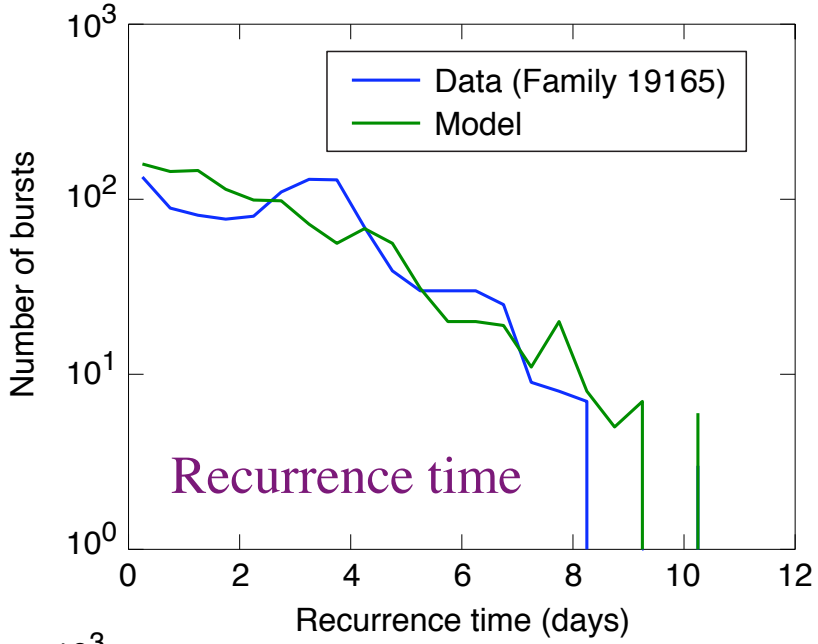
Data for bursts (groups of events):
- Recurrence time (time since previous burst)
- Burst duration

Data for individual events:
- Amplitude (PGV in observations, peak velocity in model)

Compare distributions of each quantity for model and data

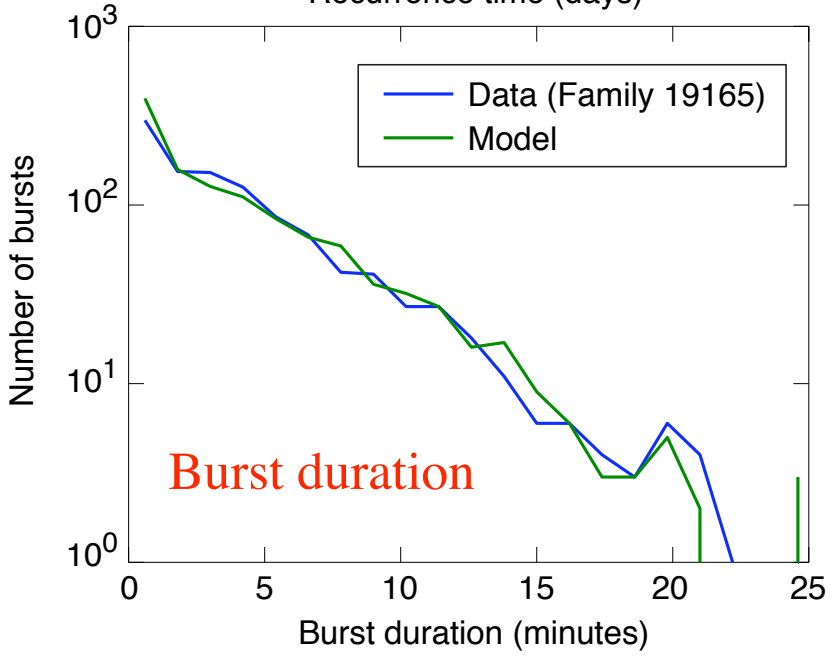


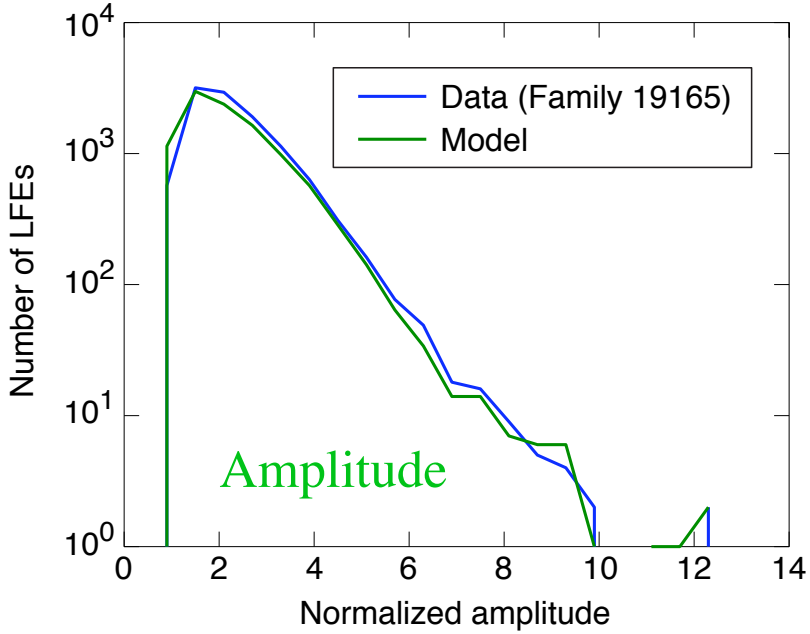
# Data/Model Comparisons




Parameters for this family indicate:

- 2 MPa normal stress
- Narrow range in failure lengths (1-7.5 microns)
- Frictional resistance is 65% brittle



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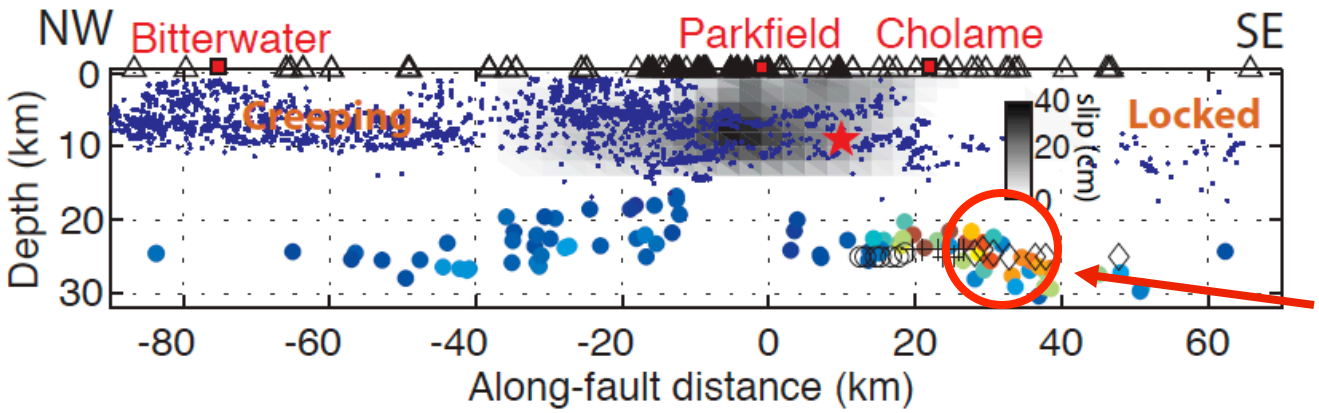
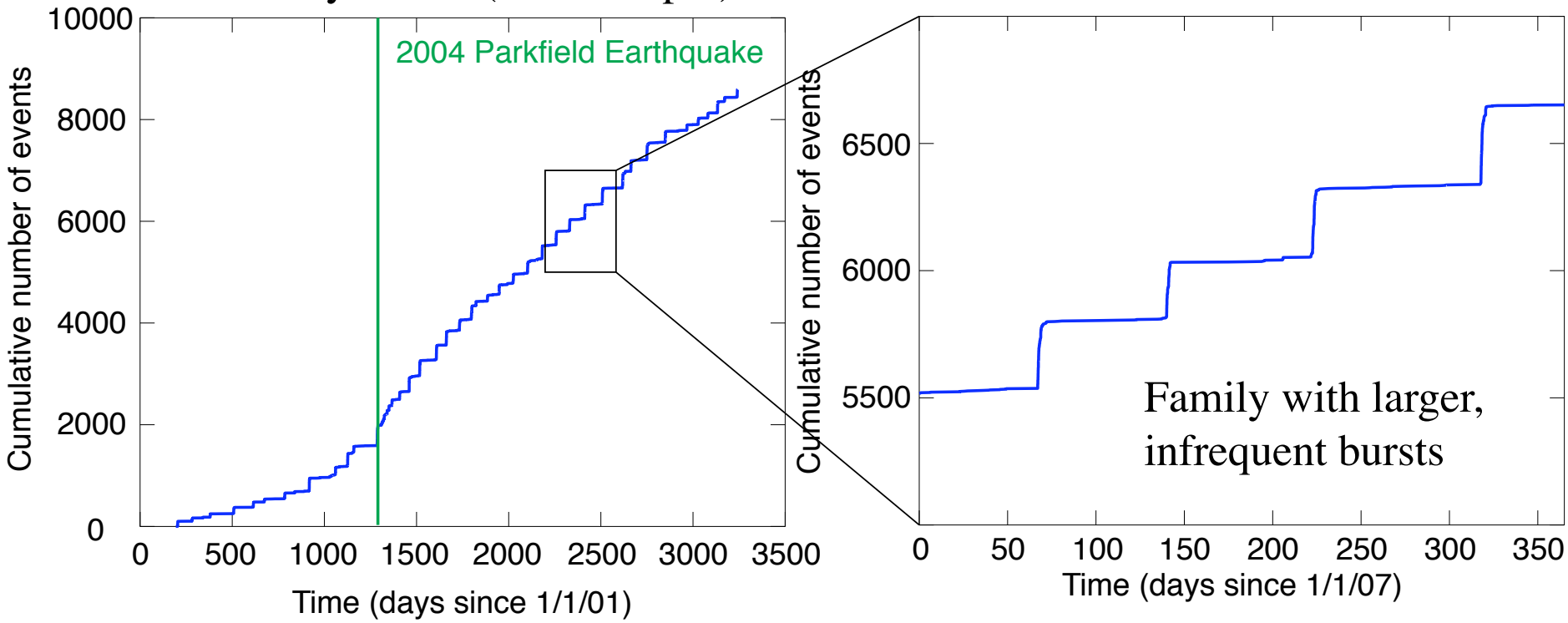



Next step: family with very different dynamics.

Also located in this area, but not as deep.

Examine heterogeneity of friction in the earth.

Family 68539 (21 km depth)

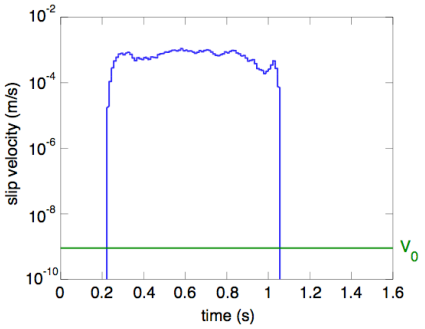


# Model Dynamics

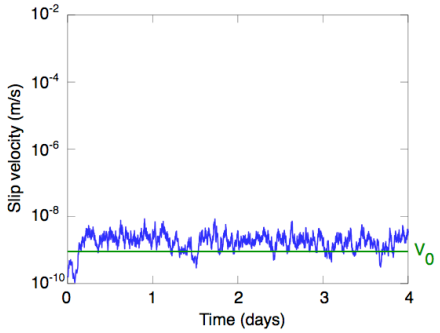
(Daub et al., GRL, in press)

Can we say anything more general about the dynamics?

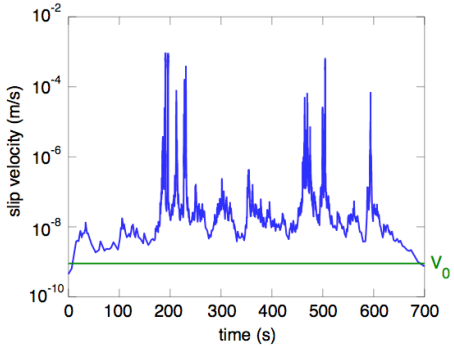
Vary brittle/ductile strengths to see type of resulting dynamics:



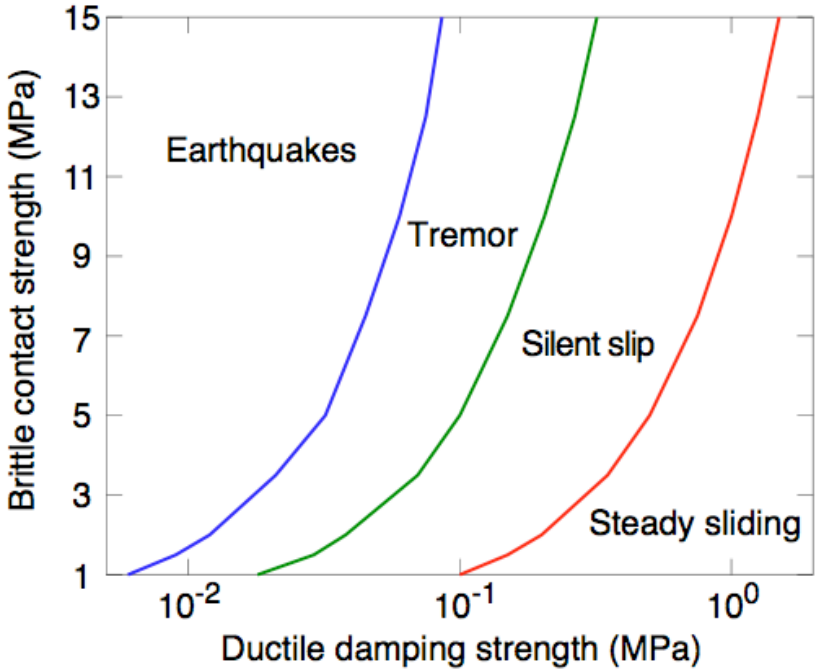

Earthquake

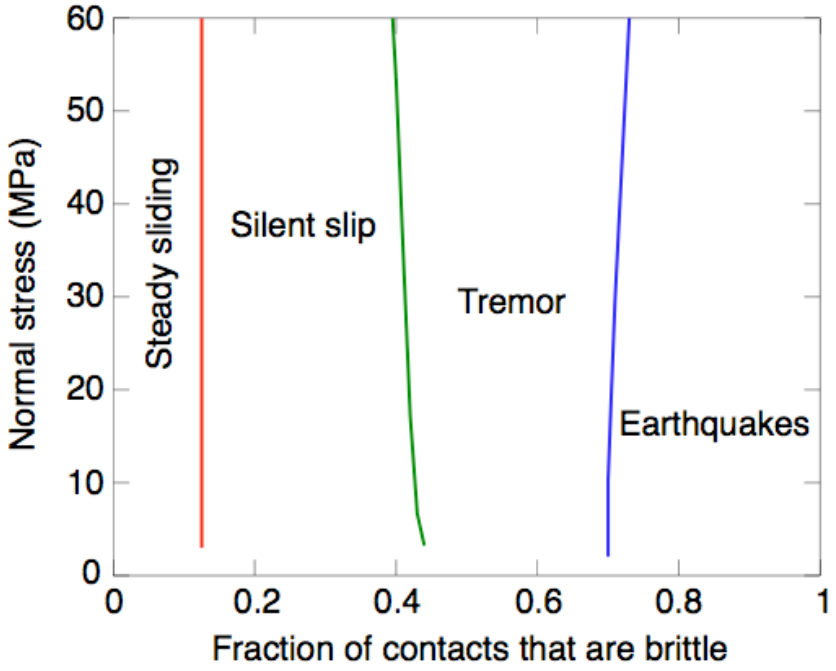



Steady sliding




Tremor (high slip rate)
Silent slip (low slip rate)



# Recap

- Brittle-Ductile friction produces tremor events rather than earthquakes
- Observations at Parkfield constrain friction, indicate low normal stress and short frictional length scales
- Ratio of brittle to ductile strength most important parameter in determining type of dynamics that occur