# The Evolution of Regional Seismicity Between Large Earthquakes


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&

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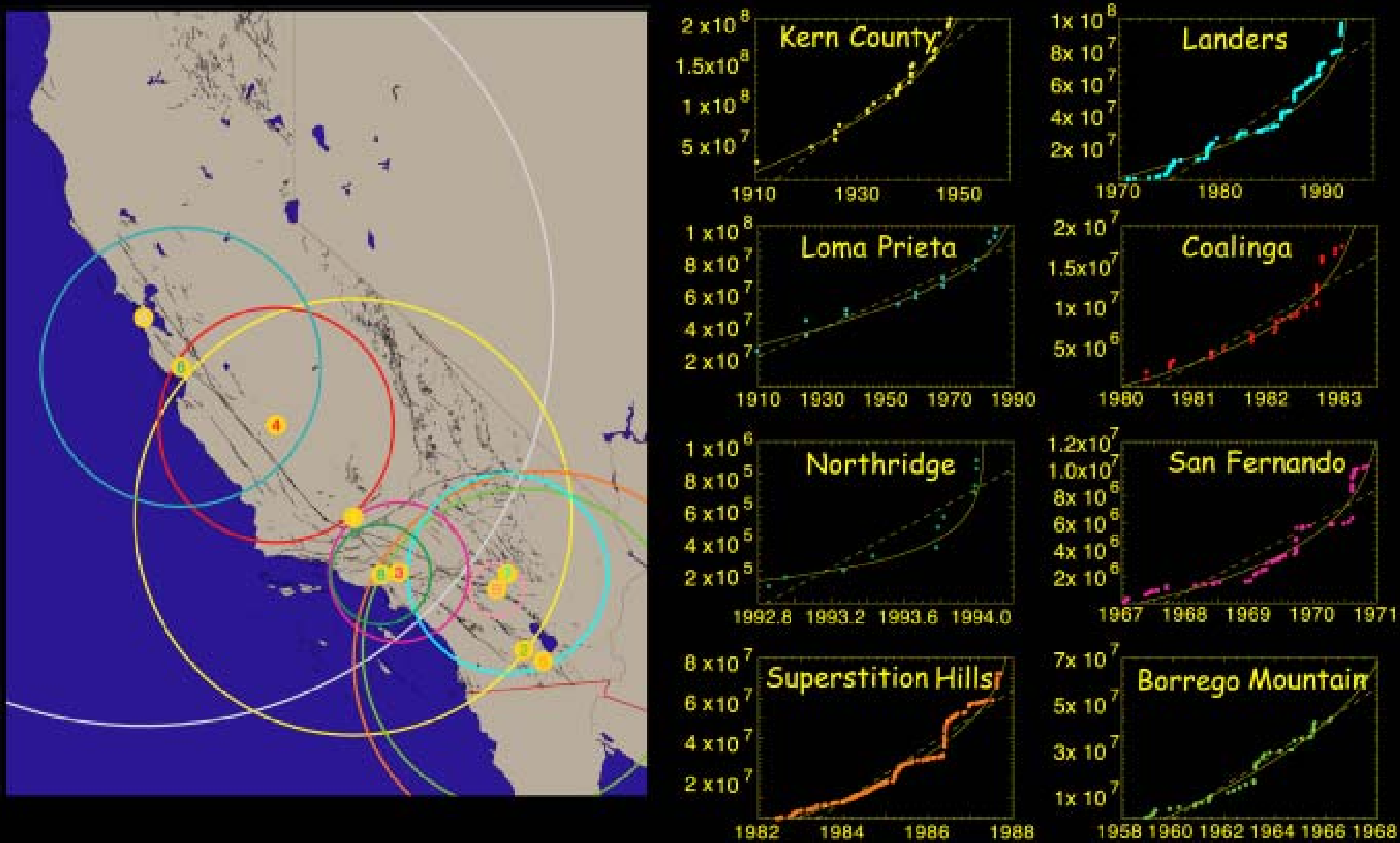
From *Sykes and Jaumé [1990]*

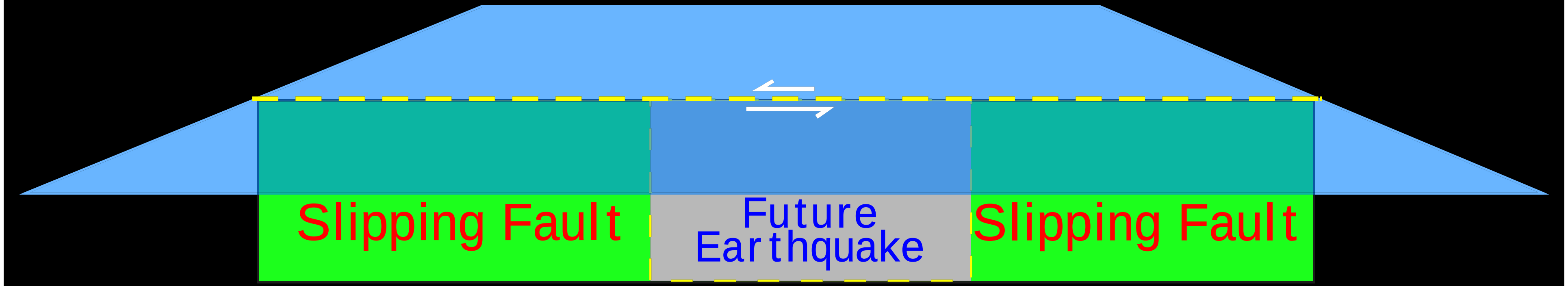
# All California Earthquakes M≥6.5
# 1950-1995




**From *Bowman et al.*, JGR, 1998**

# Stress Change From Loading a Locked Patch on a Simple Fault

Calculate from motion on all adjacent faults
plus creep at depth



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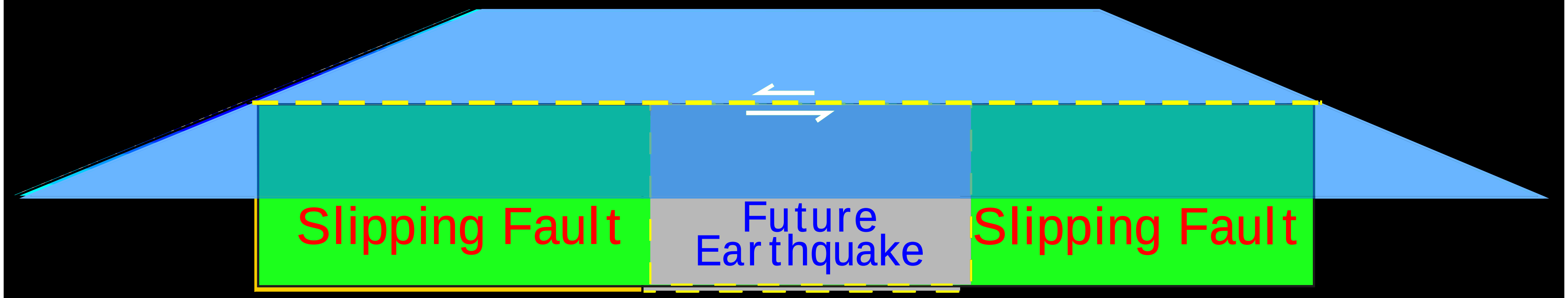

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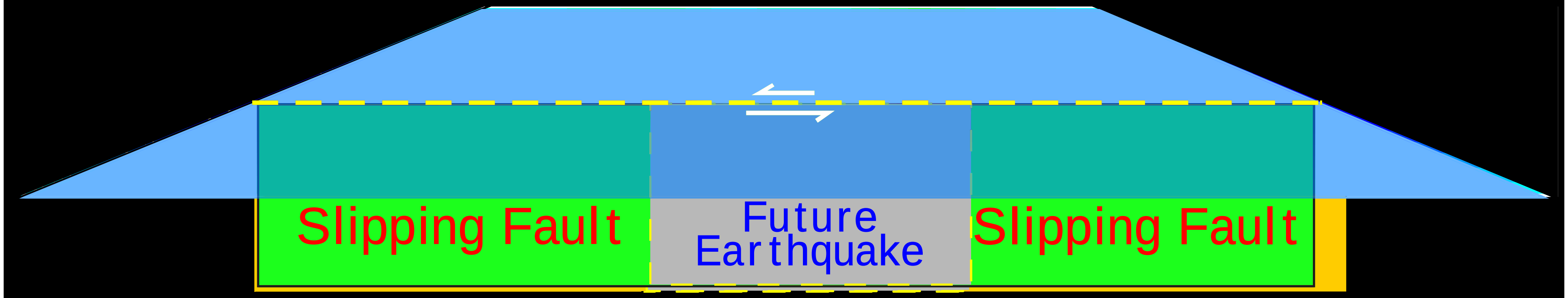

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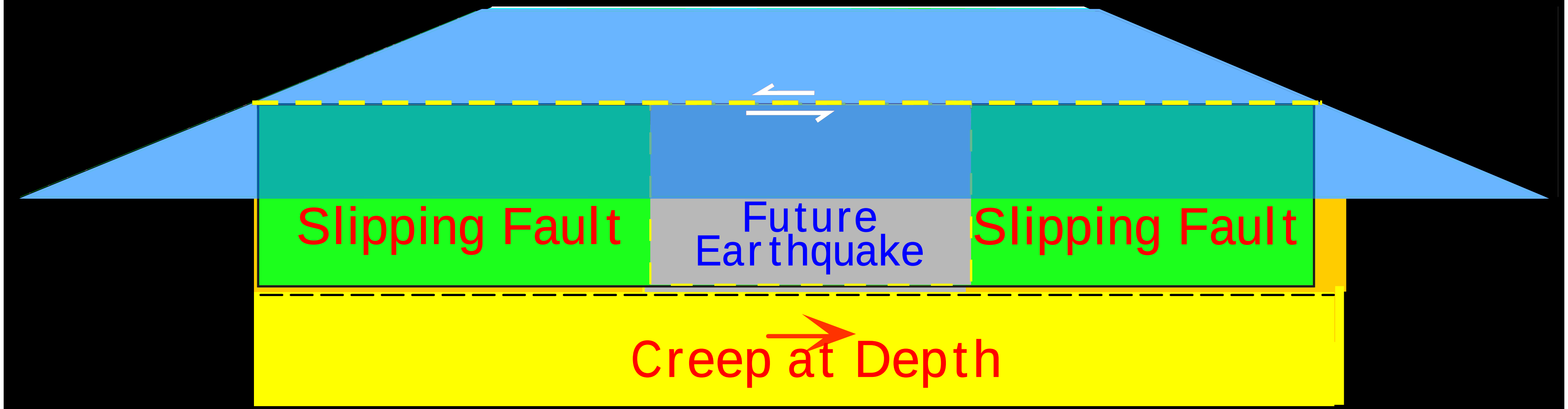
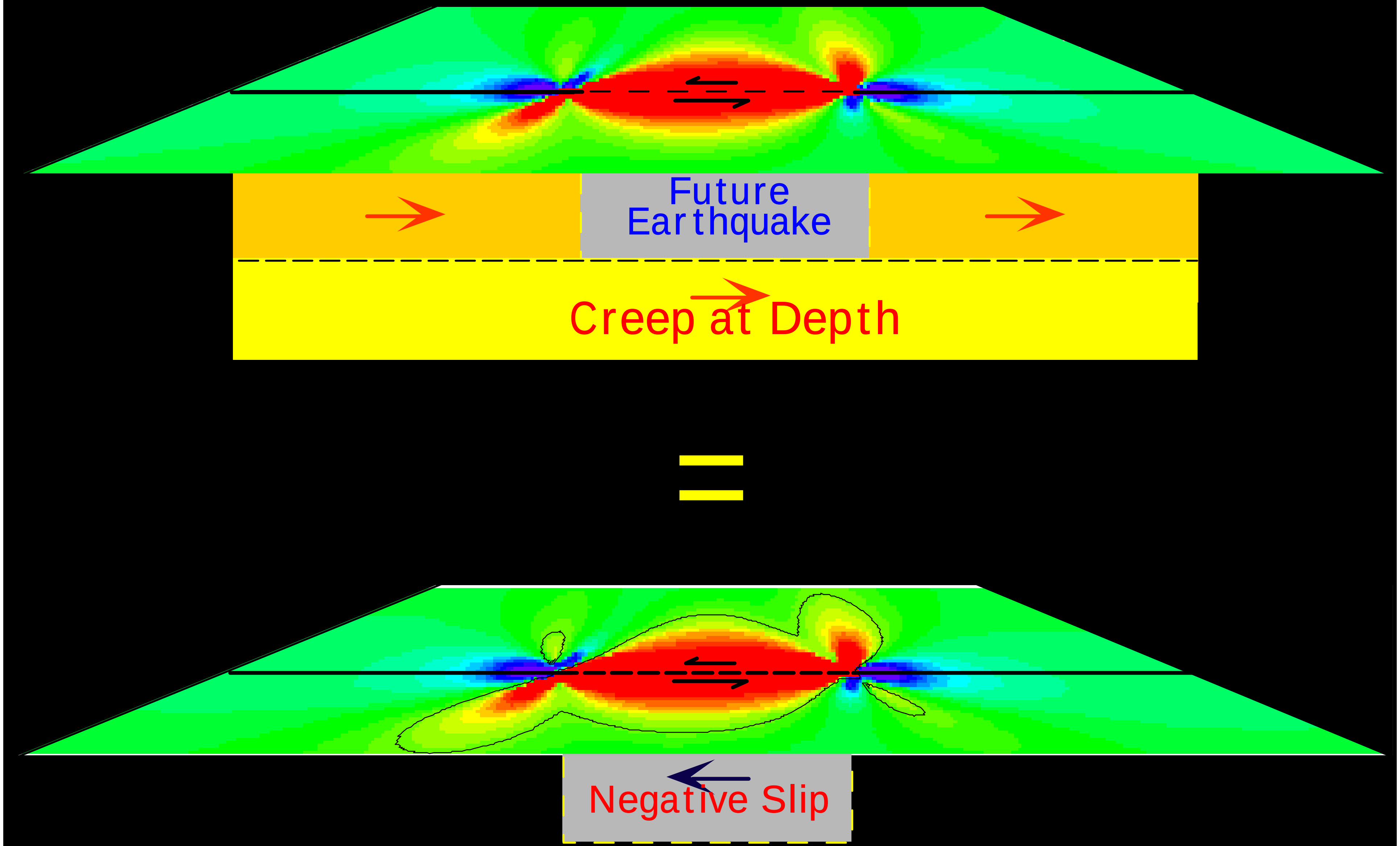
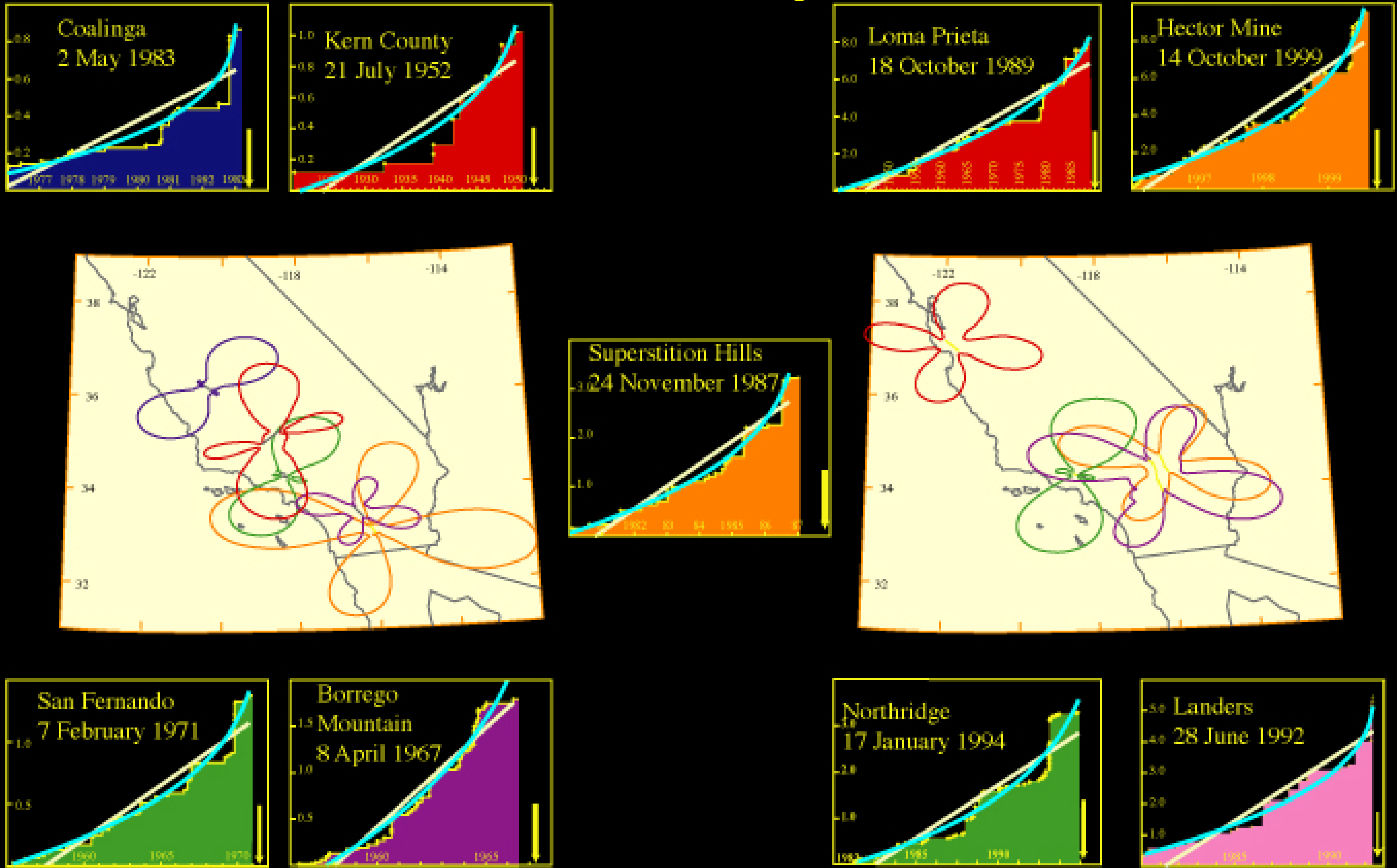


# Where are pre-earthquake stresses?



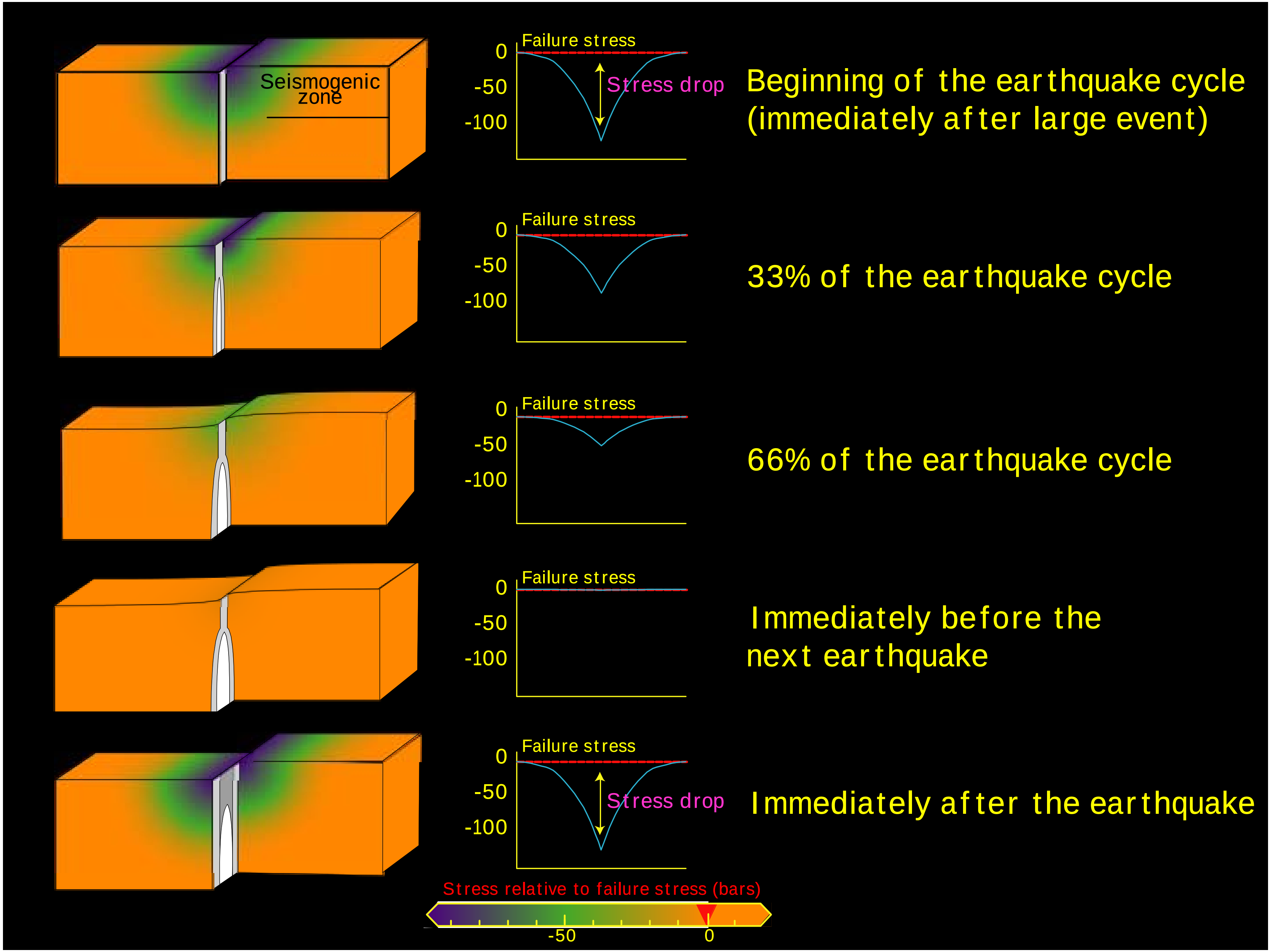
# Accelerating Seismicity in Stress Accumulation Regions

**From *Bowman and King*, GRL, 2001**



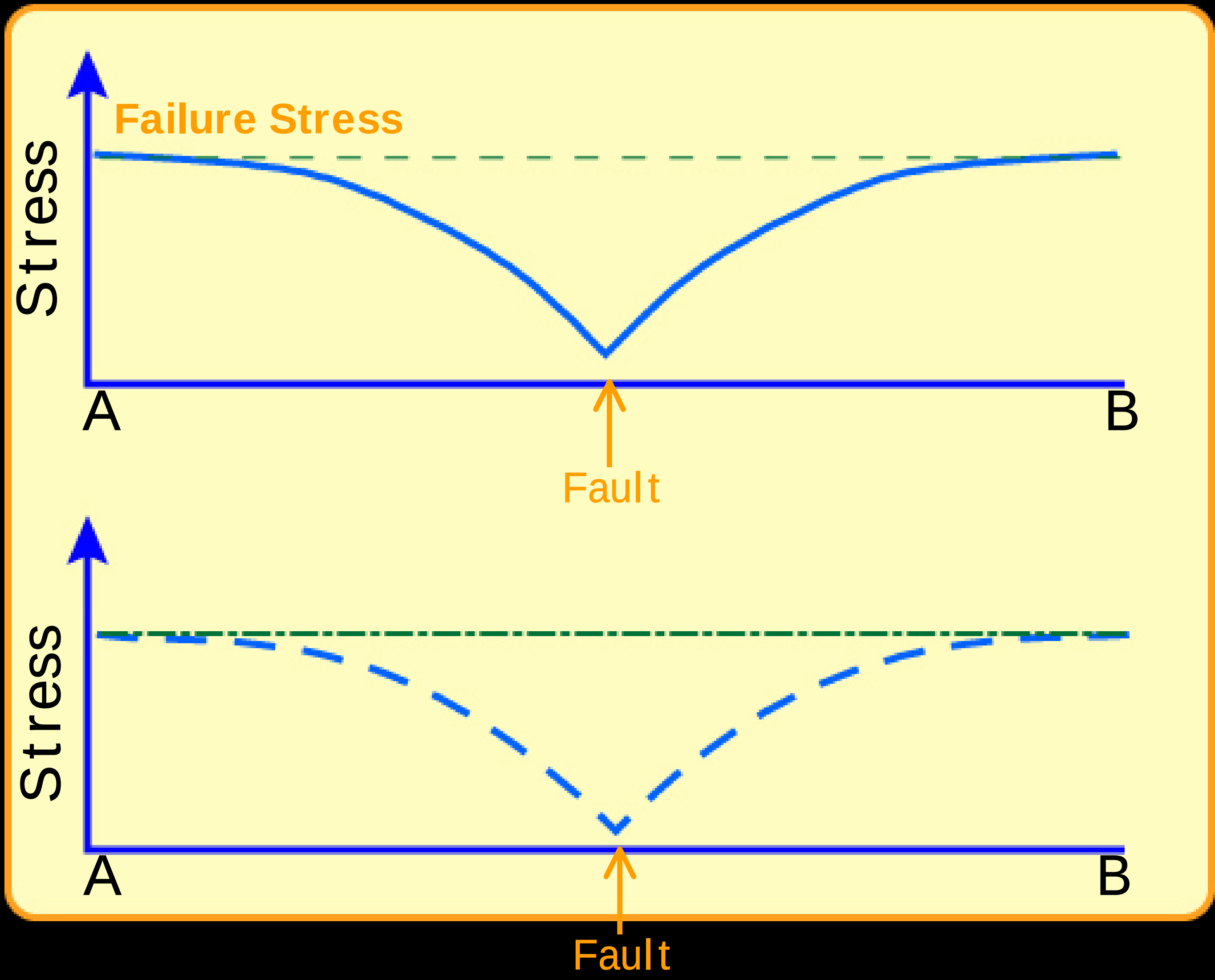
# A Simple Numerical Model

- **Based on loading of fault in interseismic period**
- **Using realistic stress transfer**
- **Taking into account tectonic history**
- **Want to produce accelerating moment release**
  ***over a broad region***



Seismogenic zone
Failure stress
0
-50
-100
Stress drop
Beginning of the earthquake cycle (immediately after large event)
33% of the earthquake cycle
66% of the earthquake cycle
Immediately before the next earthquake
Immediately after the earthquake
Stress relative to failure stress (bars)
-50
0

# An earthquake occurs when stress rises above the failure level



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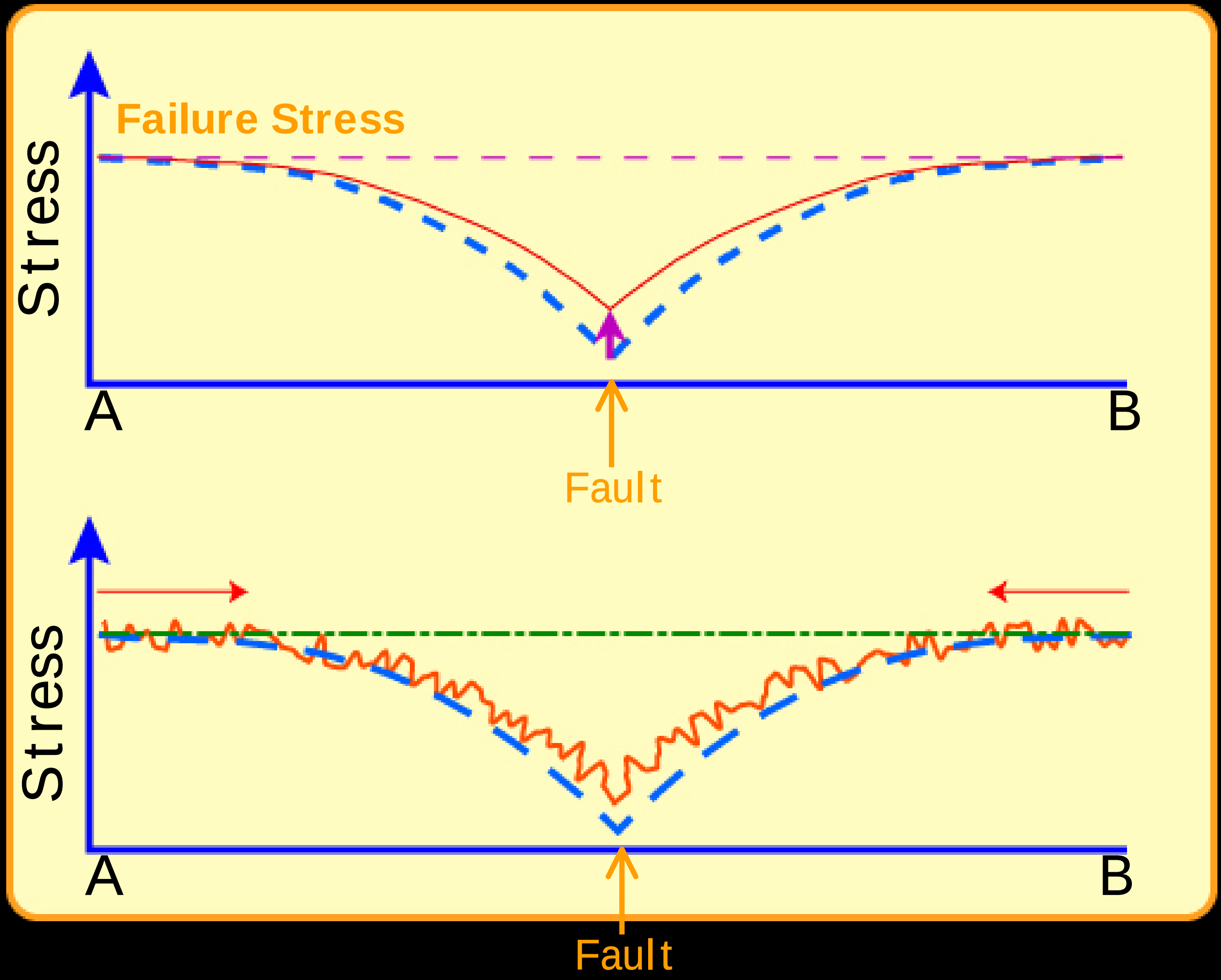

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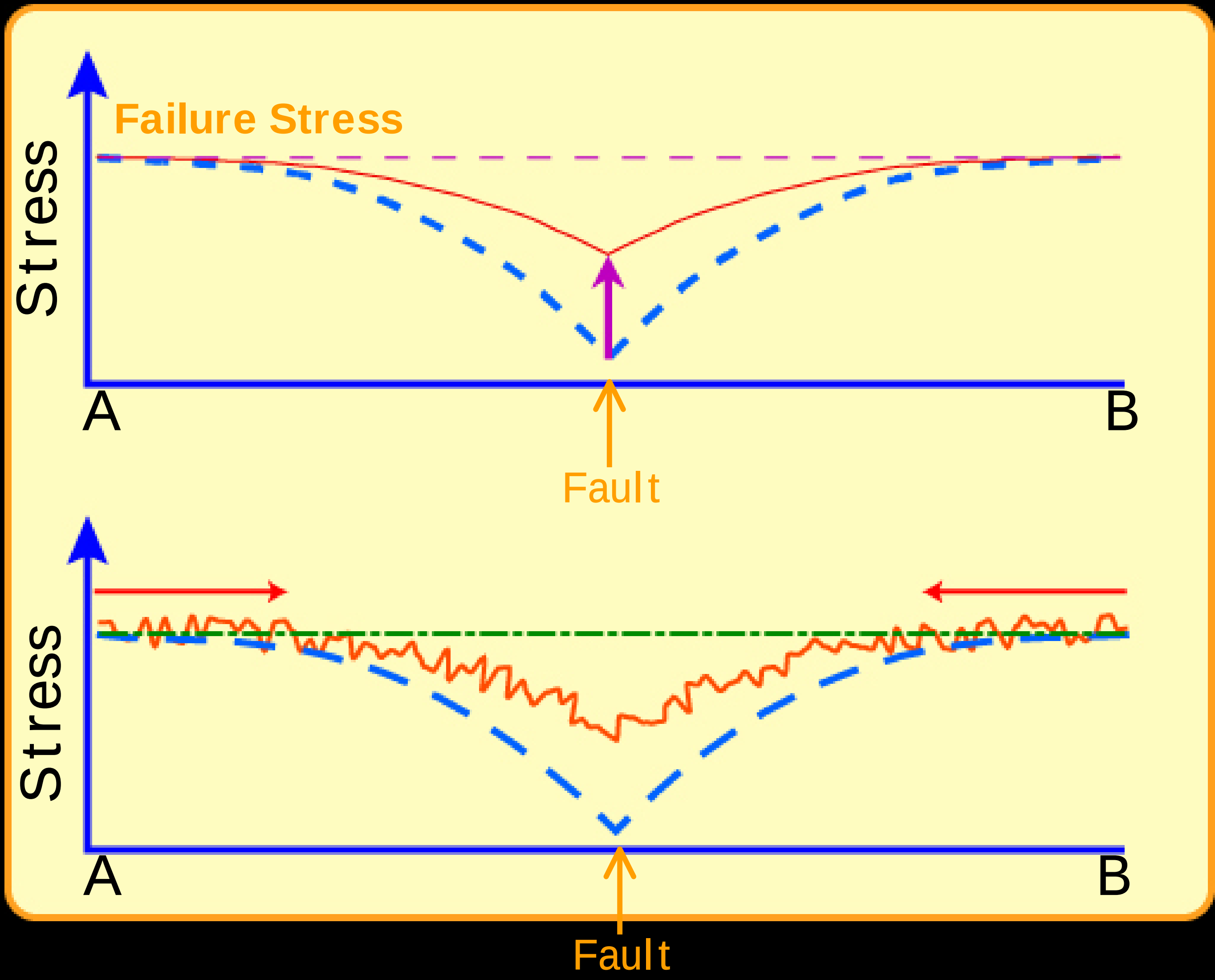

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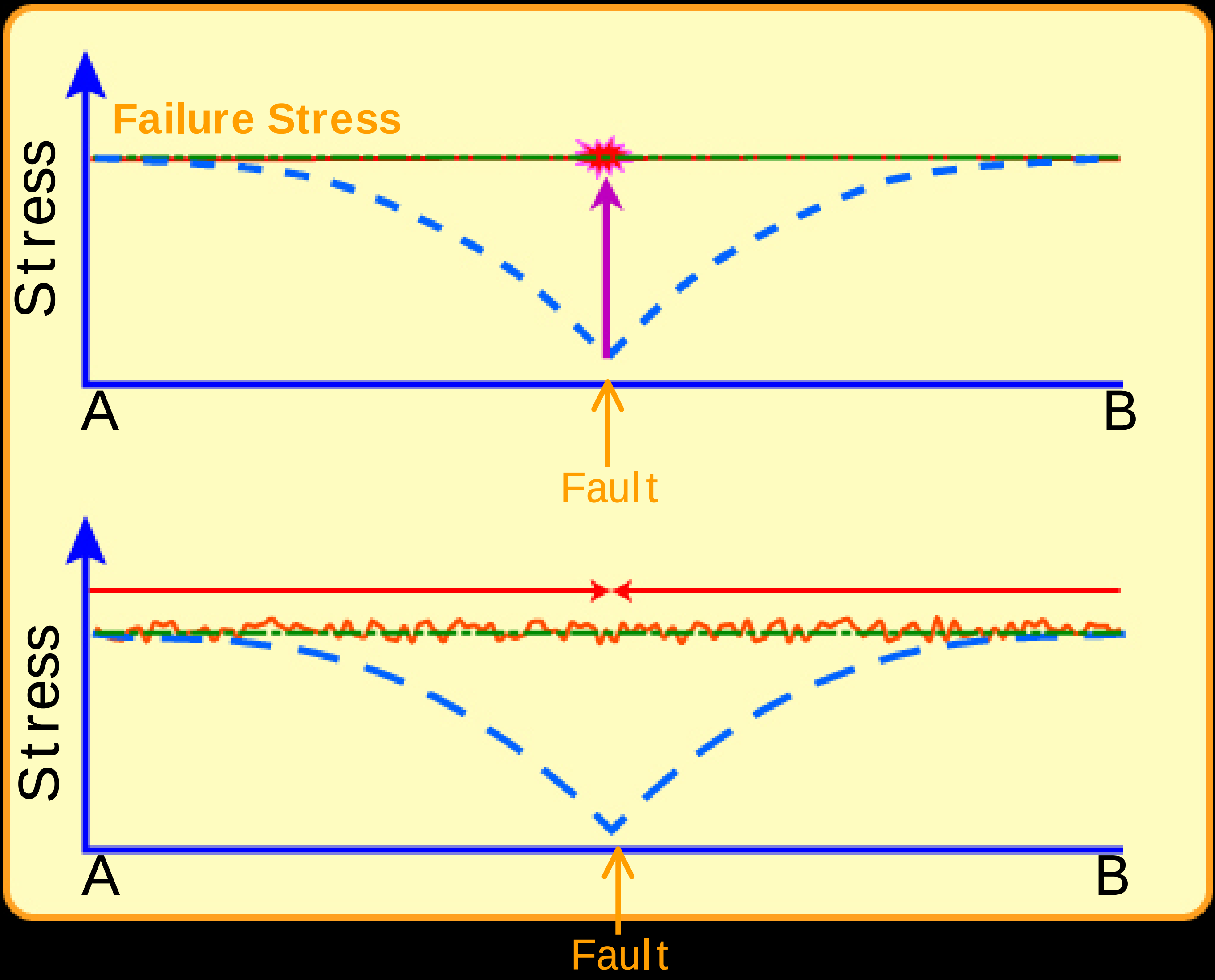


# Seismicity in the Earthquake Cycle

Start of the Earthquake Cycle

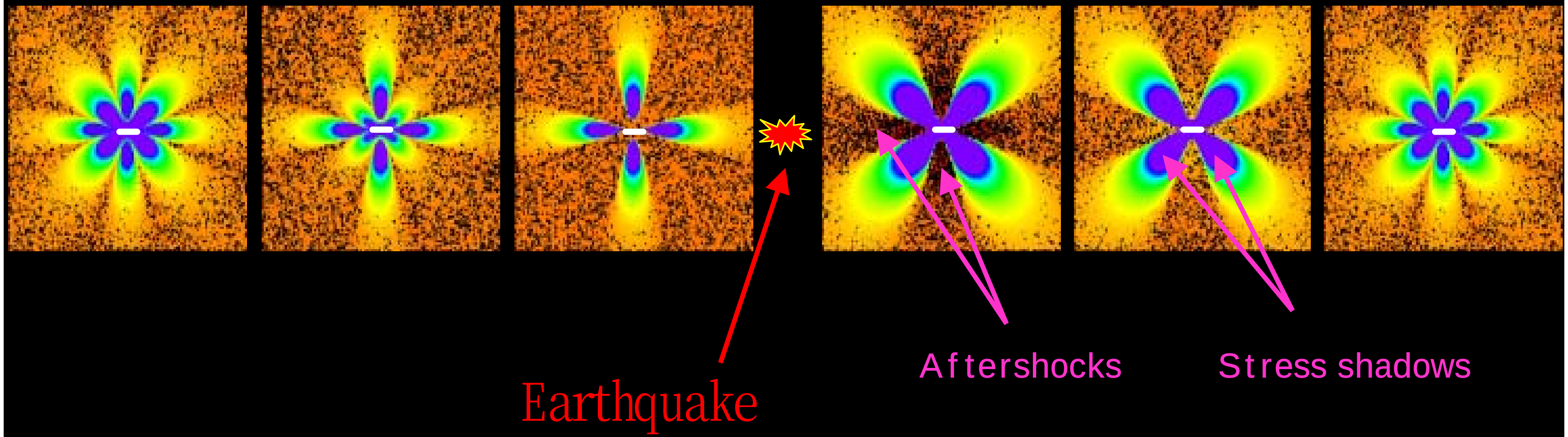
Approaching the Earthquake

Immediately before the Earthquake

Immediately after the Earthquake

75% of the Earthquake

The end of the Earthquake cycle



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- Evolution of the frequency-magnitude statistics (Gutenberg-Richter relation)

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    - Stationary (time-independent) *b*-value

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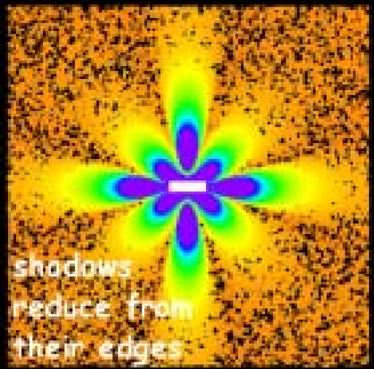
    - Stationary (time-independent) *b*-value

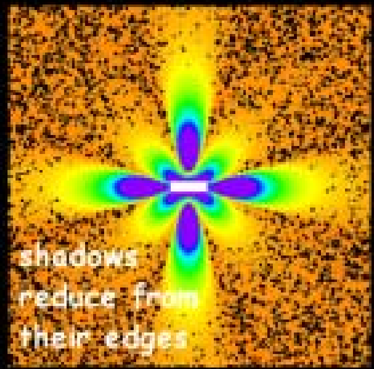
    - *a*-value increase before a large event and decreases after the event

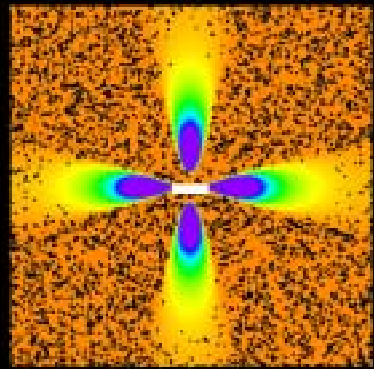
# Build-up to the Earthquake

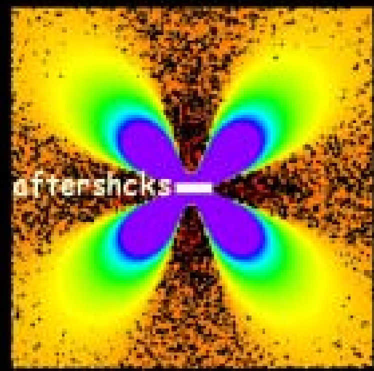
**Main Fault is Quiet**

Earthquake



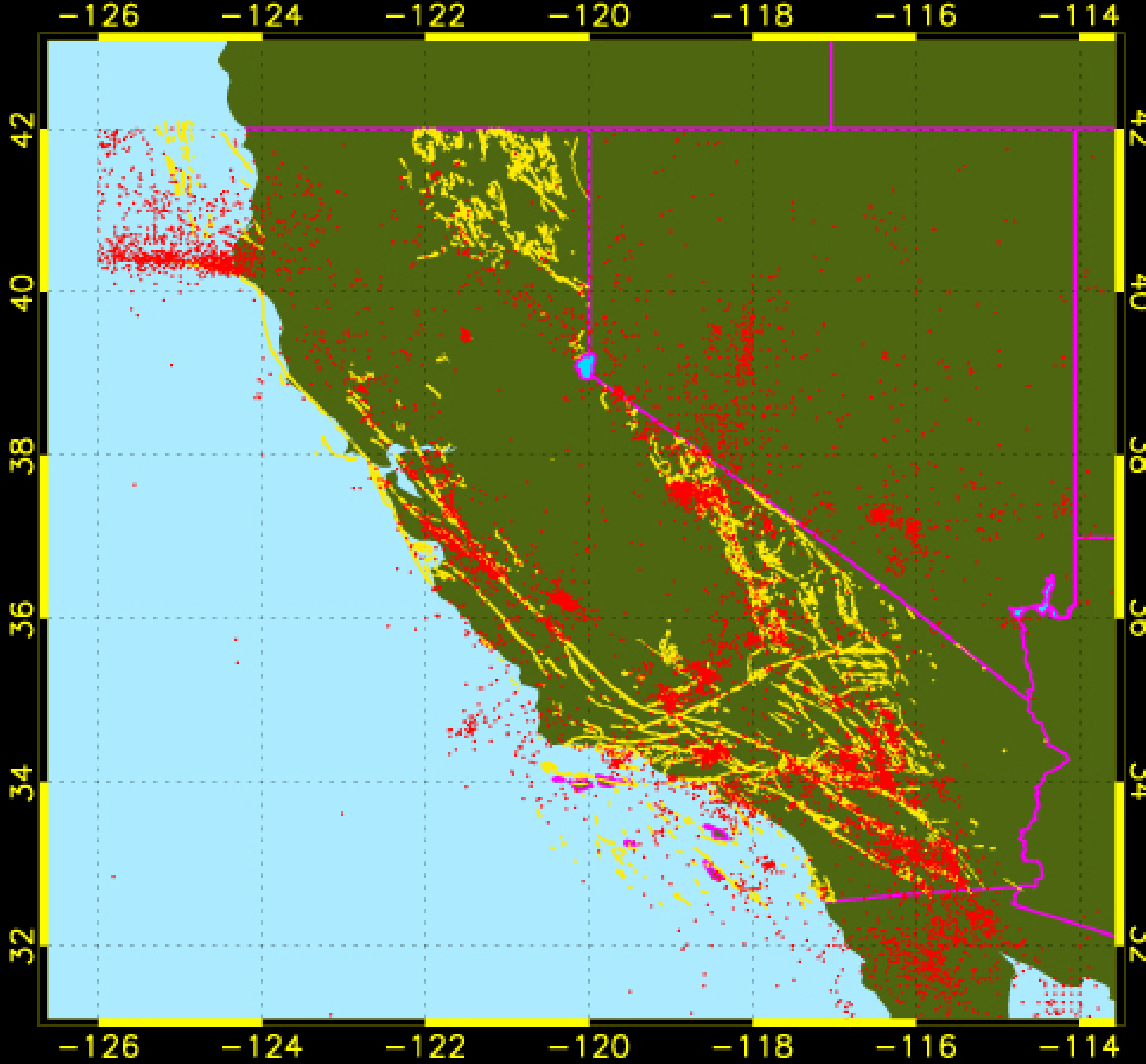



Late in the Earthquake cycle

Immediately before the earthquake

Immediately after the earthquake

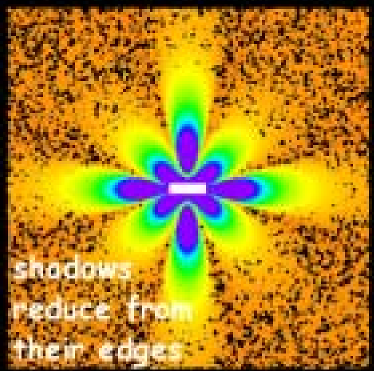
# California Seismicity 1912-2001 M>3.5

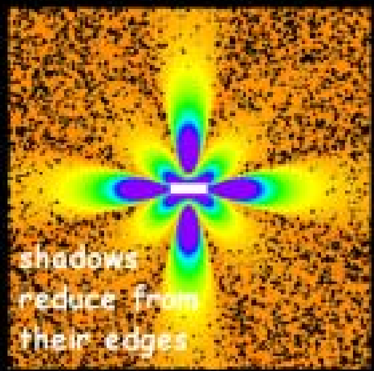


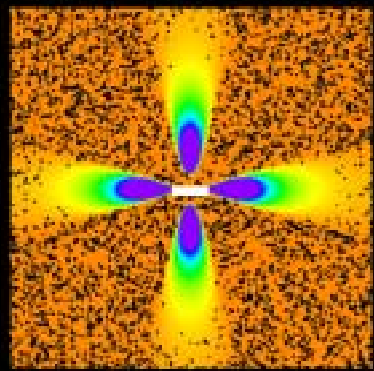
# Build-up to the Earthquake

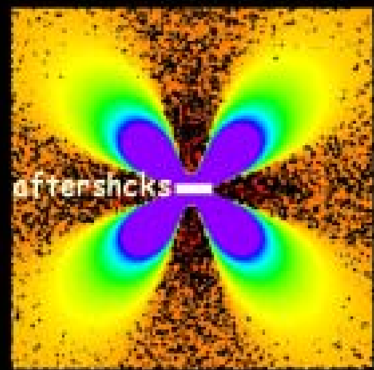
## Accelerating Moment Release

Earthquake



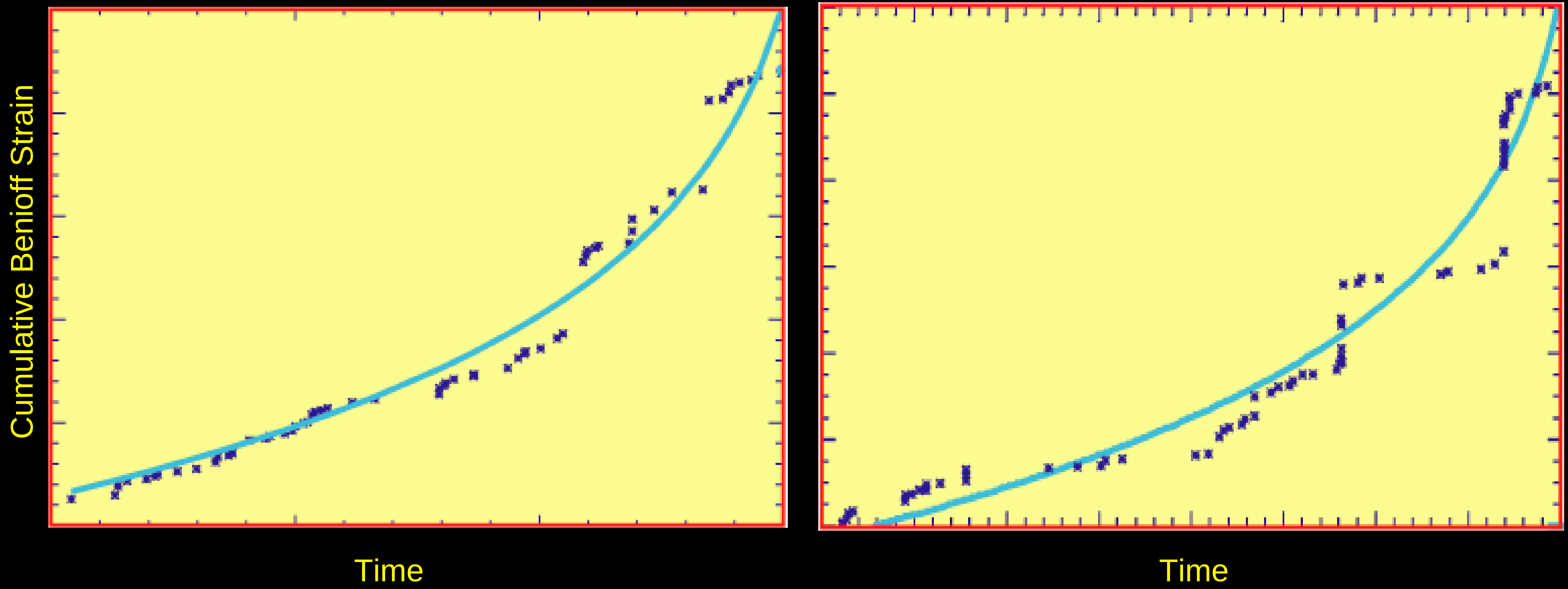



Late in the Earthquake cycle

Immediately before the earthquake

Immediately after the earthquake

## Which cumulative moment release curve is for a REAL seismicity sequence?



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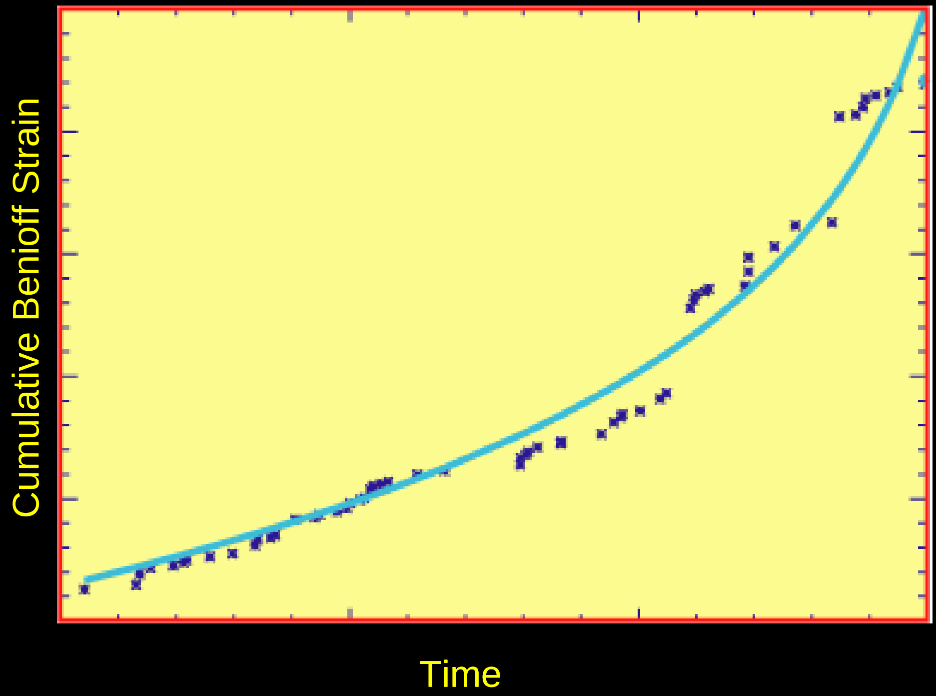
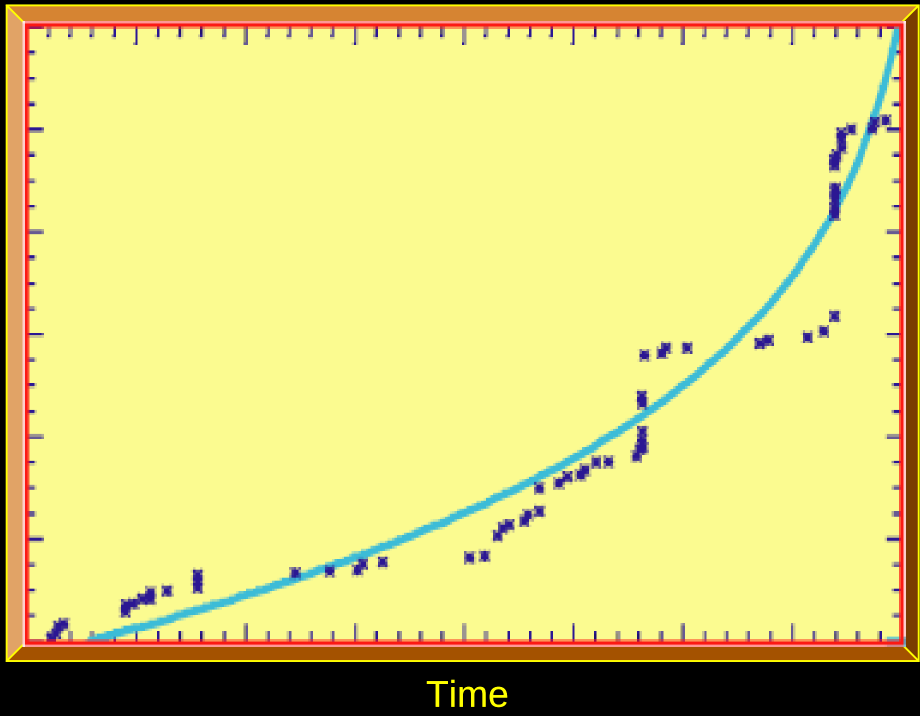
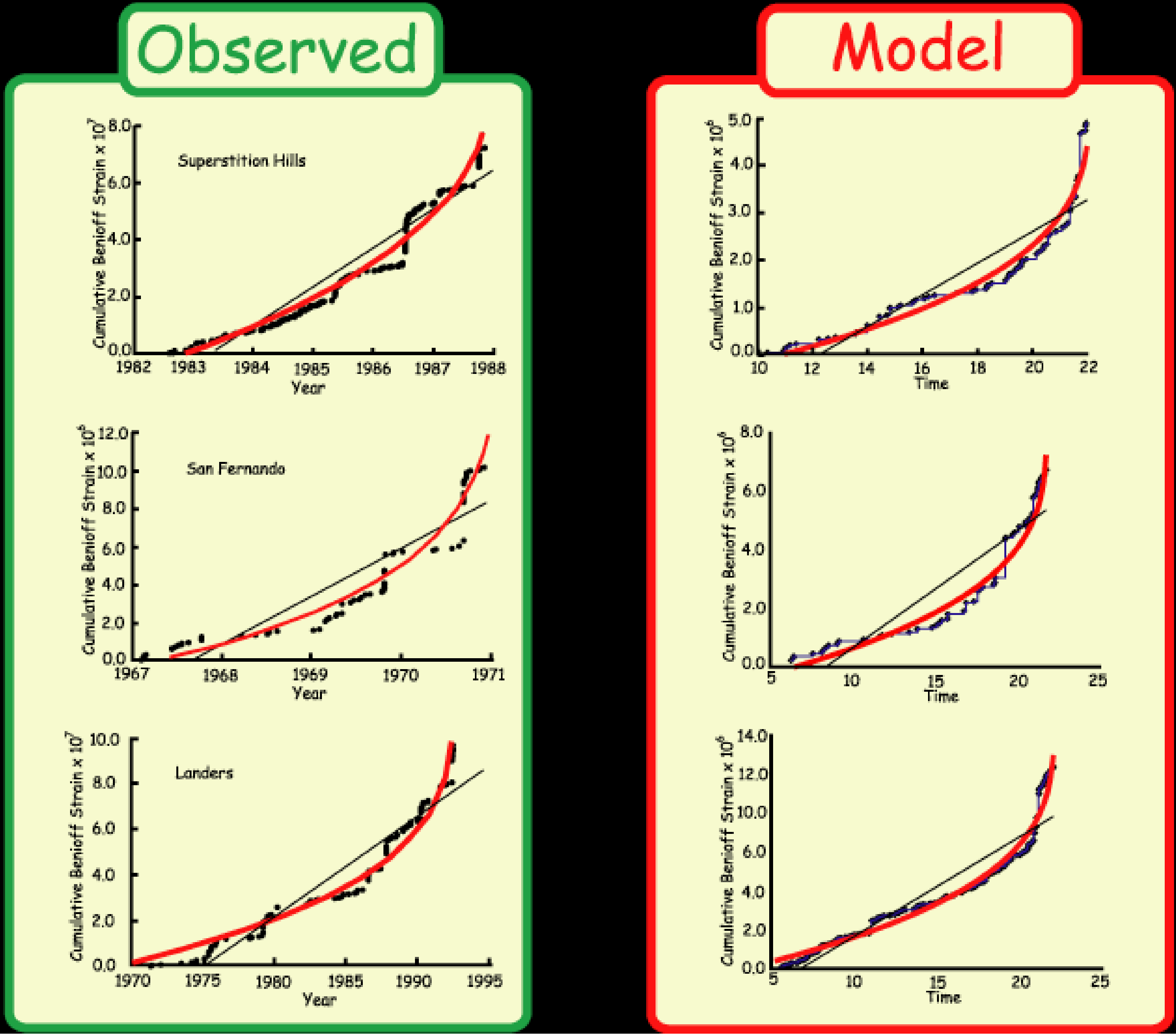



Model




San Fernando Earthquake

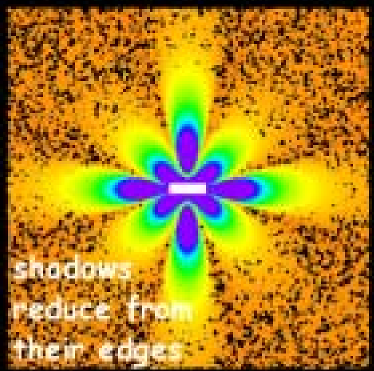
# Accelerating Seismicity

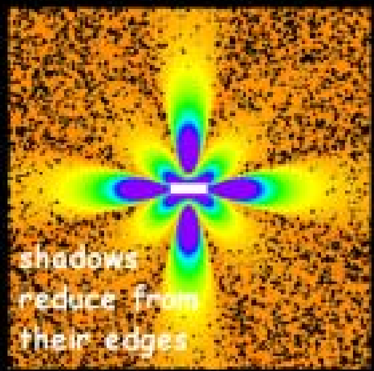


# Build-up to the Earthquake

**Evolution of Gutenberg-Richter Statistics**

Earthquake

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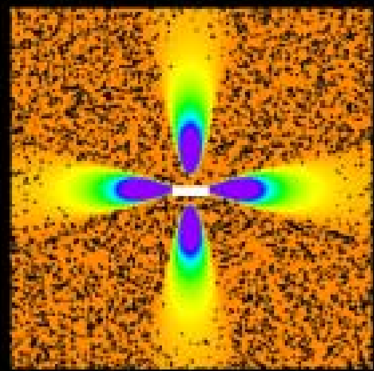


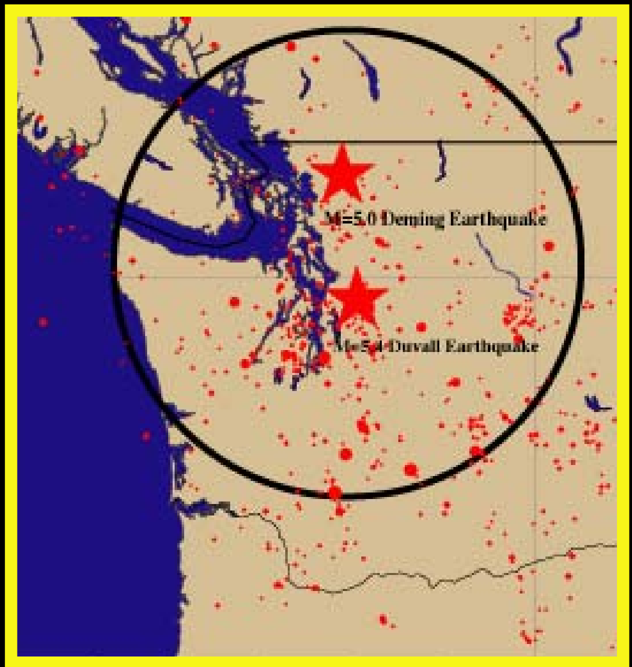
Immediately before the earthquake

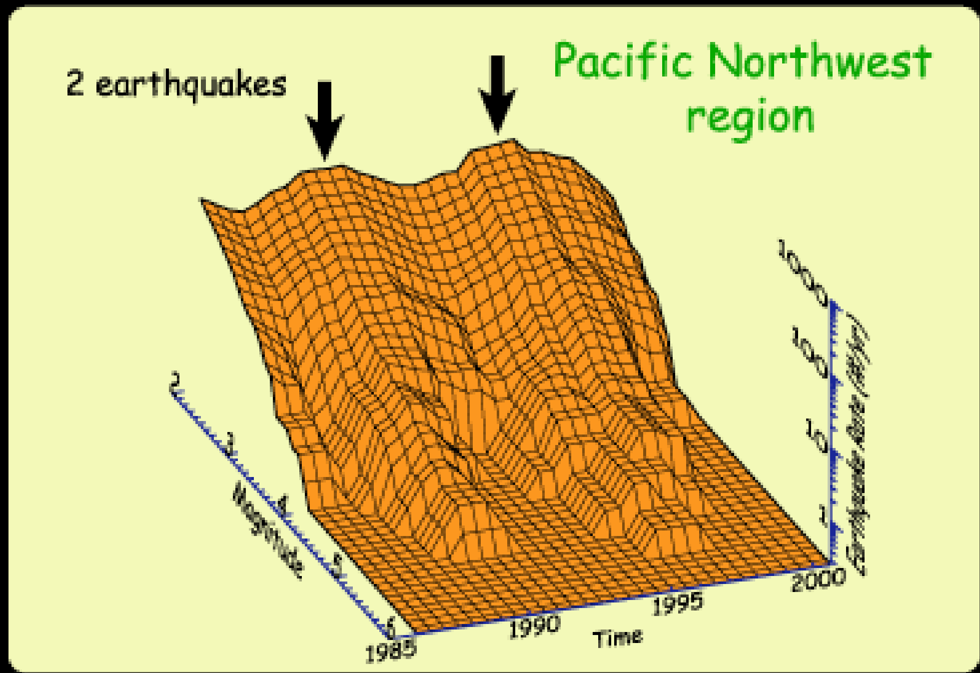

Immediately after the earthquake

# Seismicity in the Pacific Northwest

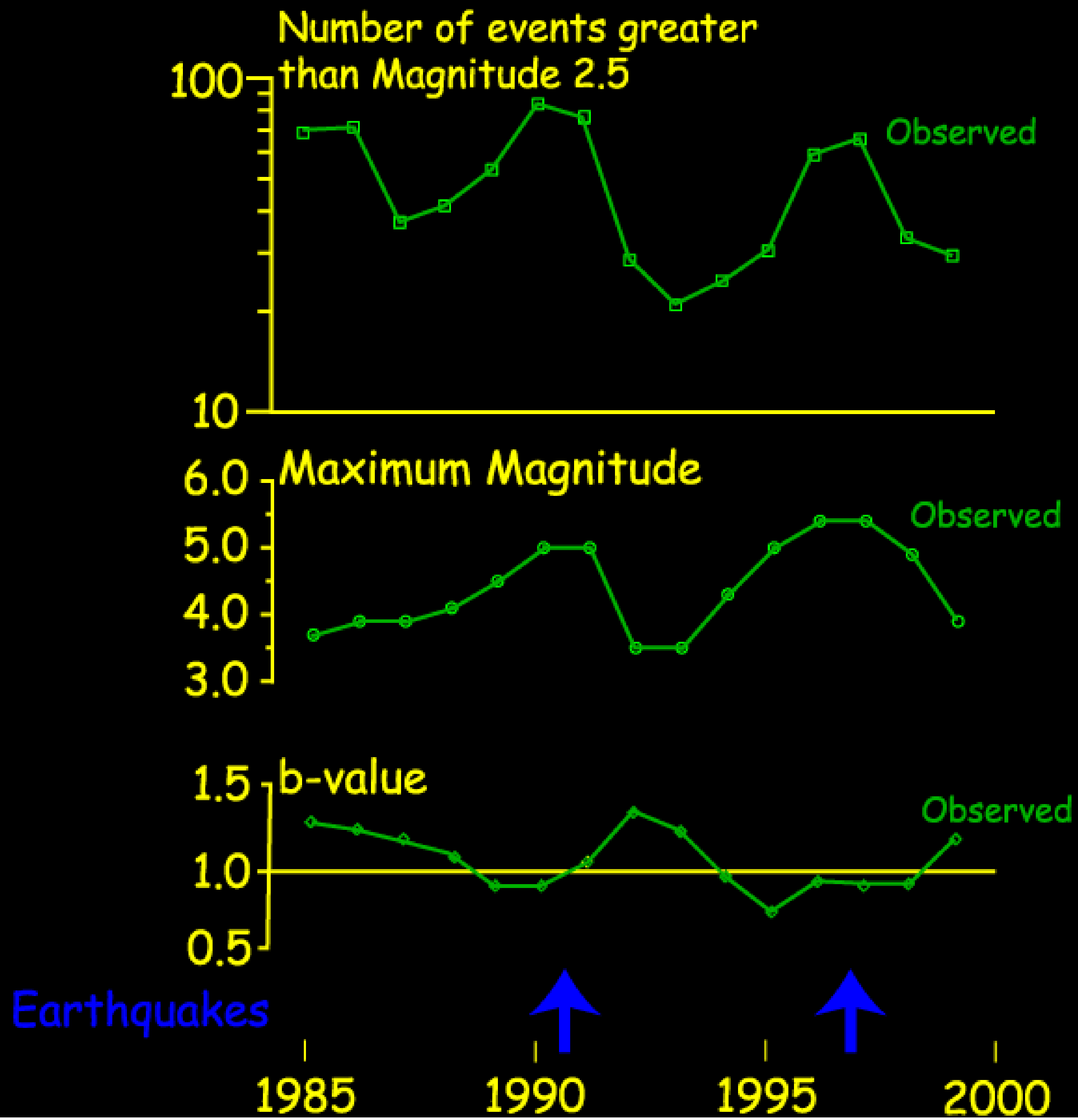
Two large nearby events show accelerating moment release

The regions overlap, approximating the evolution of the seismicity over 2.5 cycles

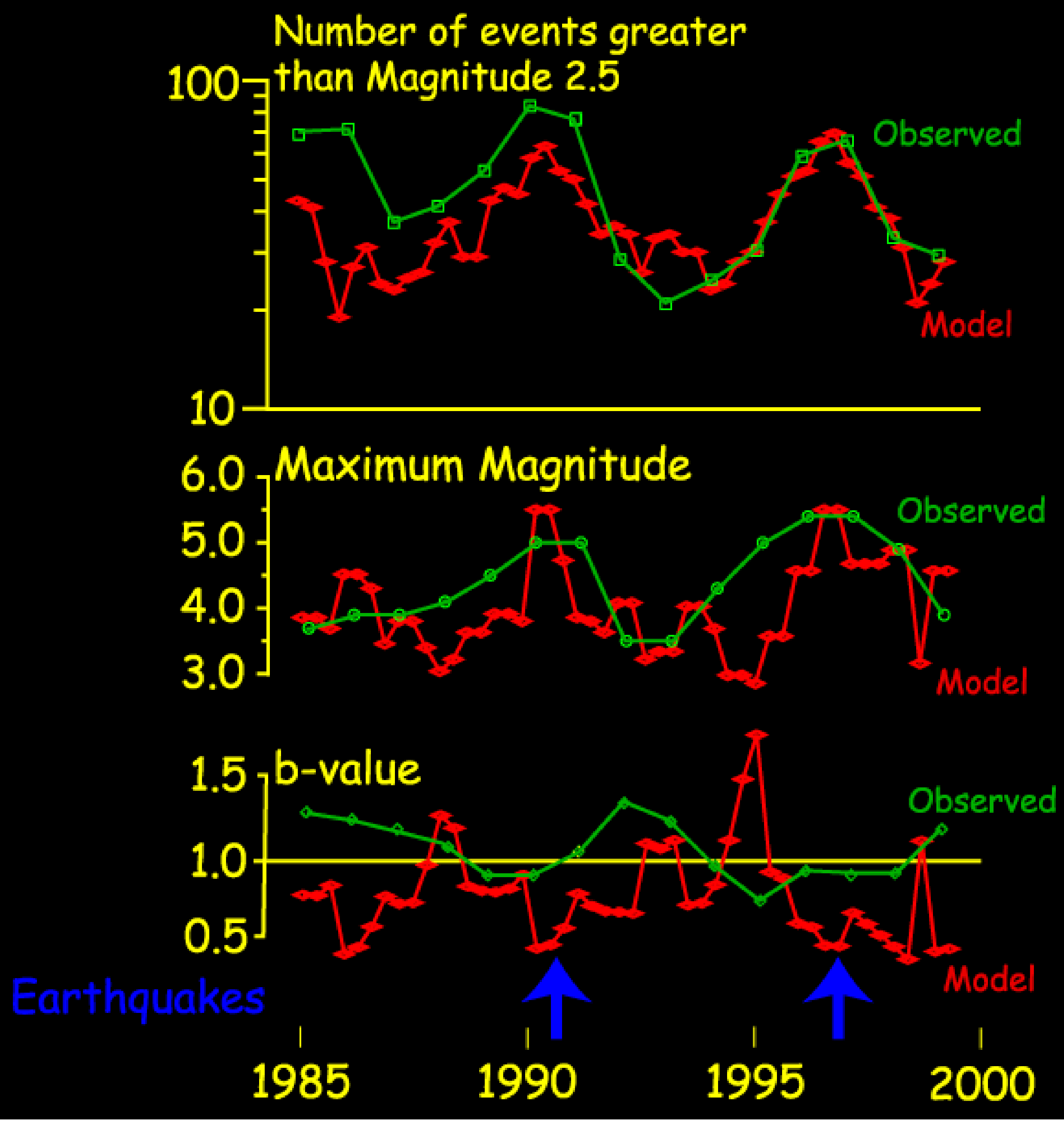


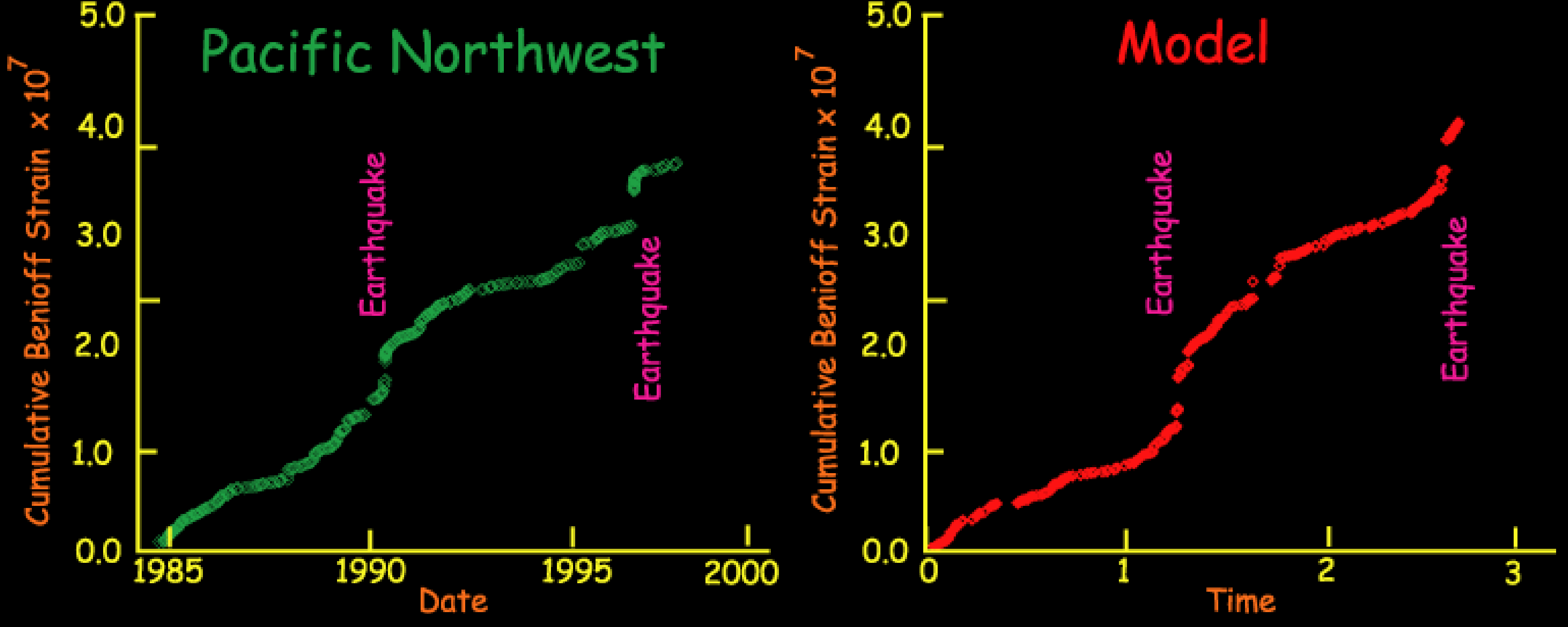
# Pacific Northwest Seismicity



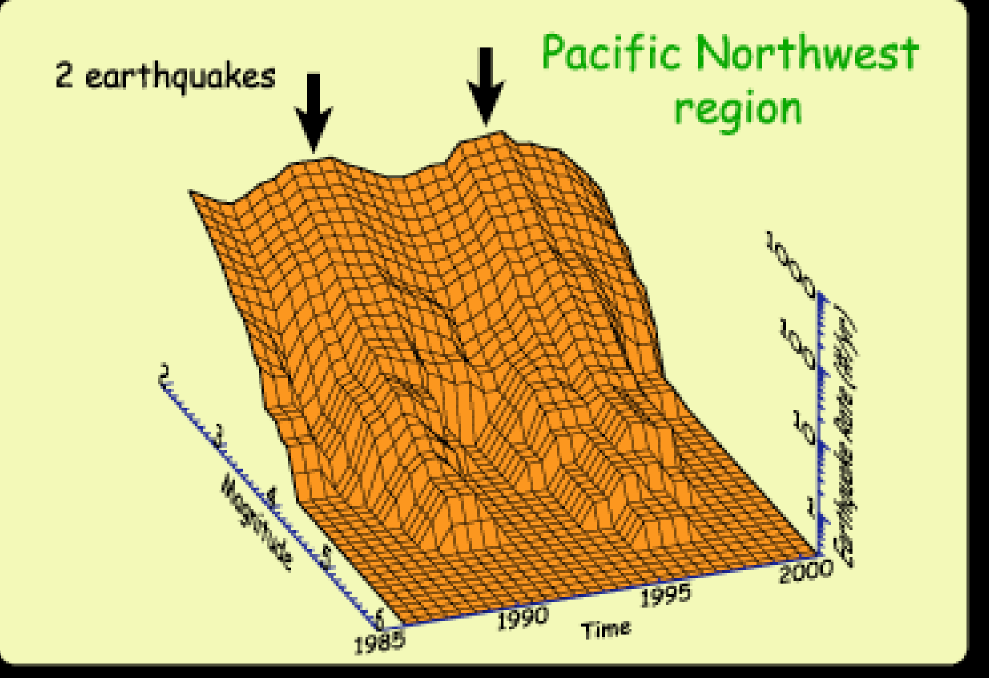
# Seismicity in the model & Pacific Northwest



# Cumulative Benioff Strain



# Evolution of the frequency-magnitude statistics



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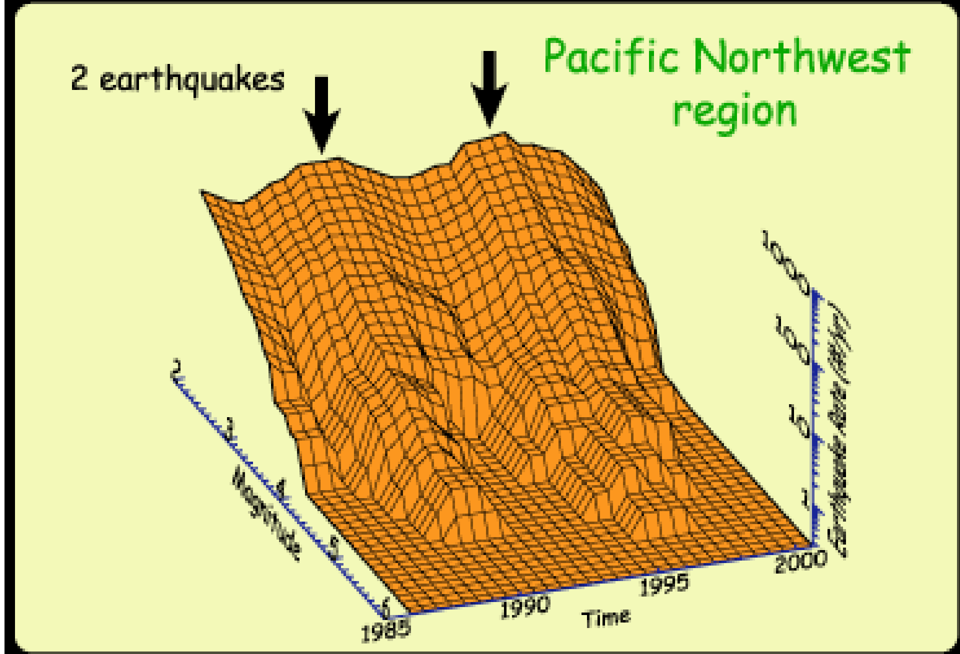
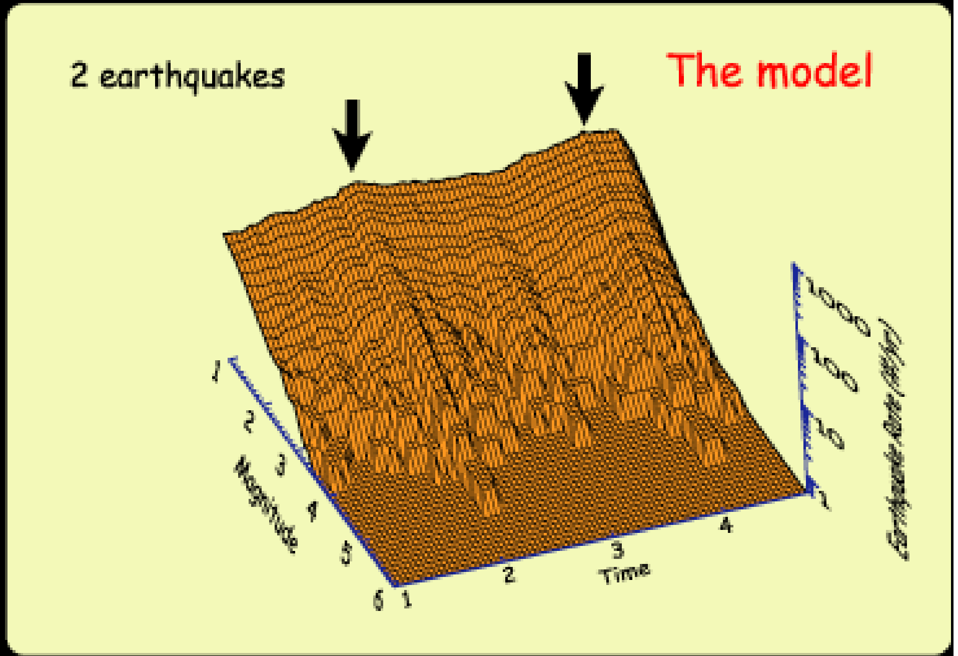


## Looking Forward:

- Better calculation of the "noise" functions
  - incorporate stress transfer for background EQs?

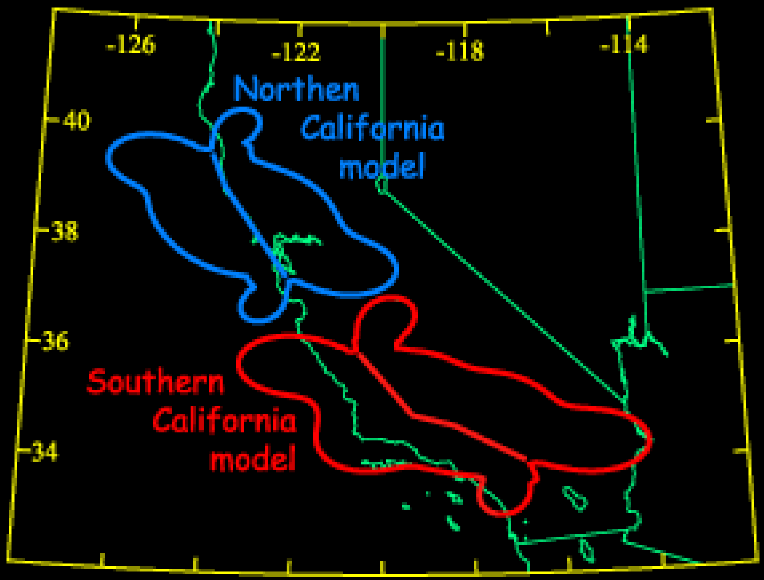
- More complex fault geometries
  - simulate real fault networks

- Additional Testing on real data
  - Test on earthquakes from other regions
    (Greece, Turkey, China, etc)
  - False alarm rate?

- Relationship to Time-Dependent Hazard Analysis

**Pre/re-prints available at:**
**http://geology.fullerton.edu/faculty/dbowman**

# Future California Earthquakes?



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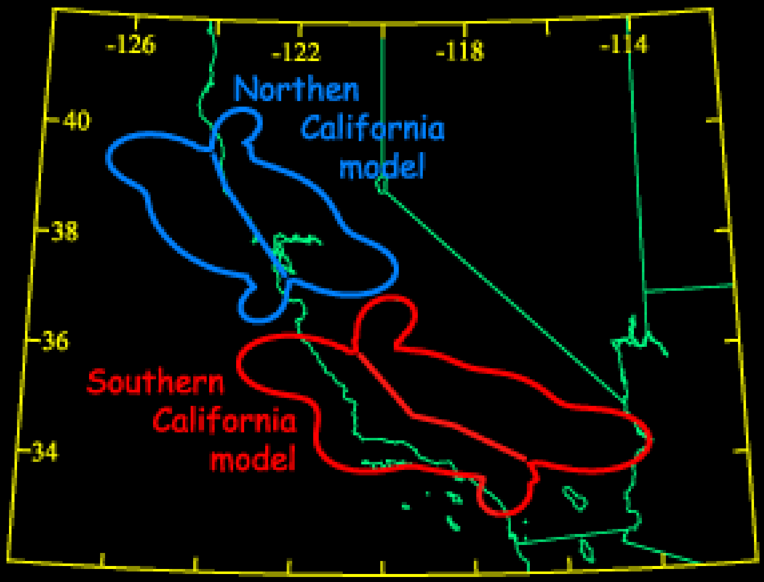


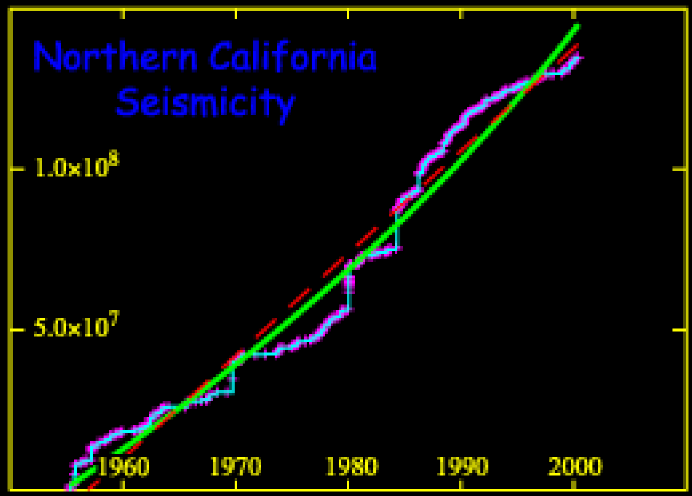

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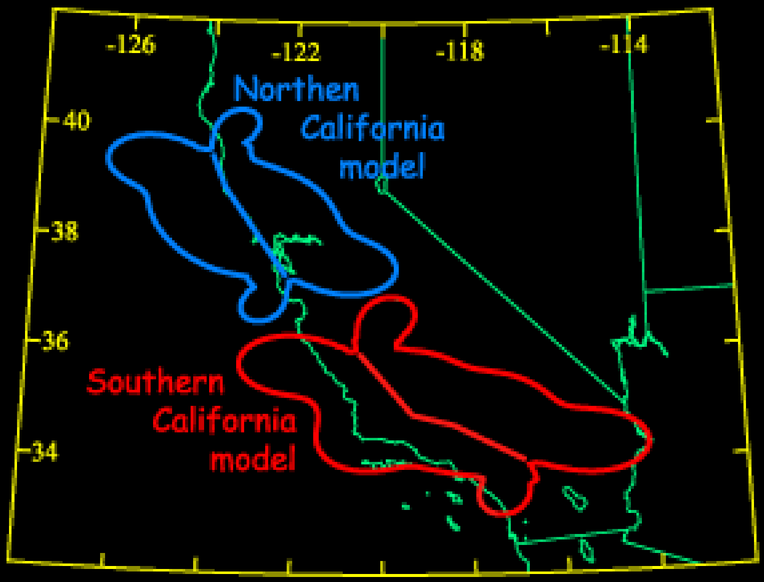


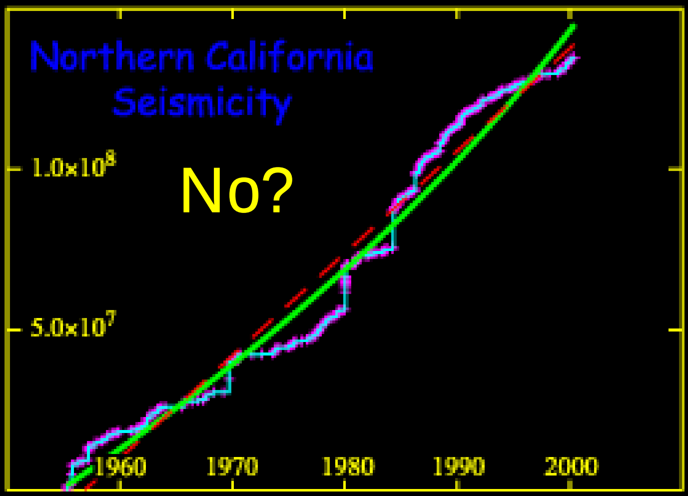

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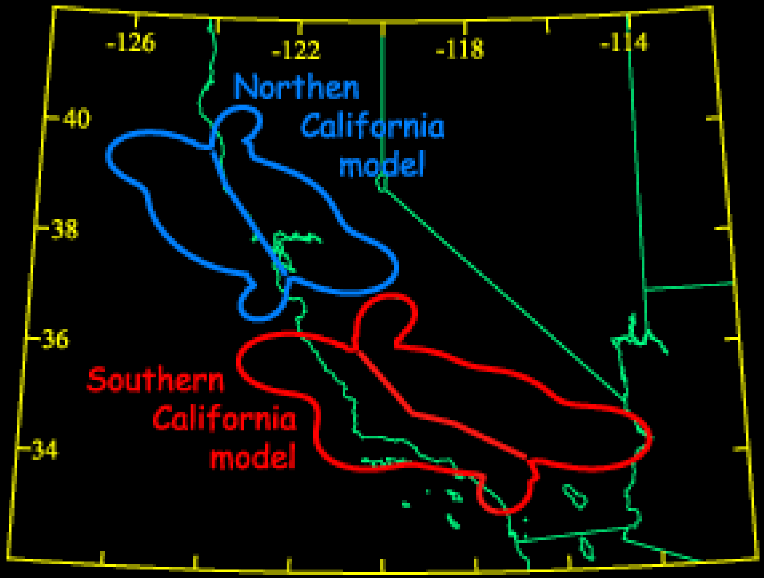


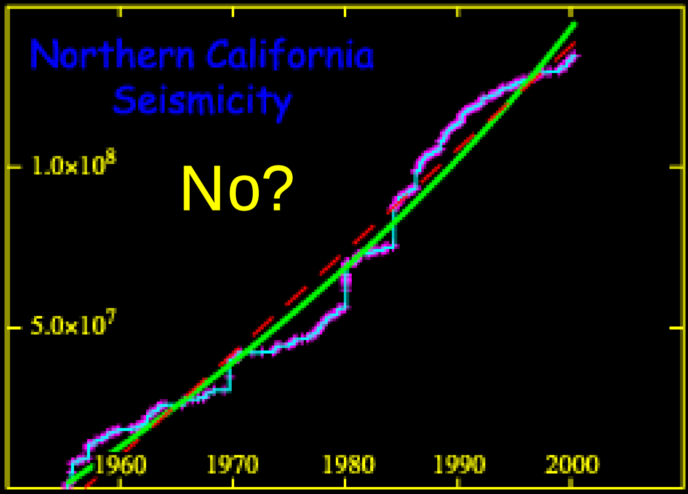


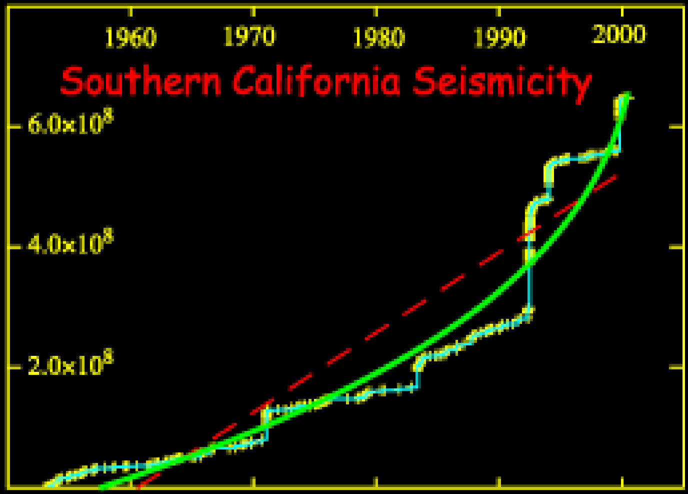

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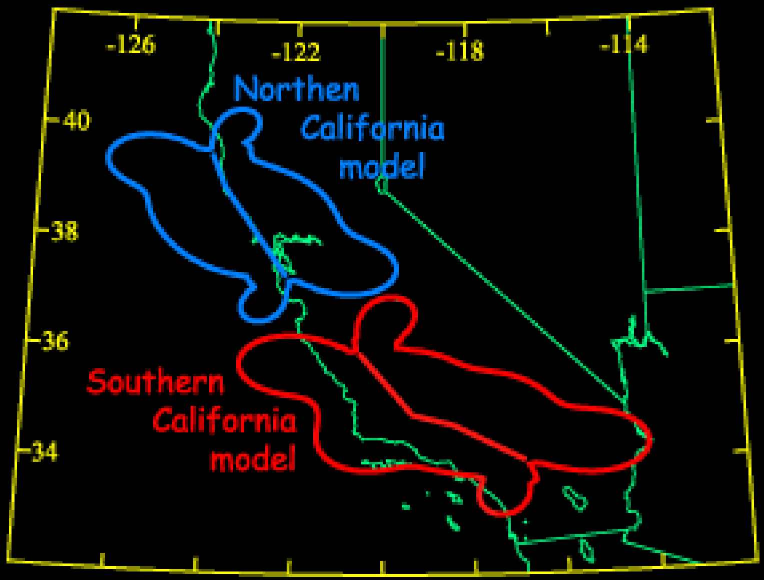
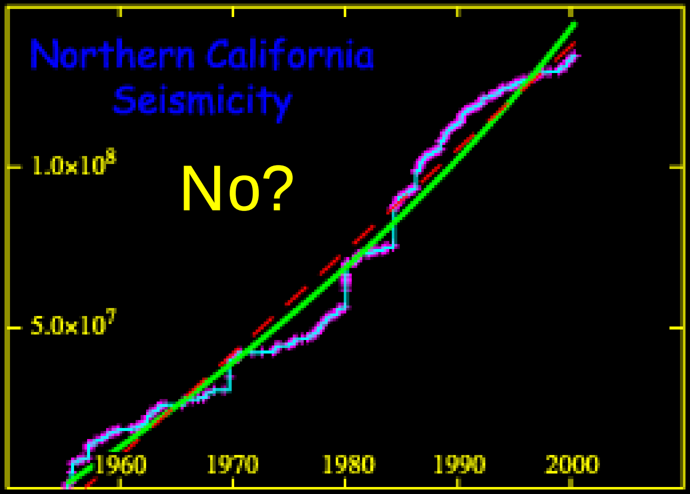
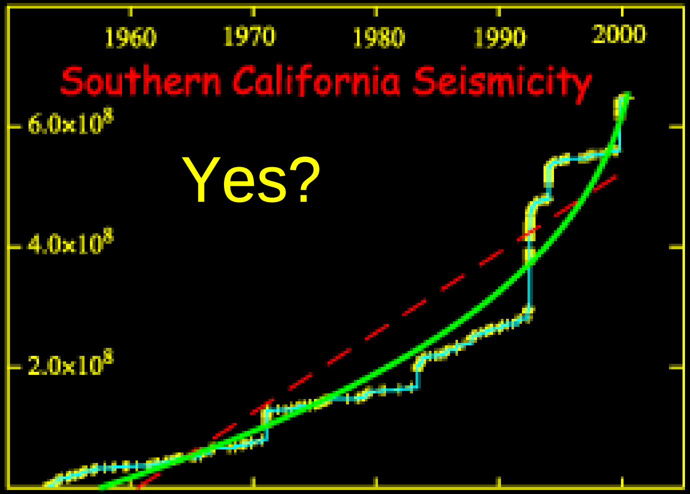
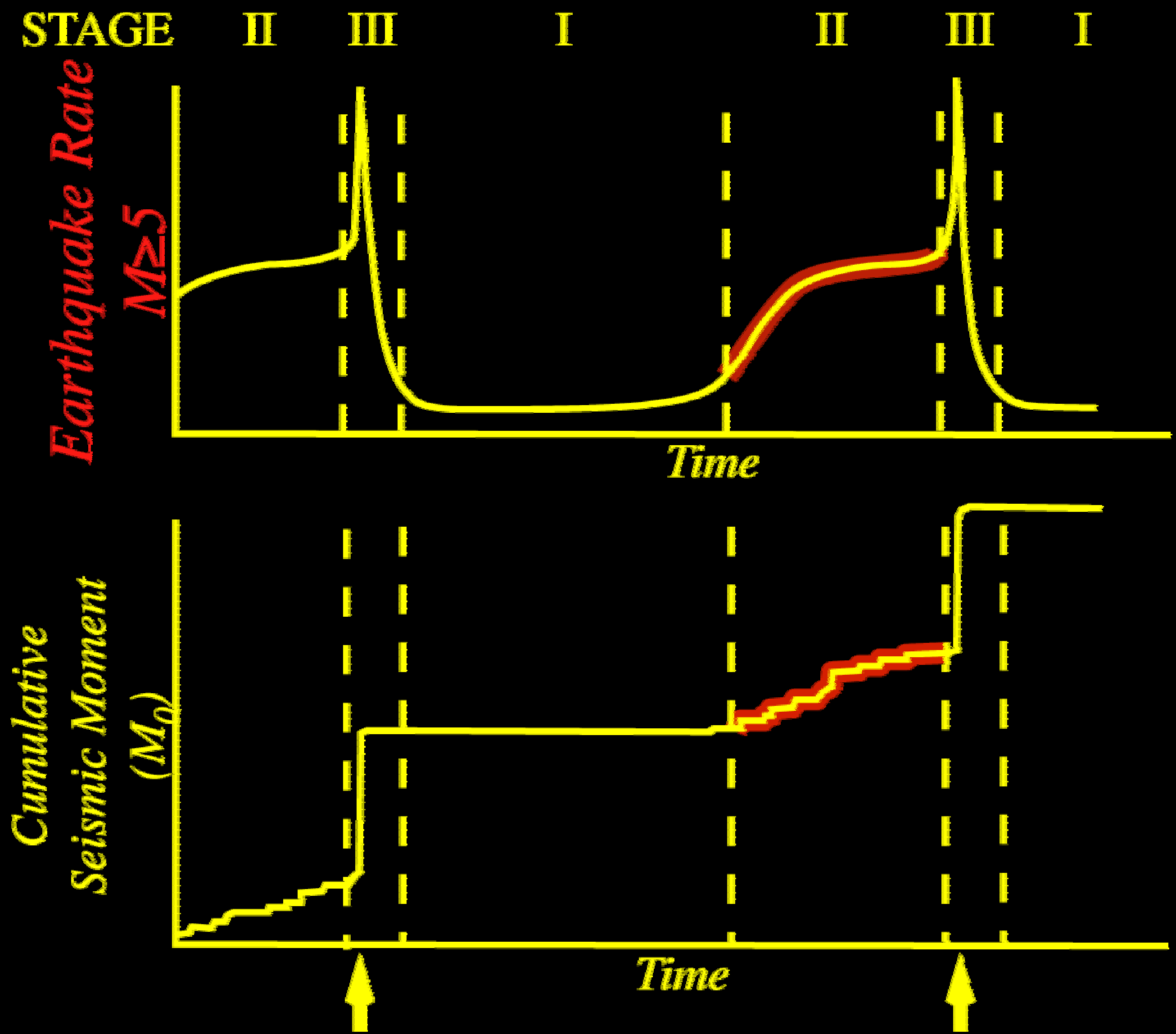


# The Seismic Cycle



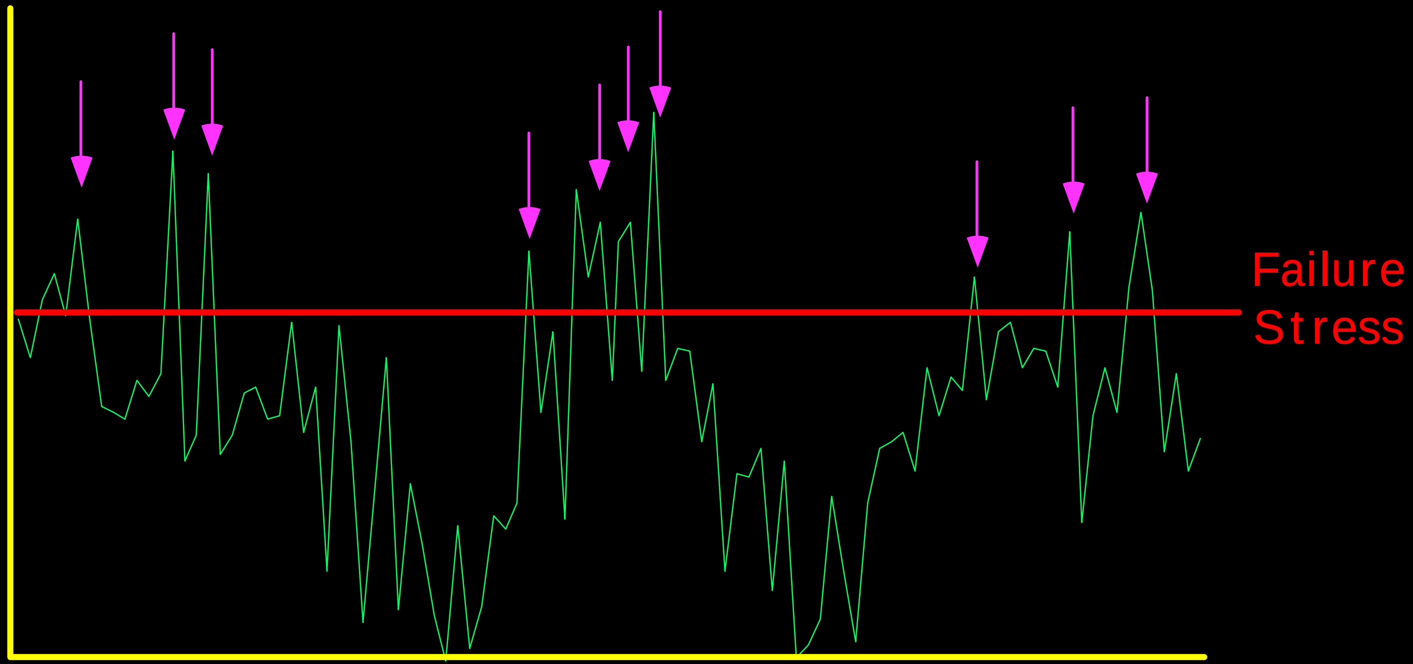

From *Ellsworth* [1981]

[redacted]

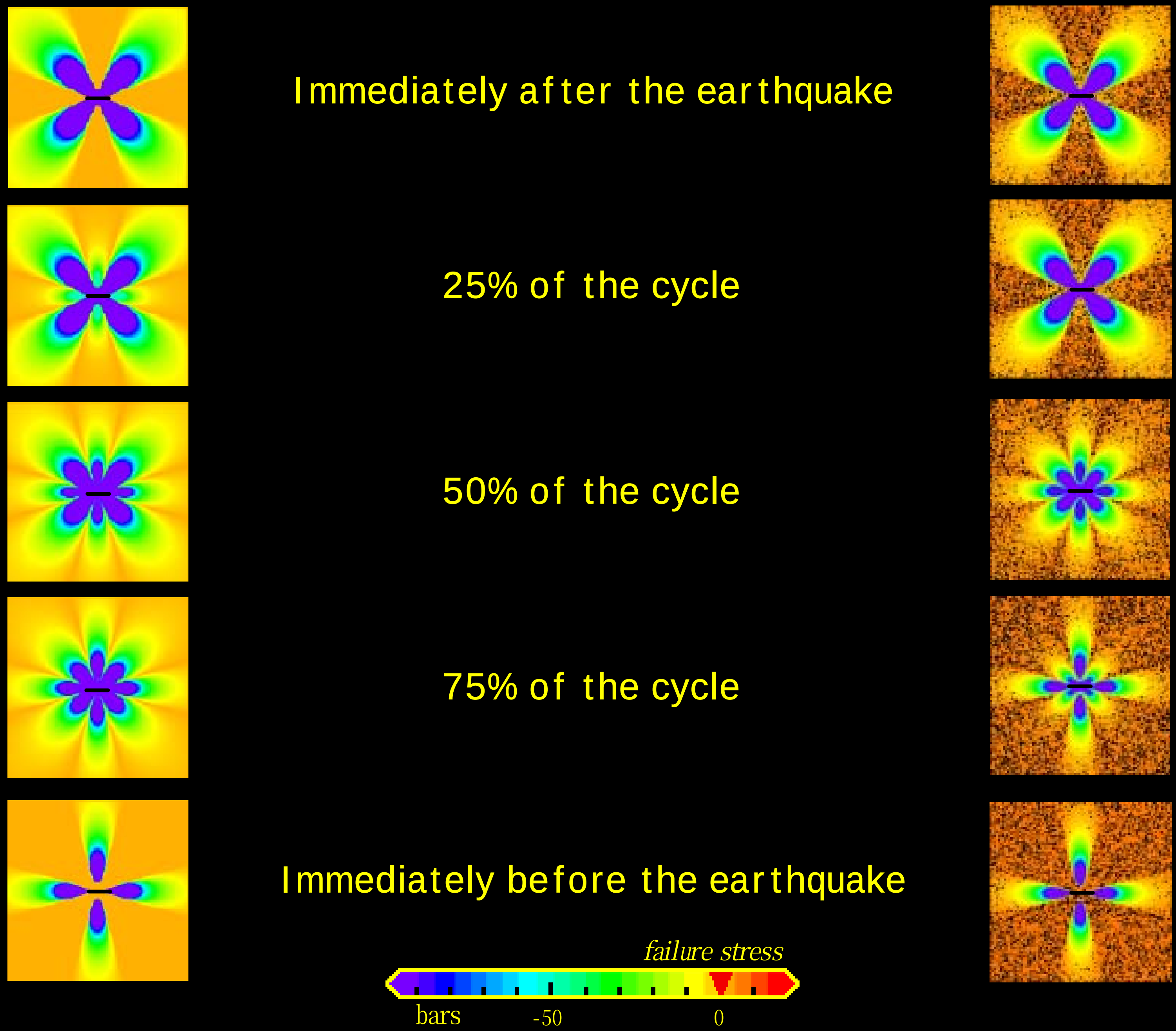
# Creating a Synthetic Catalog

Magnitude of the event depends on the size of the stress concentration

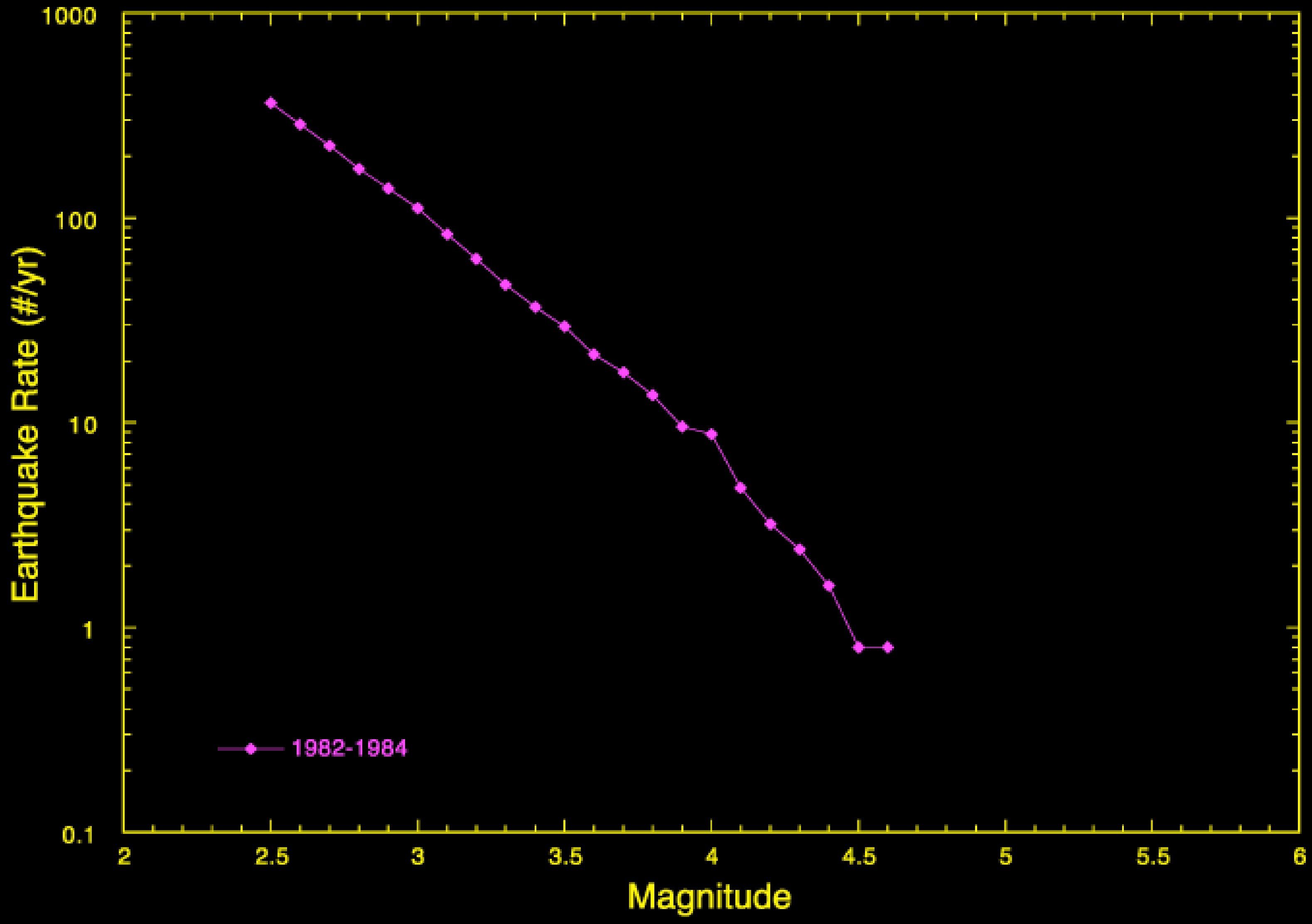
This allows the calculation of the Frequency-Magnitude relation



# Stress and Seismicity Through the Seismic Cycle



# Evolution of Gutenberg-Richter Scaling Before the 1987 Superstition Hills Earthquake



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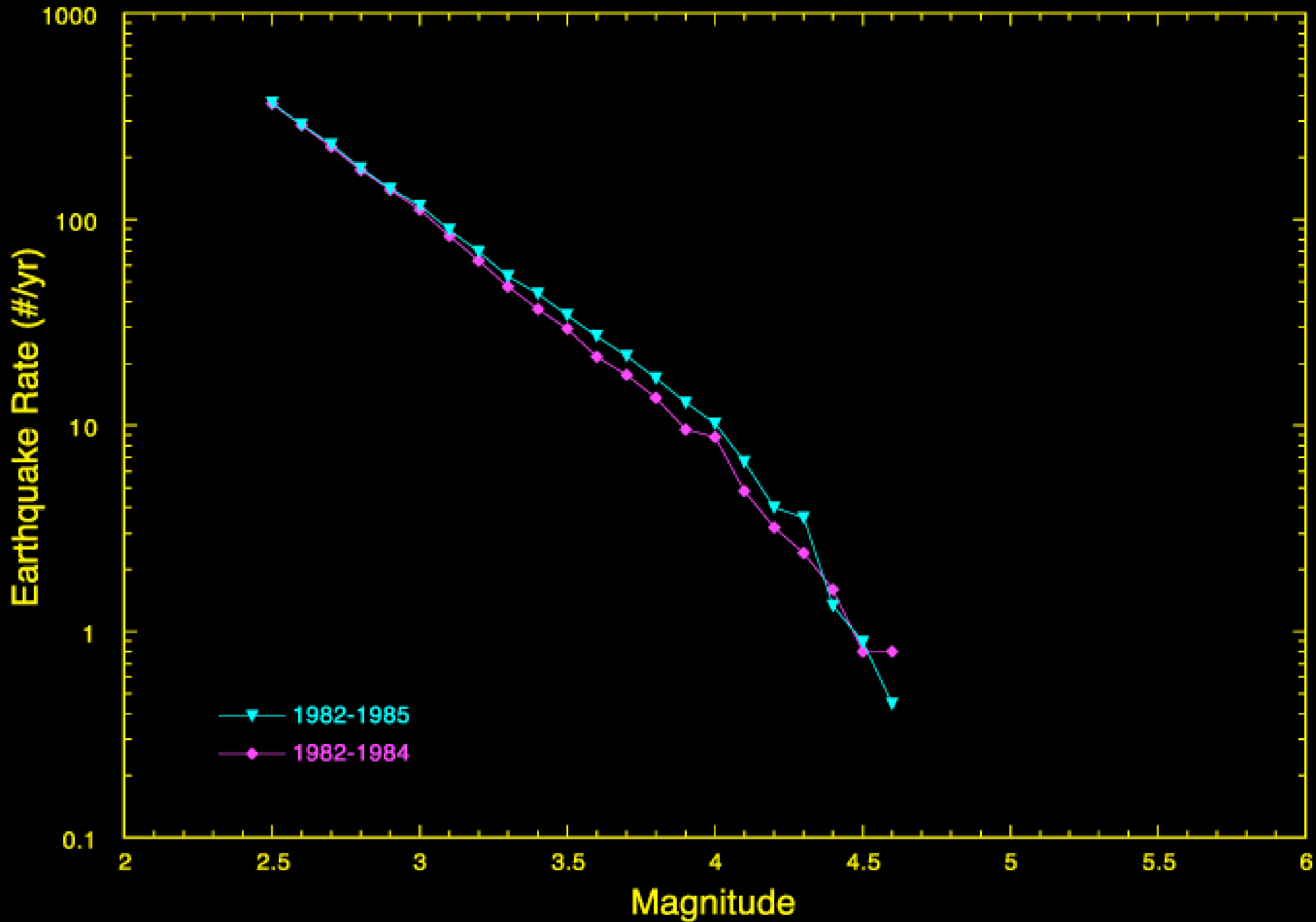

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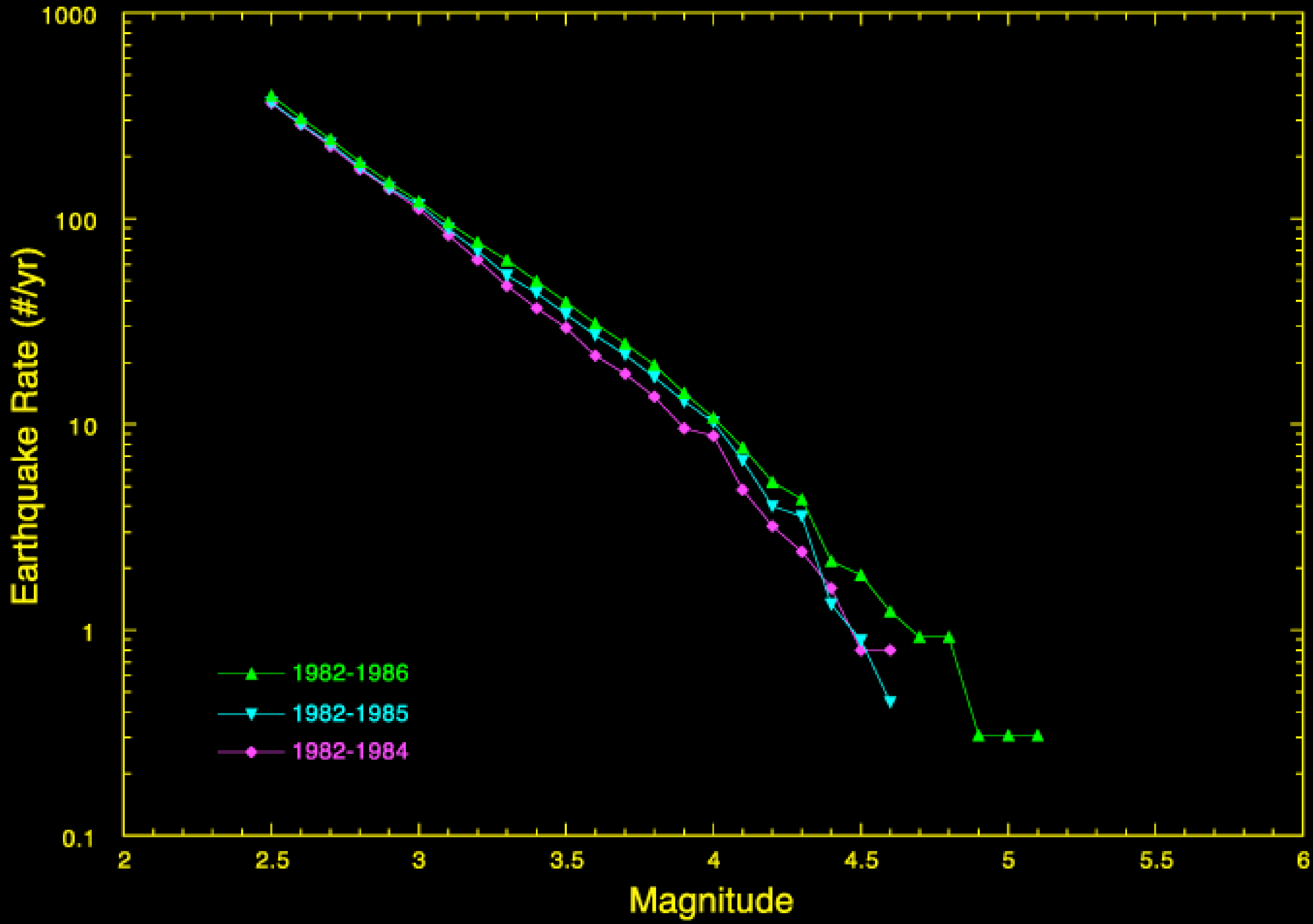

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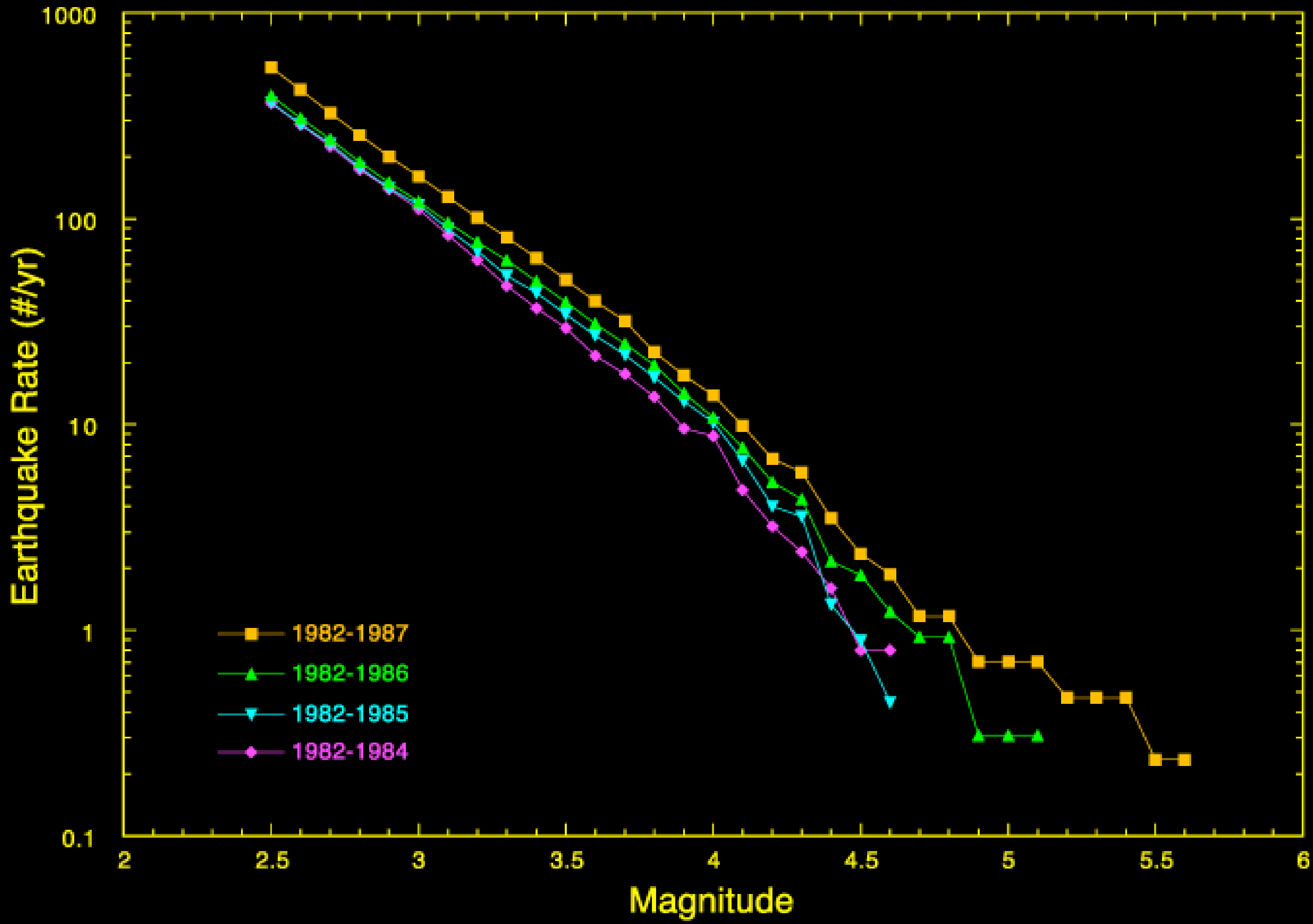

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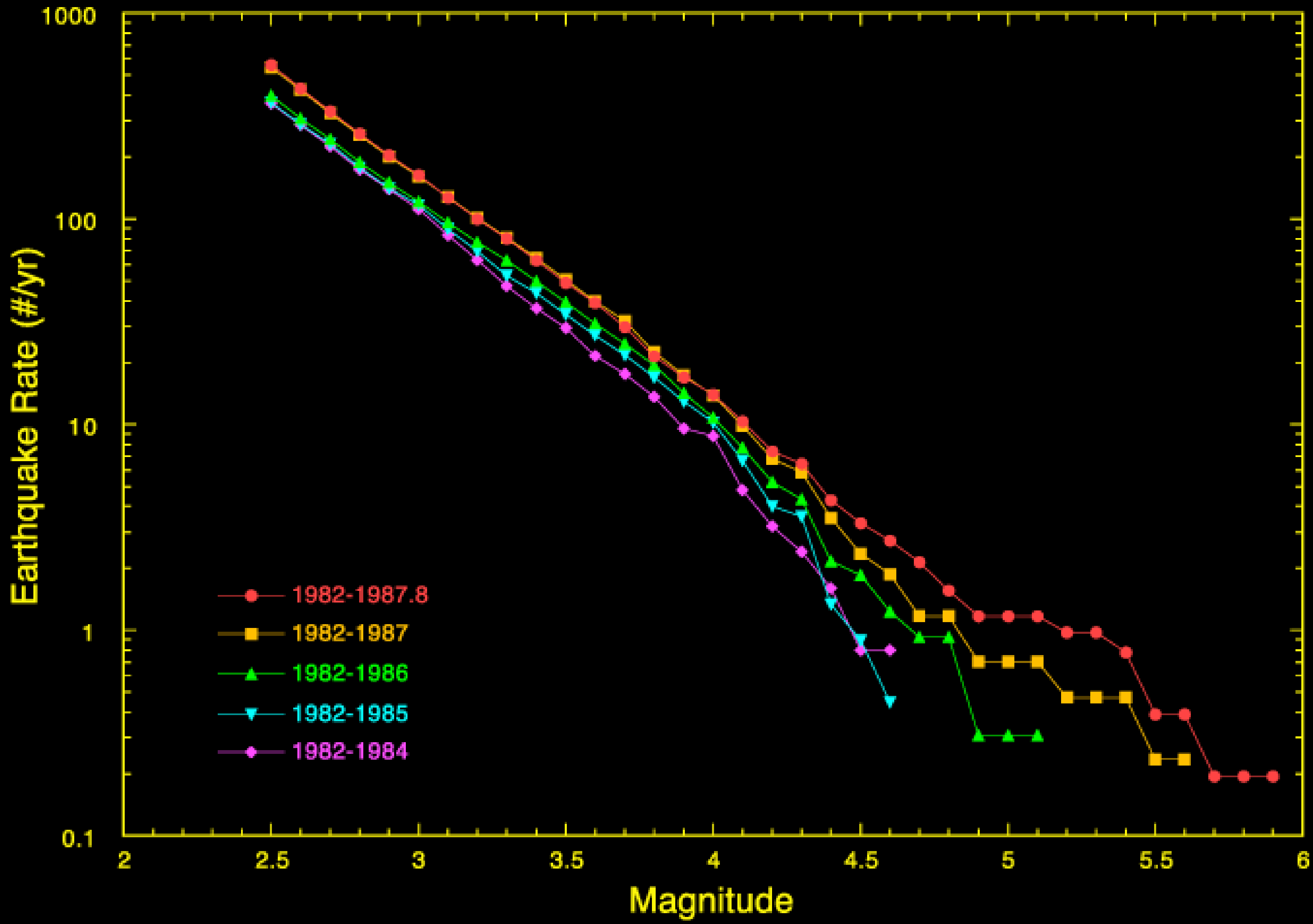
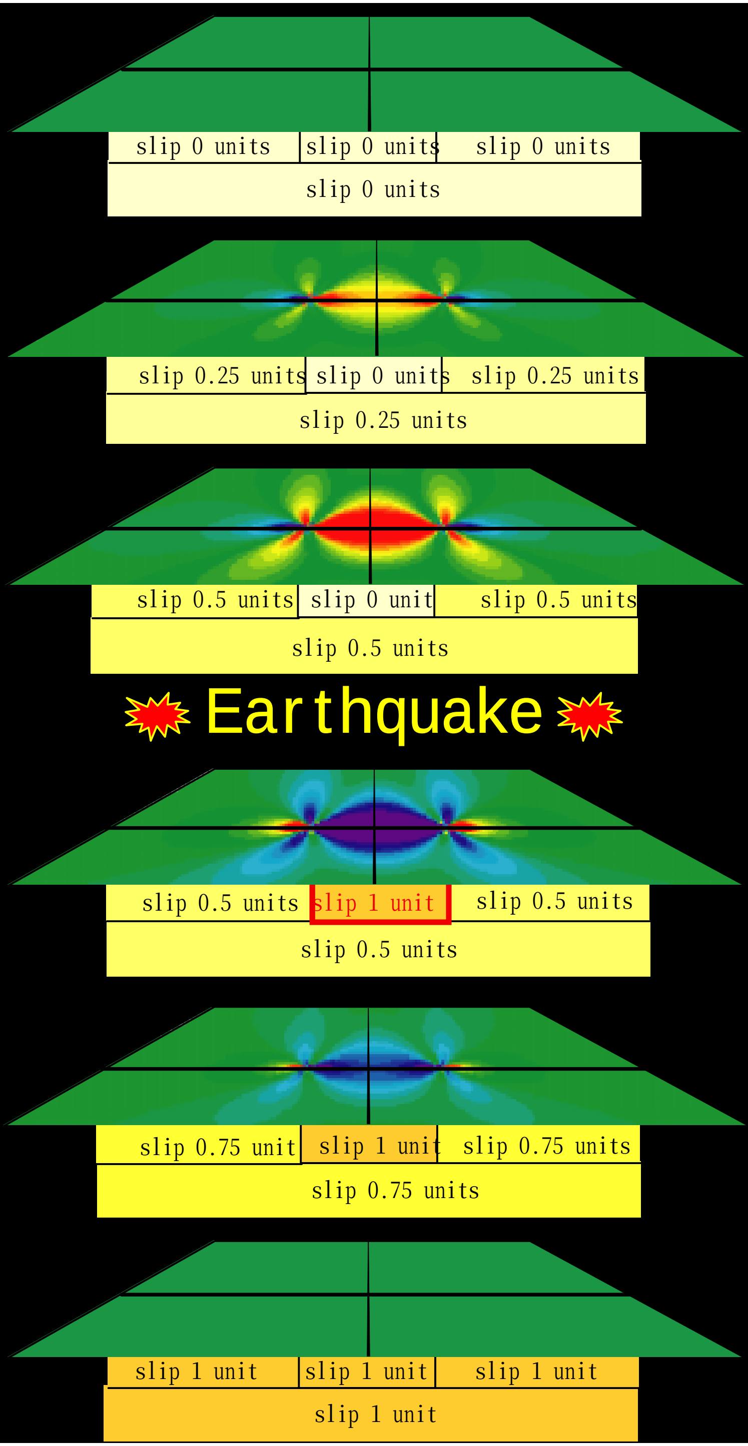


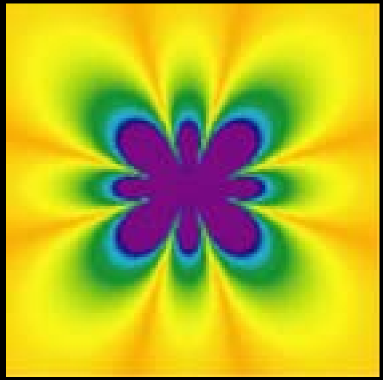



Static stress (Coulomb) changes during the earthquake cycle

**Current Stress Field** = **Stress Field From Previous History of EQs** + **Stress Field From Loading**

# Characteristics of the Background Stress Field
(for a simple model)

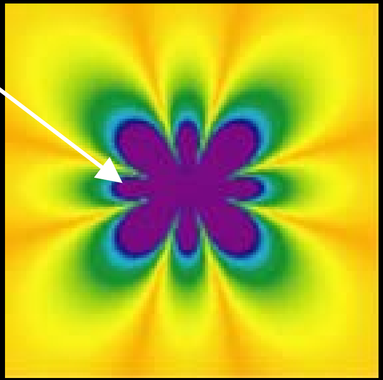
Background stress field



# Characteristics of the Background Stress Field
(for a simple model)

• Stress must be low along the strike of the fault (or rupture would continue)

Background stress field



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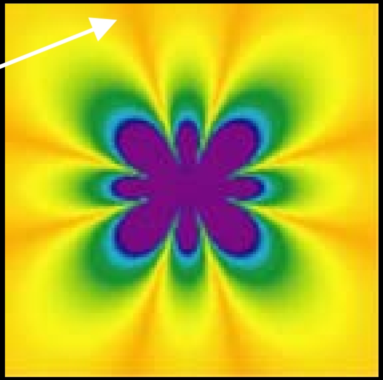
(for a simple model)

- Stress must be low along the strike of the fault (or rupture would continue)

- Stress distant from the fault must approach, but not exceed, the failure stress

Background stress field



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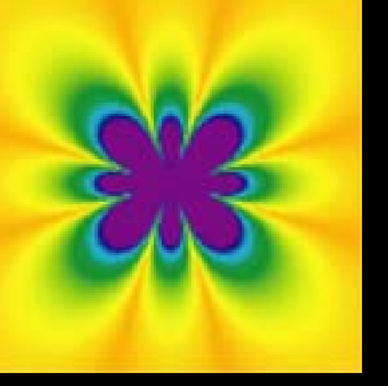

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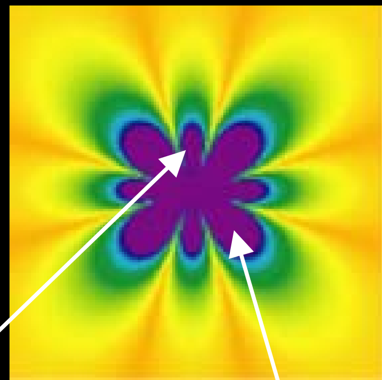
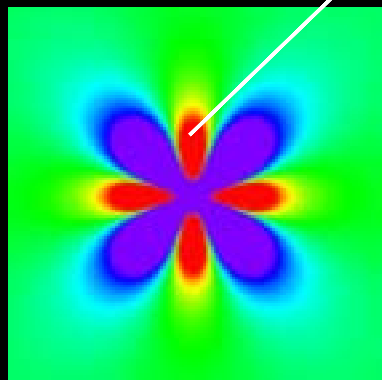
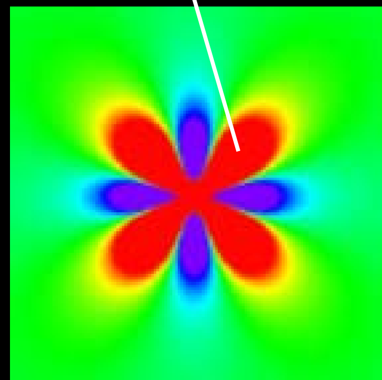
  - Positive Coulomb stresses must have a corresponding negative value in the background field

Background stress field





Coulomb field immediately before the event



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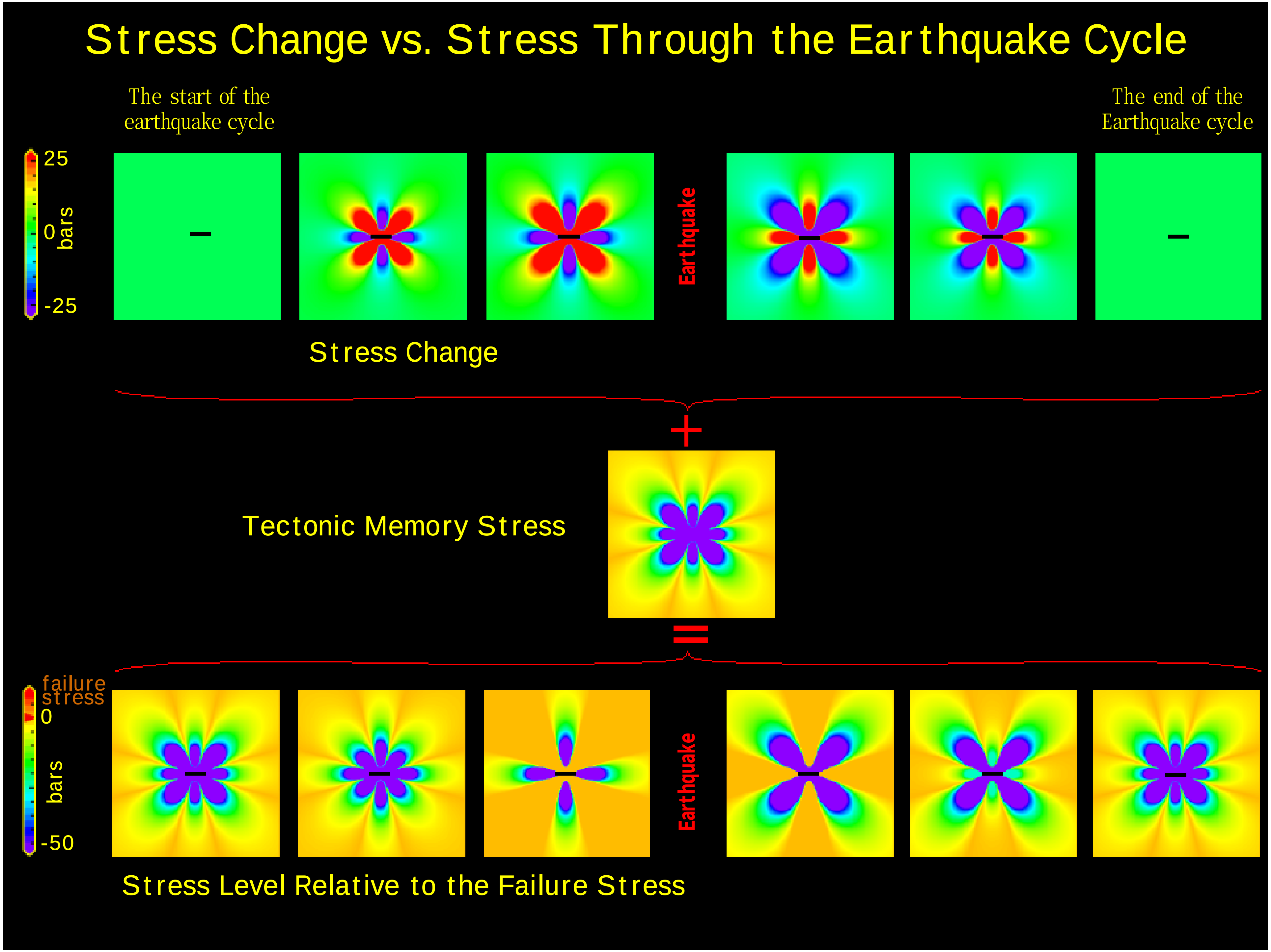
Stress Change vs. Stress Through the Earthquake Cycle
The start of the earthquake cycle
The end of the Earthquake cycle
25
0
bars
-25
Earthquake
Stress Change
+
Tectonic Memory Stress
=
failure stress
0
bars
-50
Earthquake
Stress Level Relative to the Failure Stress