

# **Environmental Effects of Contemporary Earth Tectonics**

**What Special geological  
problems exist for people living  
in various parts of the world?**

*Our Core Principle*

**Minerals and Rocks**

**(and everything else including us)**

**Are Stable**

**Only Under the Conditions**

**At Which They Form**

**Change the Conditions and**

**They Must Change Also**

# ***Tectonics and Plate Tectonics***

**Tectonics** – Earth deformation and the structures that result

**Plate Tectonics** – the idea that the Earth's rigid lithosphere is composed of large “plates” that slide around over the Earth's lower plastic layers.

# Stress and Strain

Getting all bent and broken out of shape

**Stress** – a force applied

- Tension
- Compression
- Shear

**Strain** – changes in size and shape caused by stress

**Structural Geology** – study of stress and strain in the Earth

# Stress and Strain

Getting all bent and broken out of shape

## TENSION

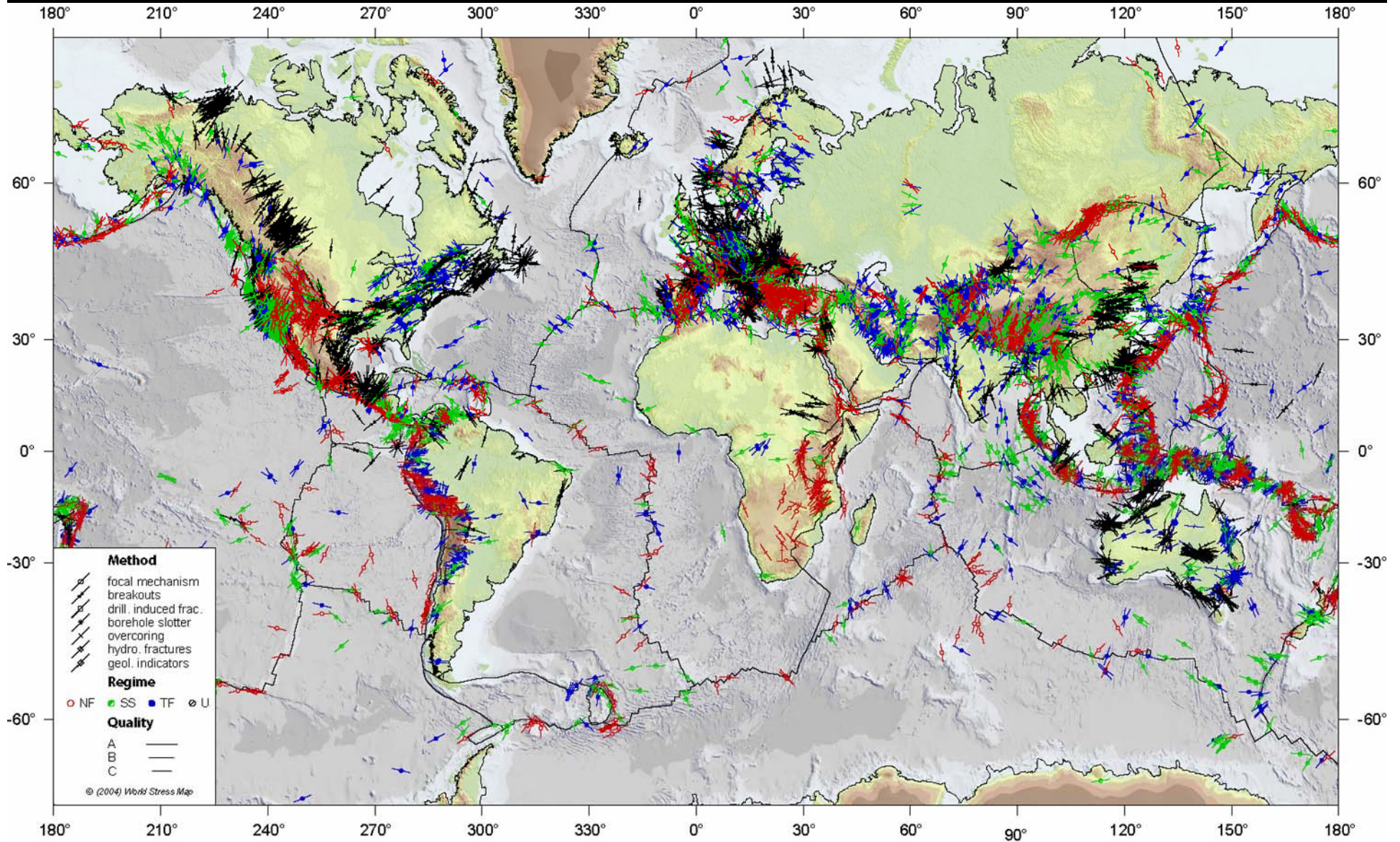
Pulling  
hair  
apart

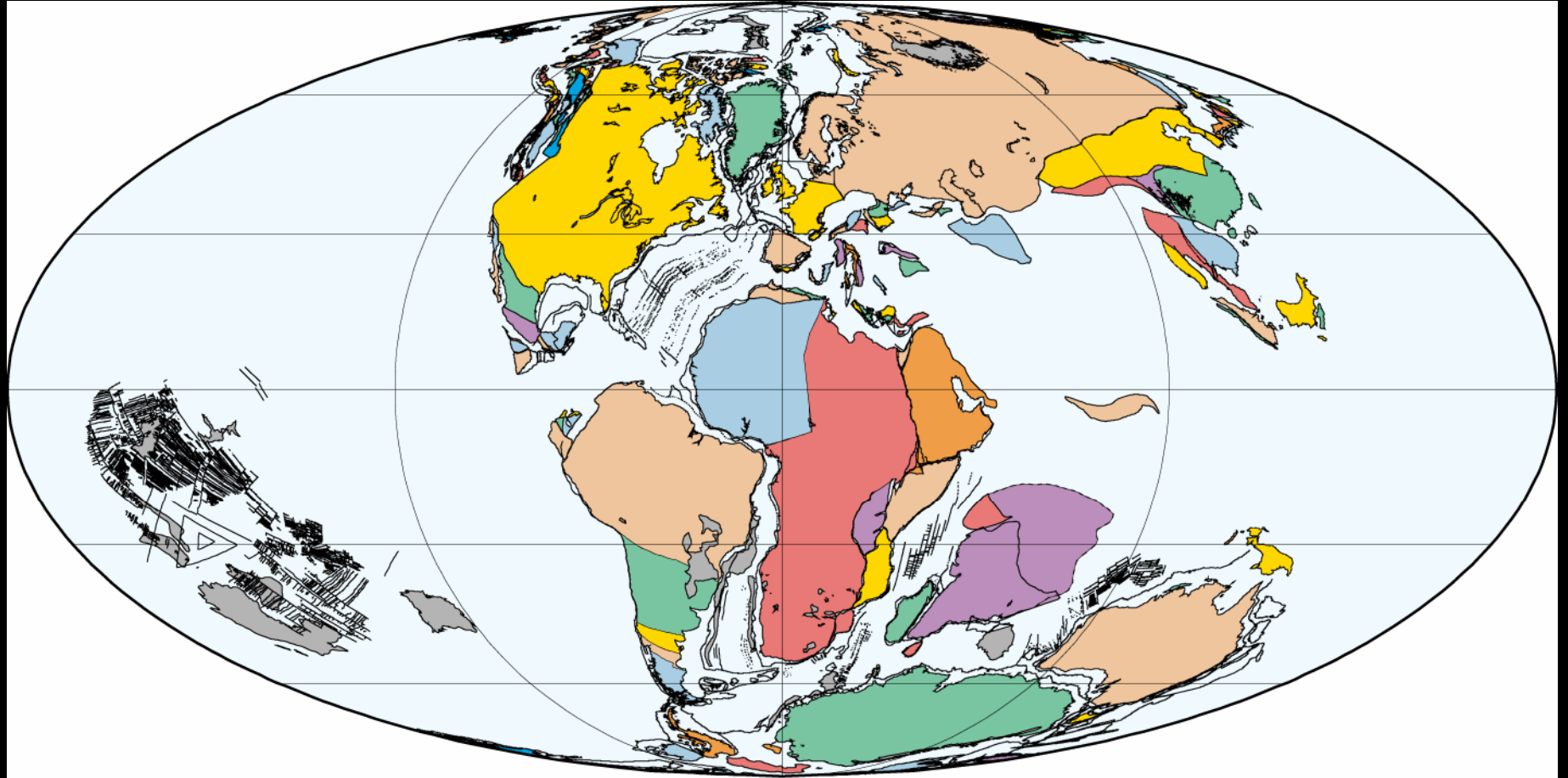


**COMPRESSION**  
Clenching teeth together

**SHEAR**  
Grinding  
Teeth Side  
to Side

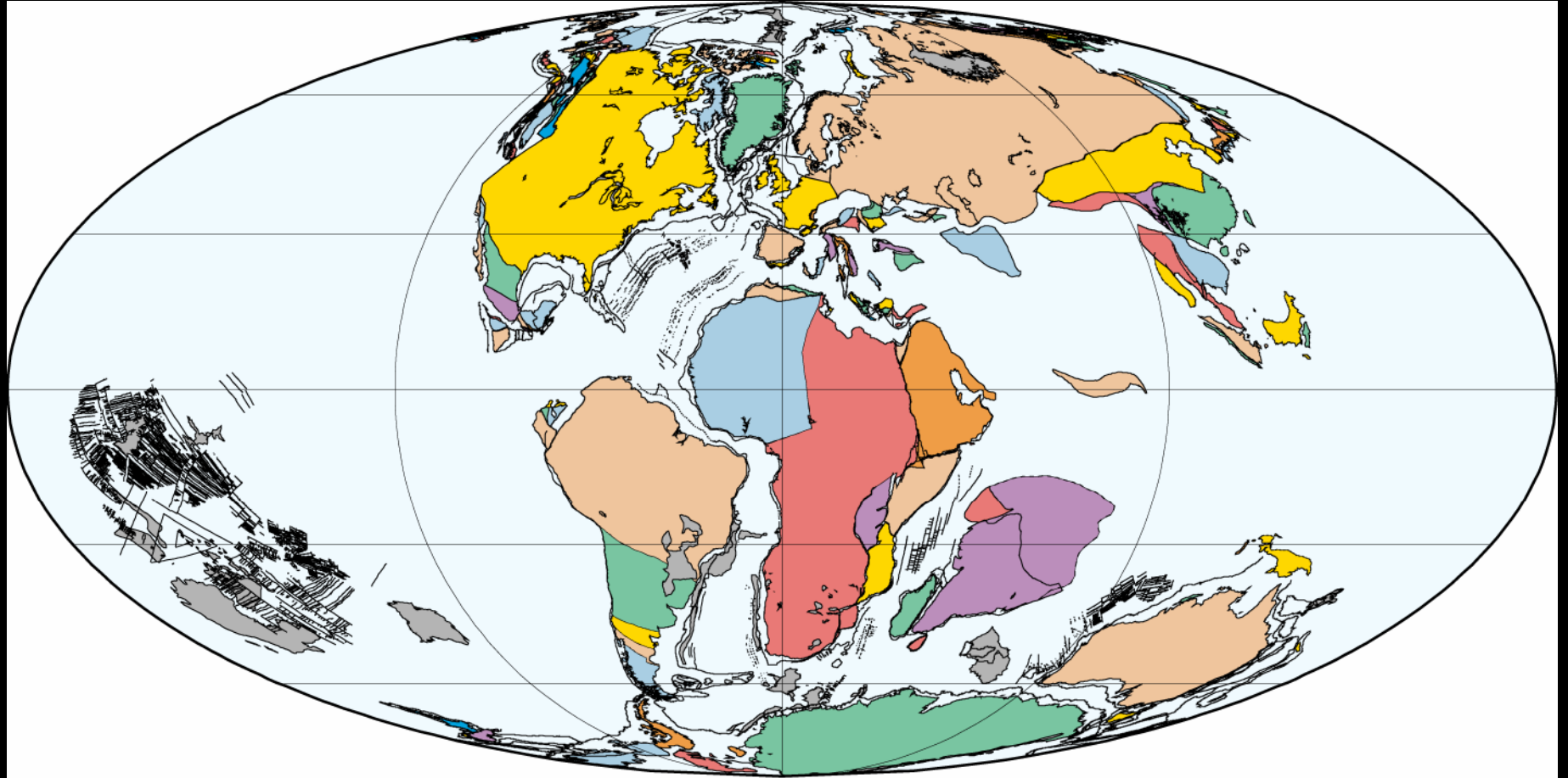
# Stress Map of the World





110 Ma  
Early Albian (Early Cretaceous)

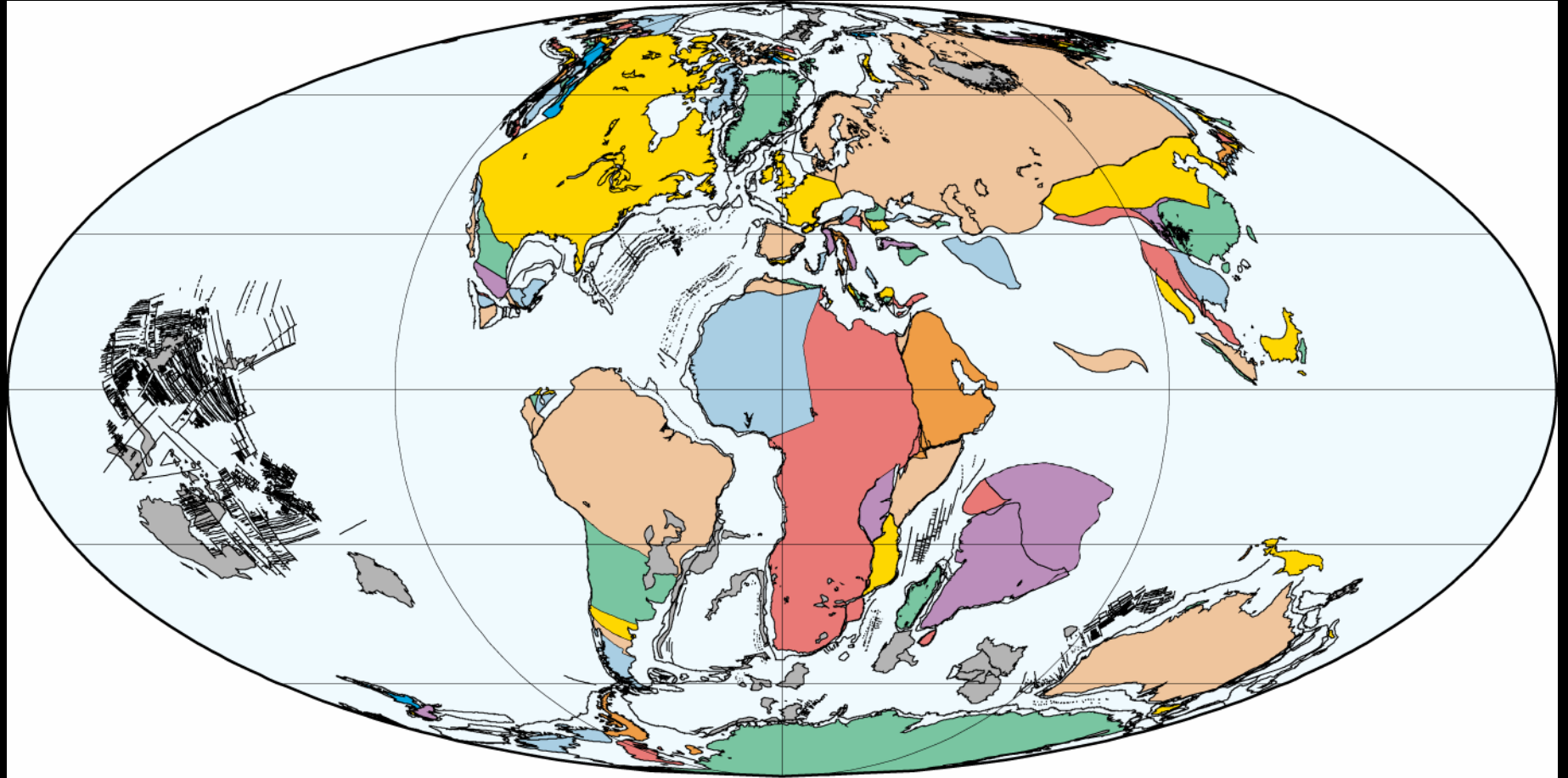
PLATES/UTIG  
August 2002



100 Ma  
Late Albian (Early Cretaceous)

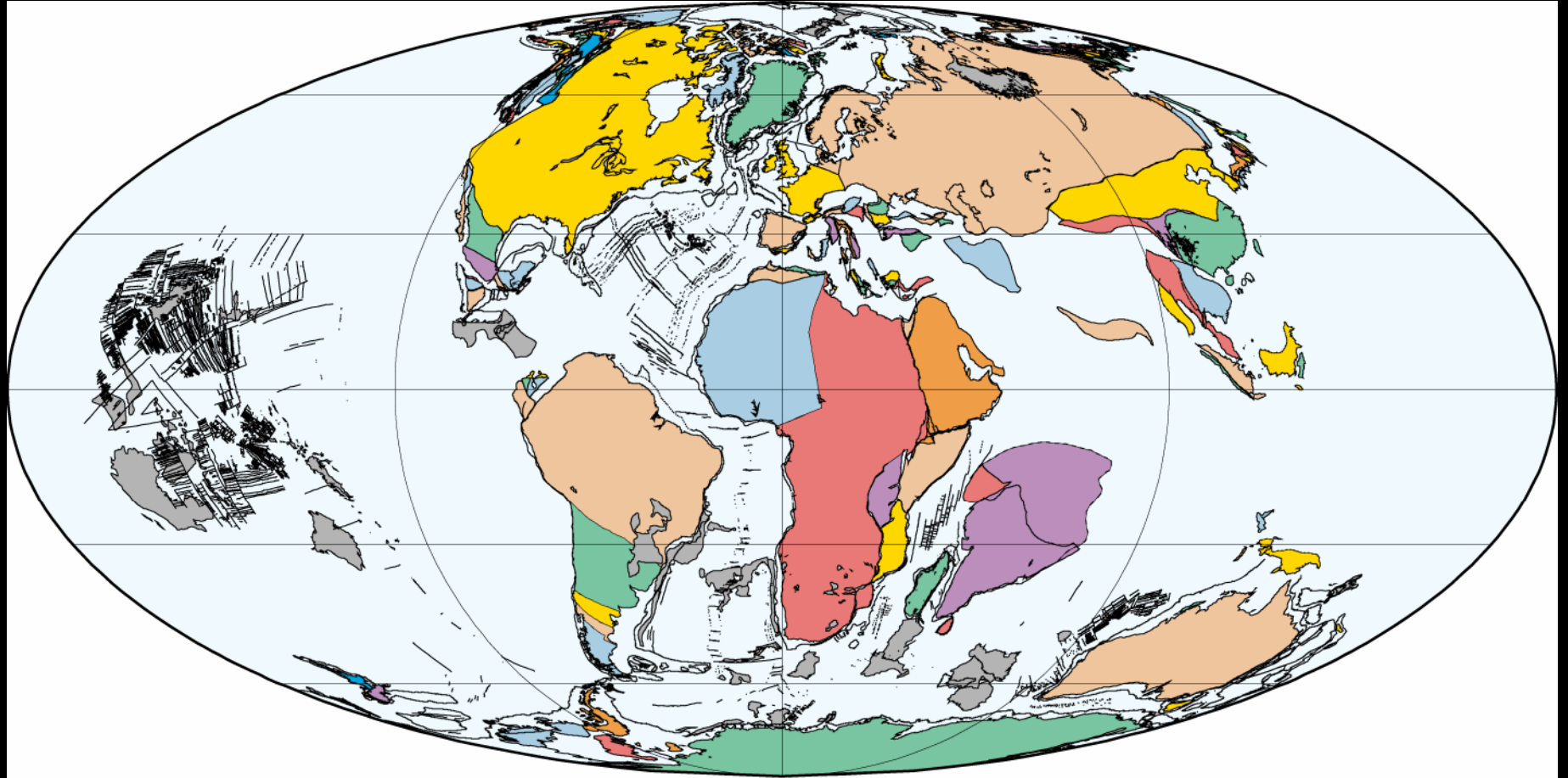
PLATES/UTIG  
August 2002





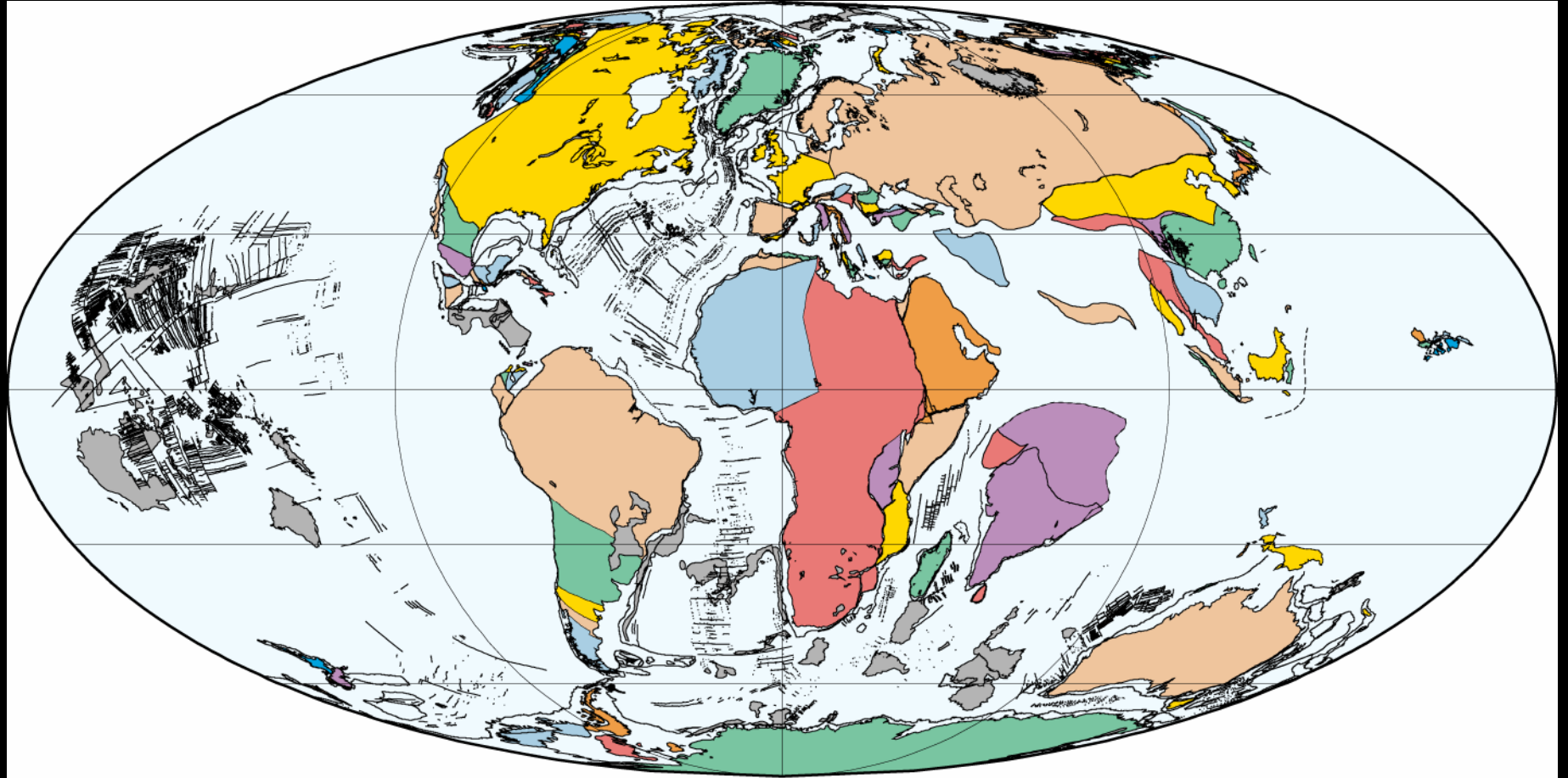
90 Ma  
Turonian (Late Cretaceous)

PLATES/UTIG  
August 2002



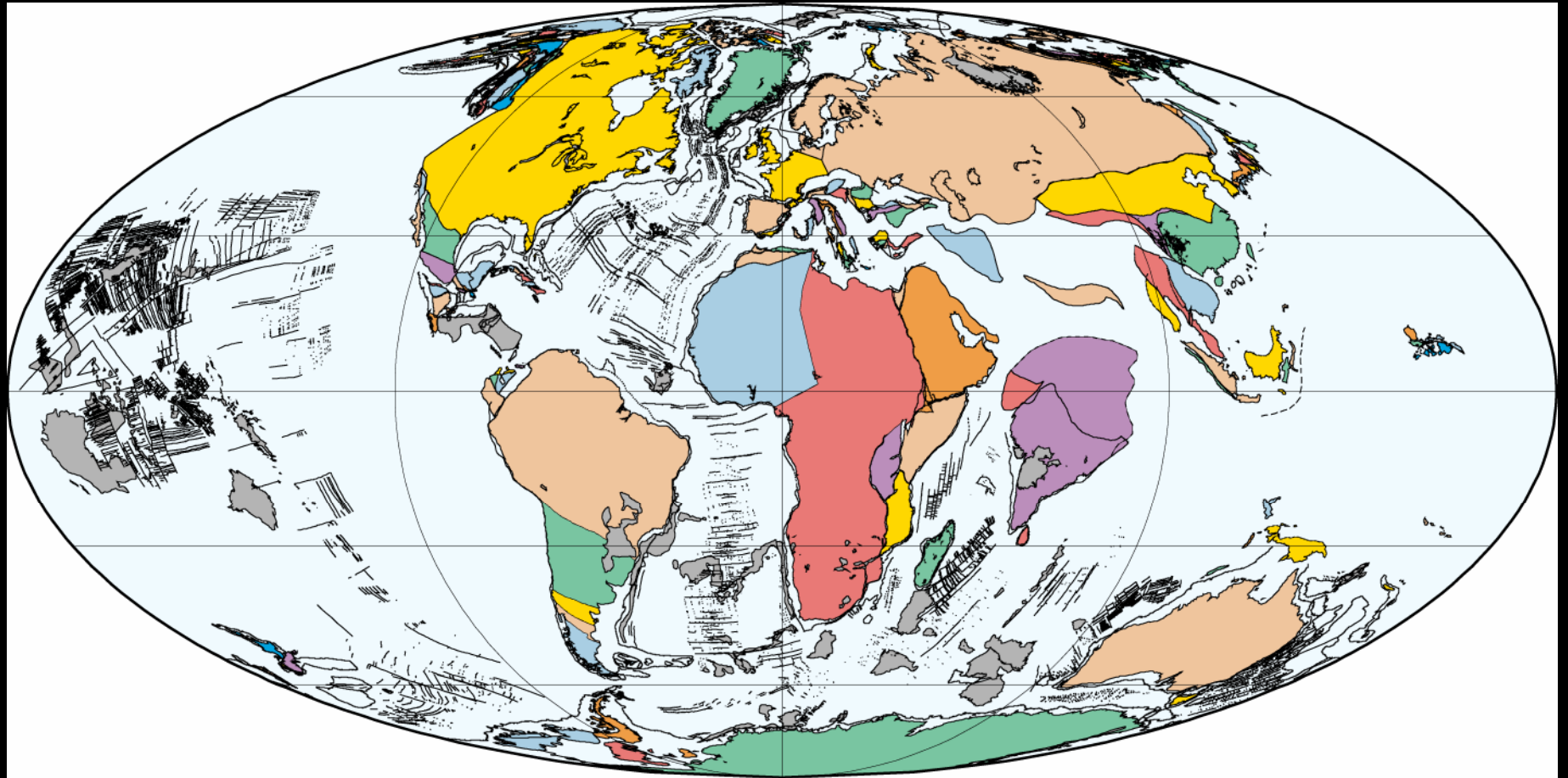
80 Ma  
Campanian (Late Cretaceous)

PLATES/UTIG  
August 2002



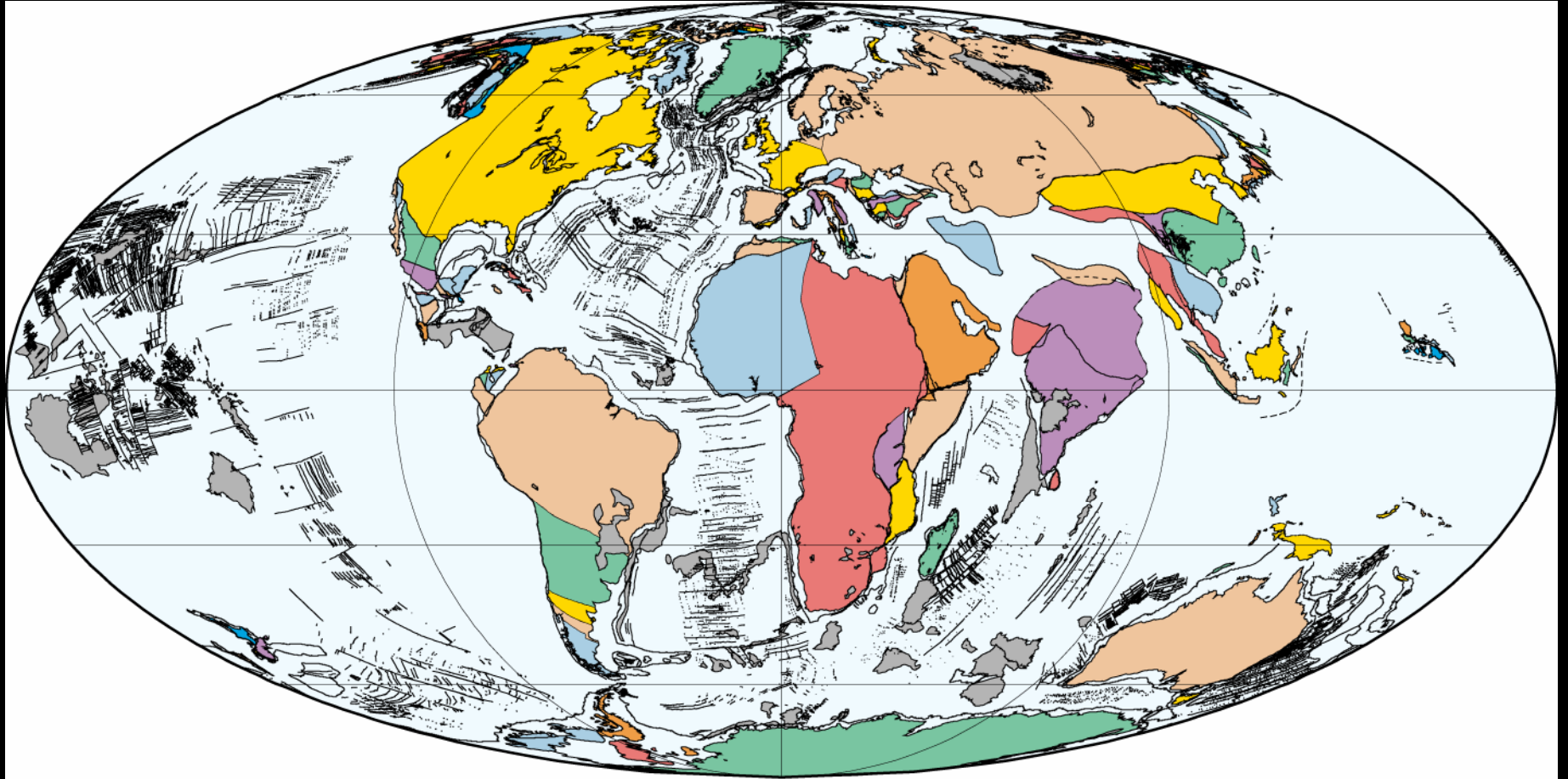
70 Ma  
Maastrichtian (Late Cretaceous)

PLATESUTIG  
August 2002



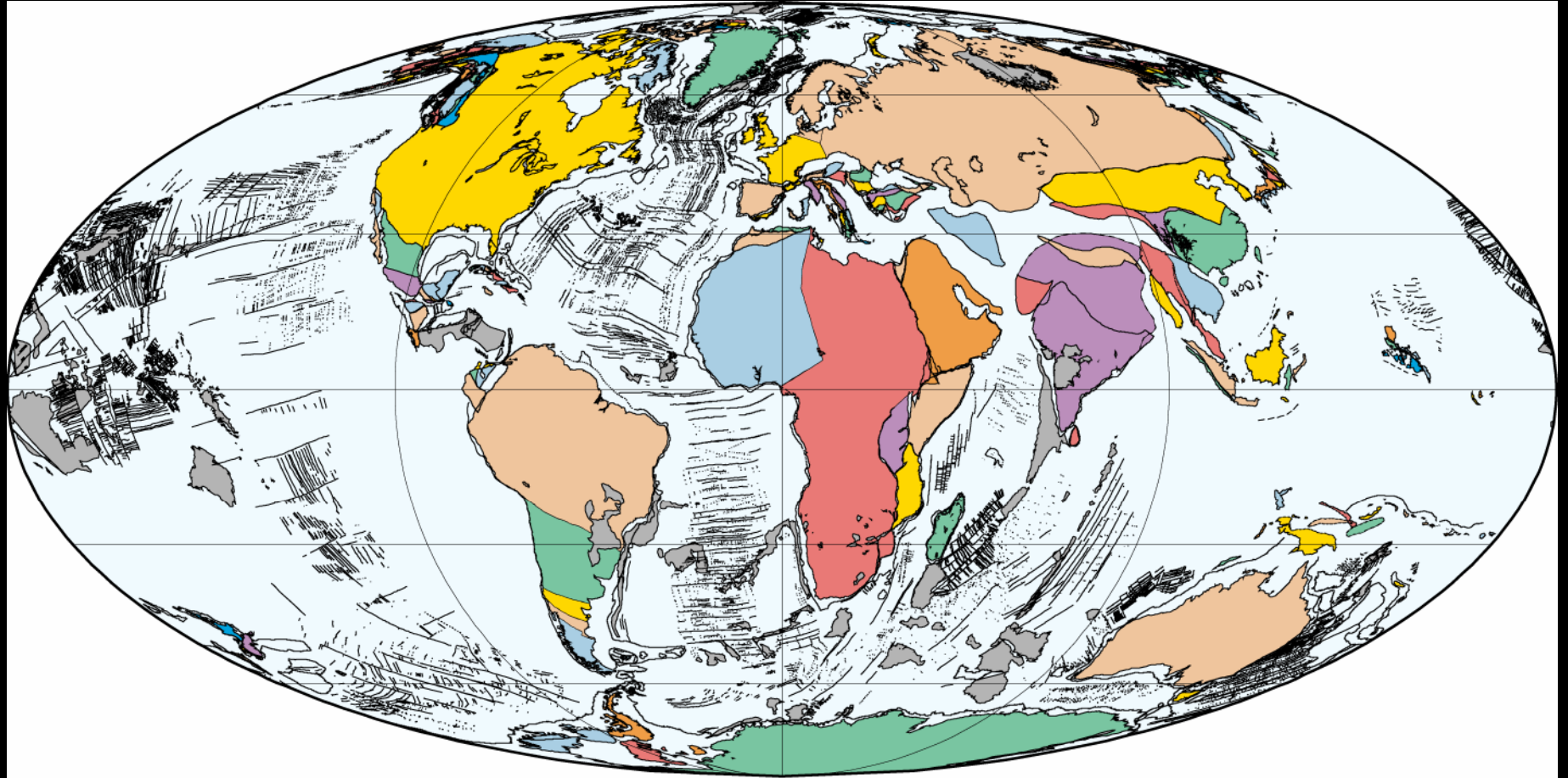
60 Ma  
Late Paleocene

PLATES/UTIG  
August 2002



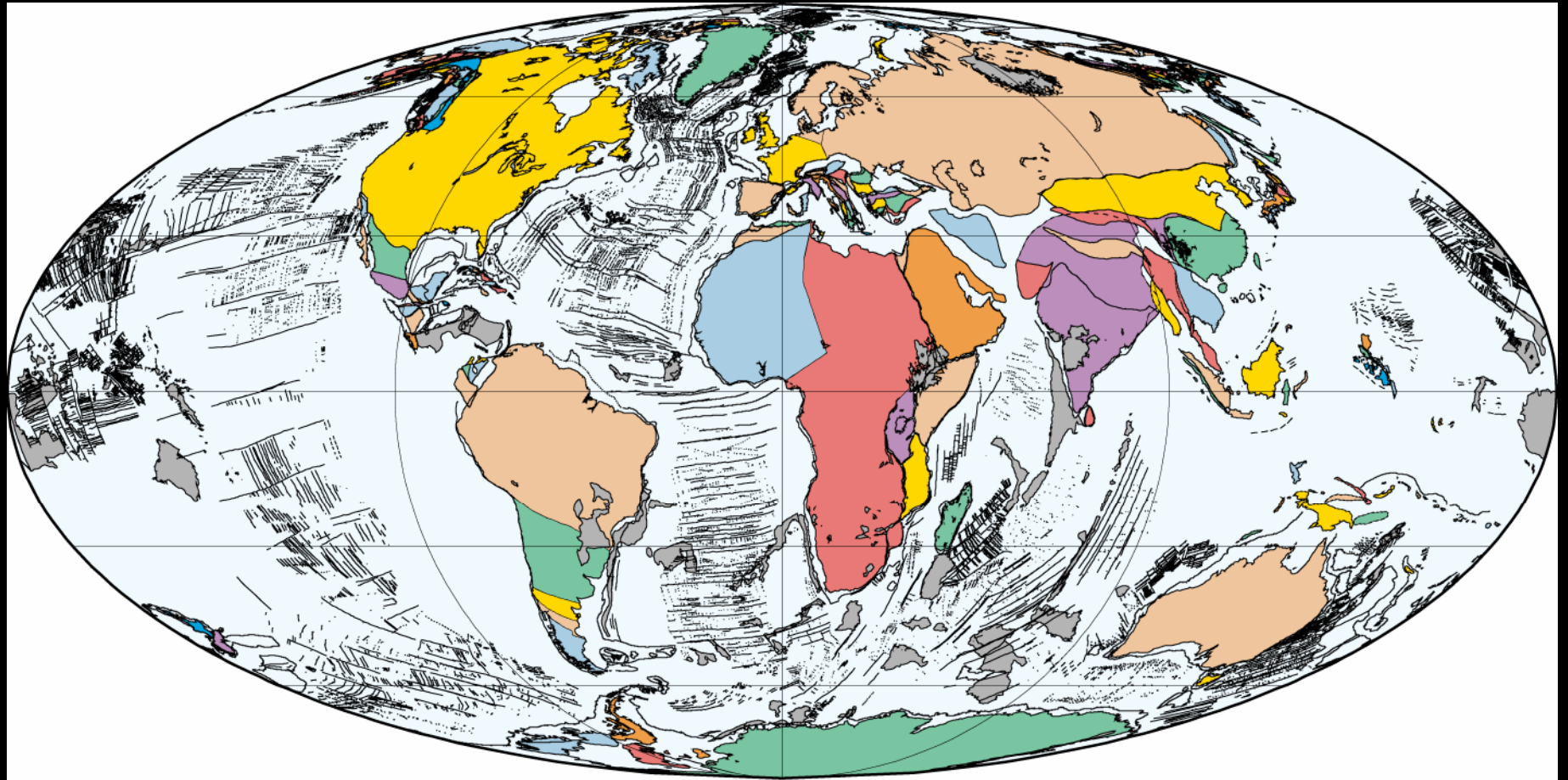
50 Ma  
Early Eocene

PLATES/UTIG  
August 2002



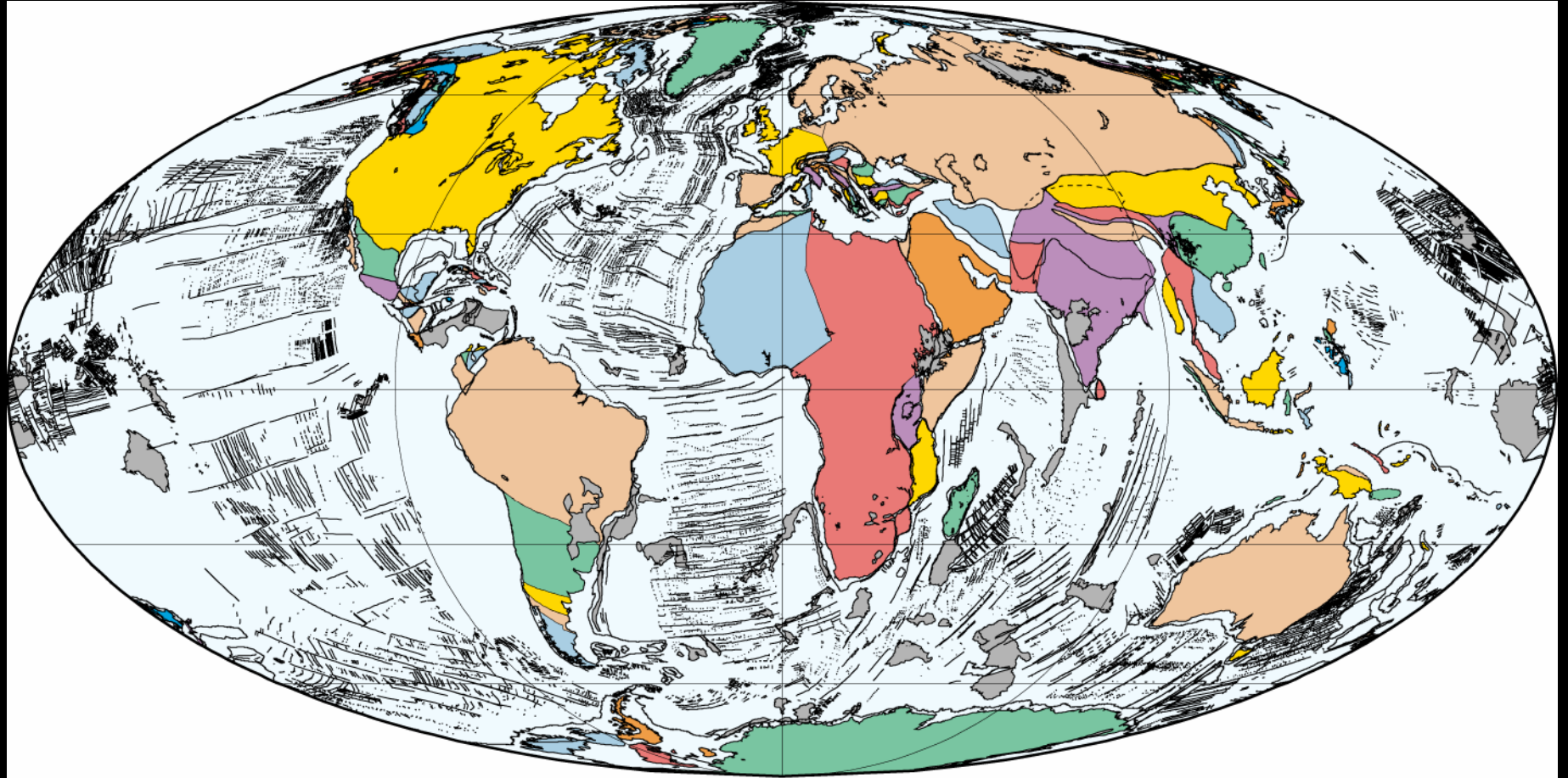
40 Ma  
Middle Eocene

PLATES/UTIG  
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30 Ma  
Early Oligocene

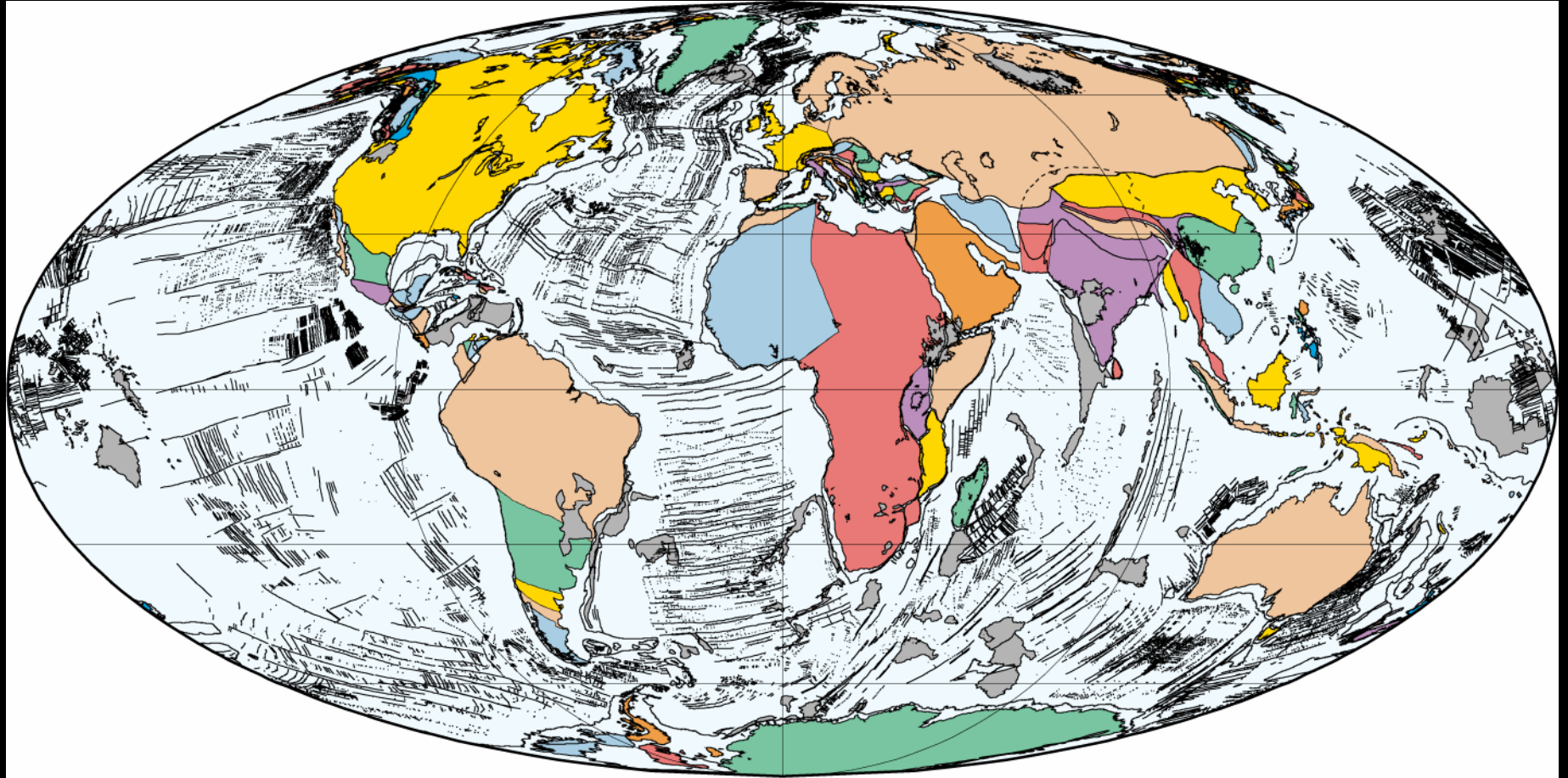
PLATES/UTIG  
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20 Ma  
Early Miocene

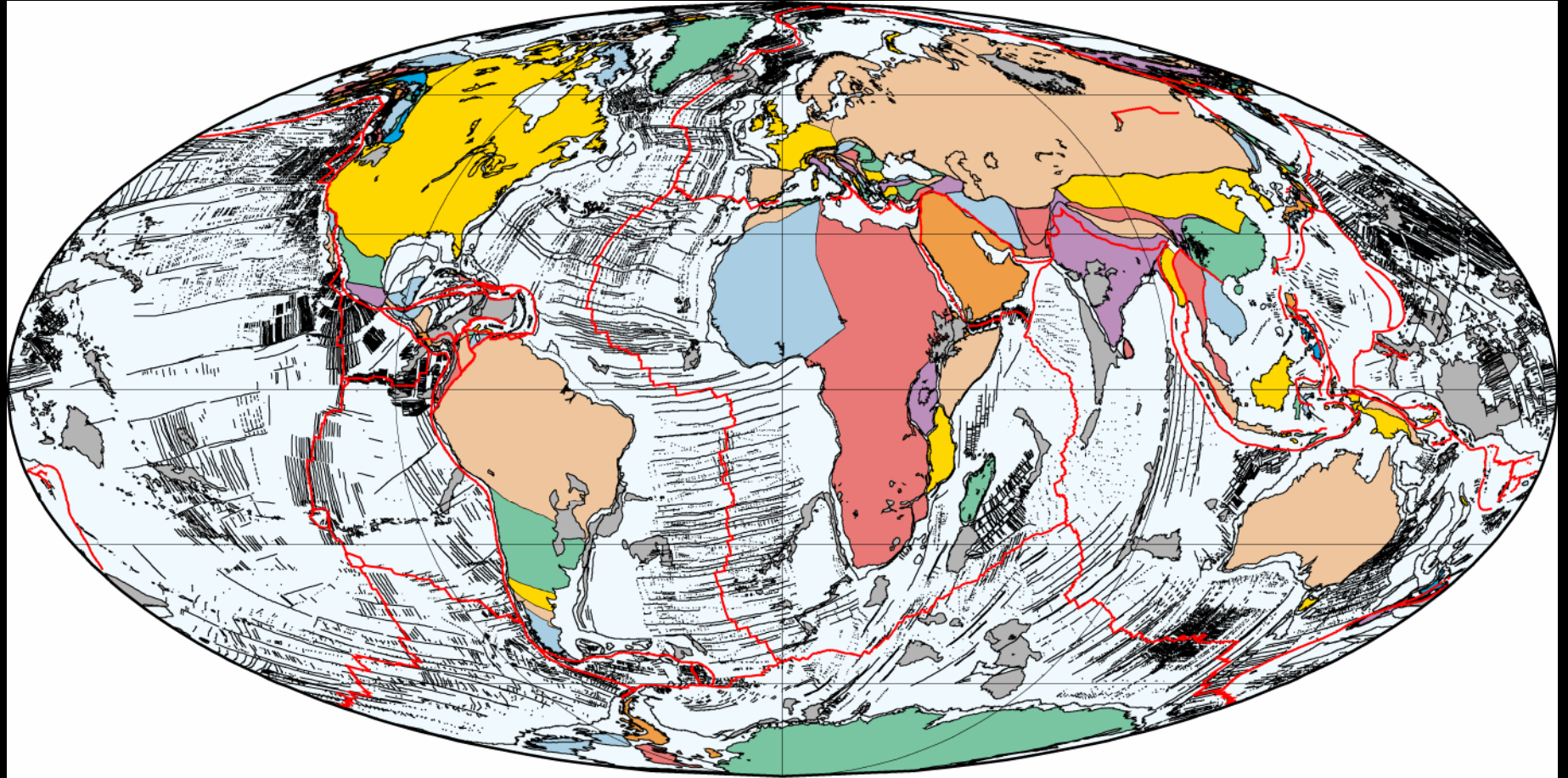
PLATESUTIG  
August 2002





10 Ma  
Late Miocene

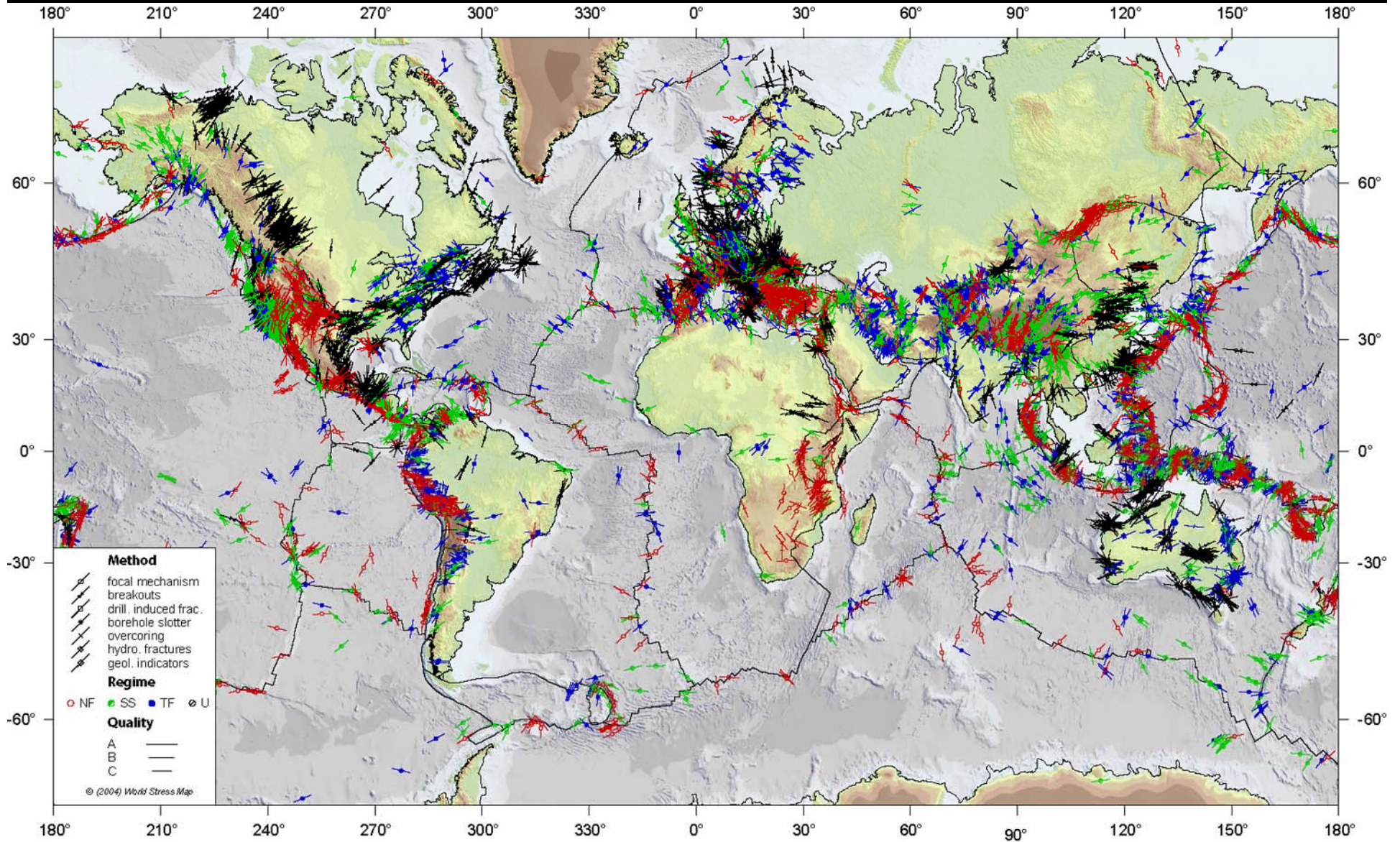
PLATES/UTIG  
August 2002



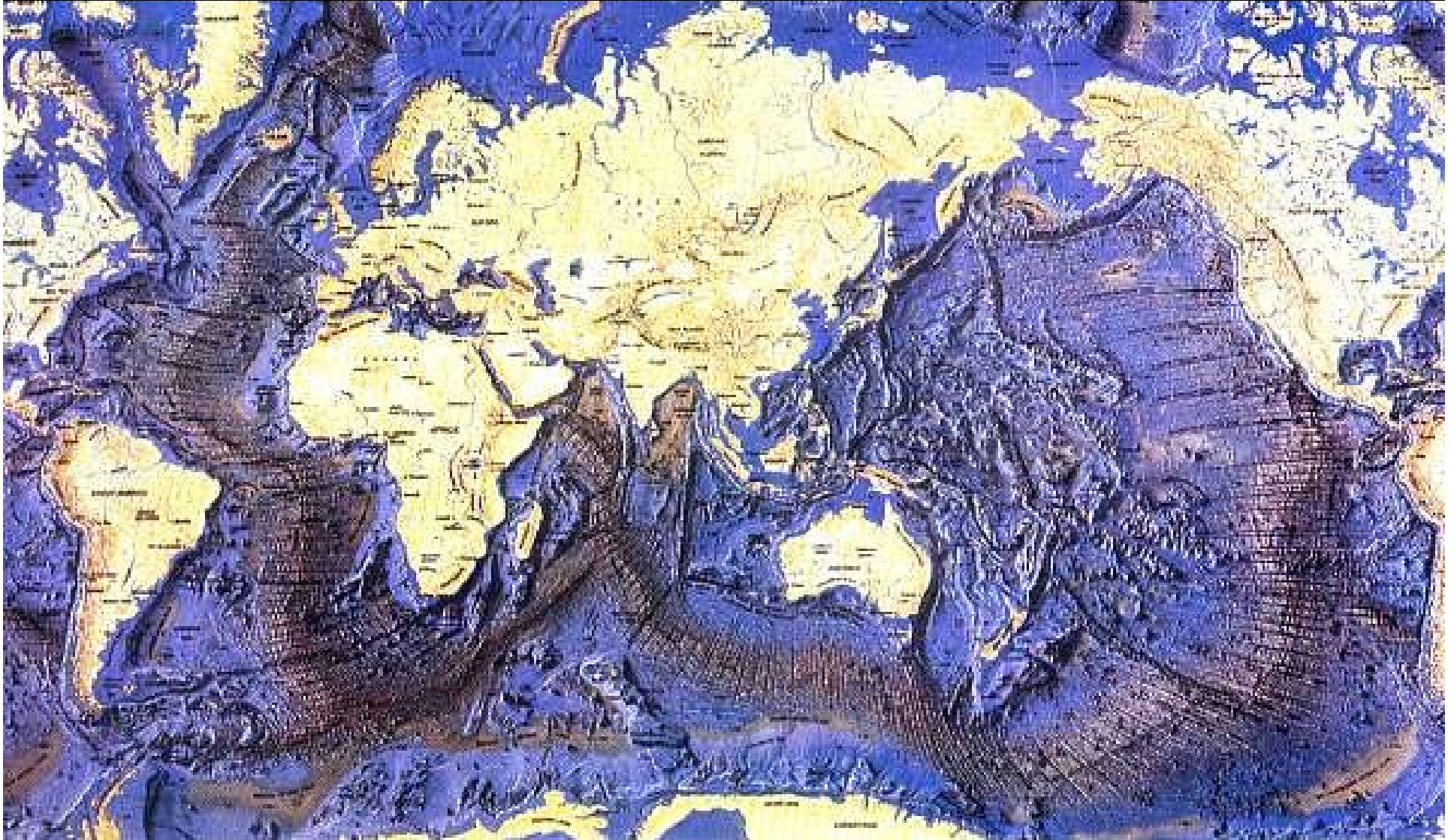
0Ma  
Present Day

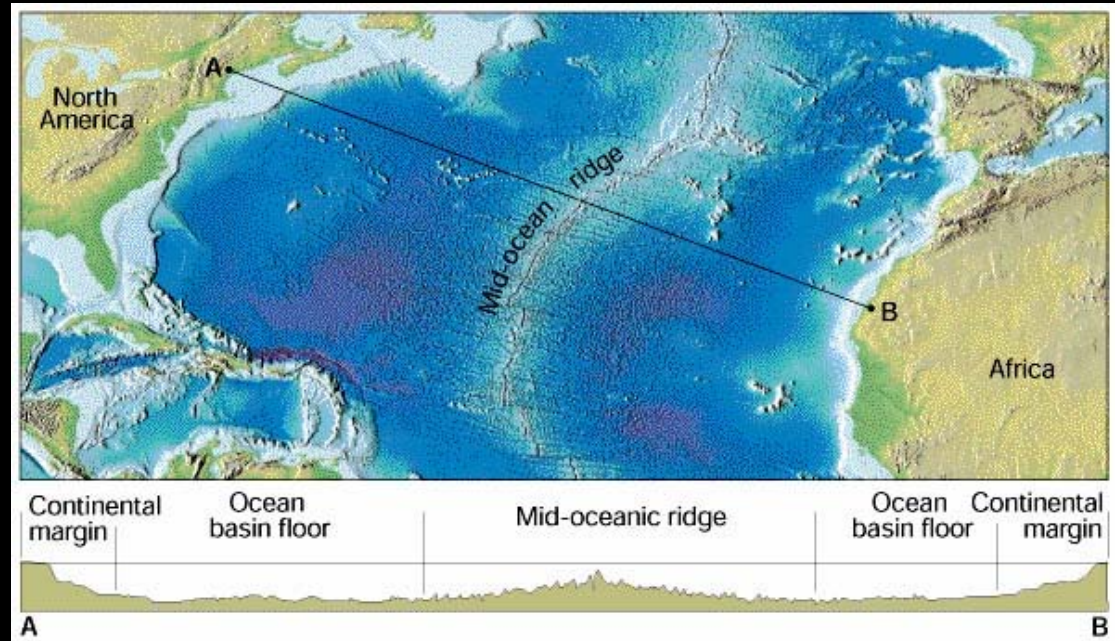
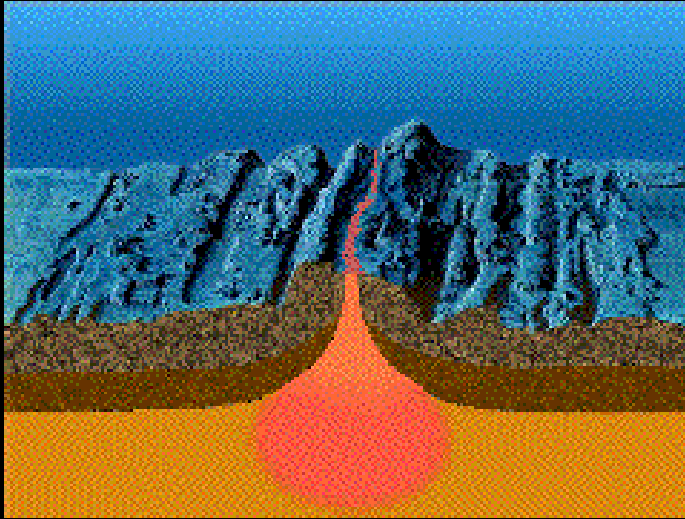
PLATES/UTIG  
August 2002

# Stress Map of the World



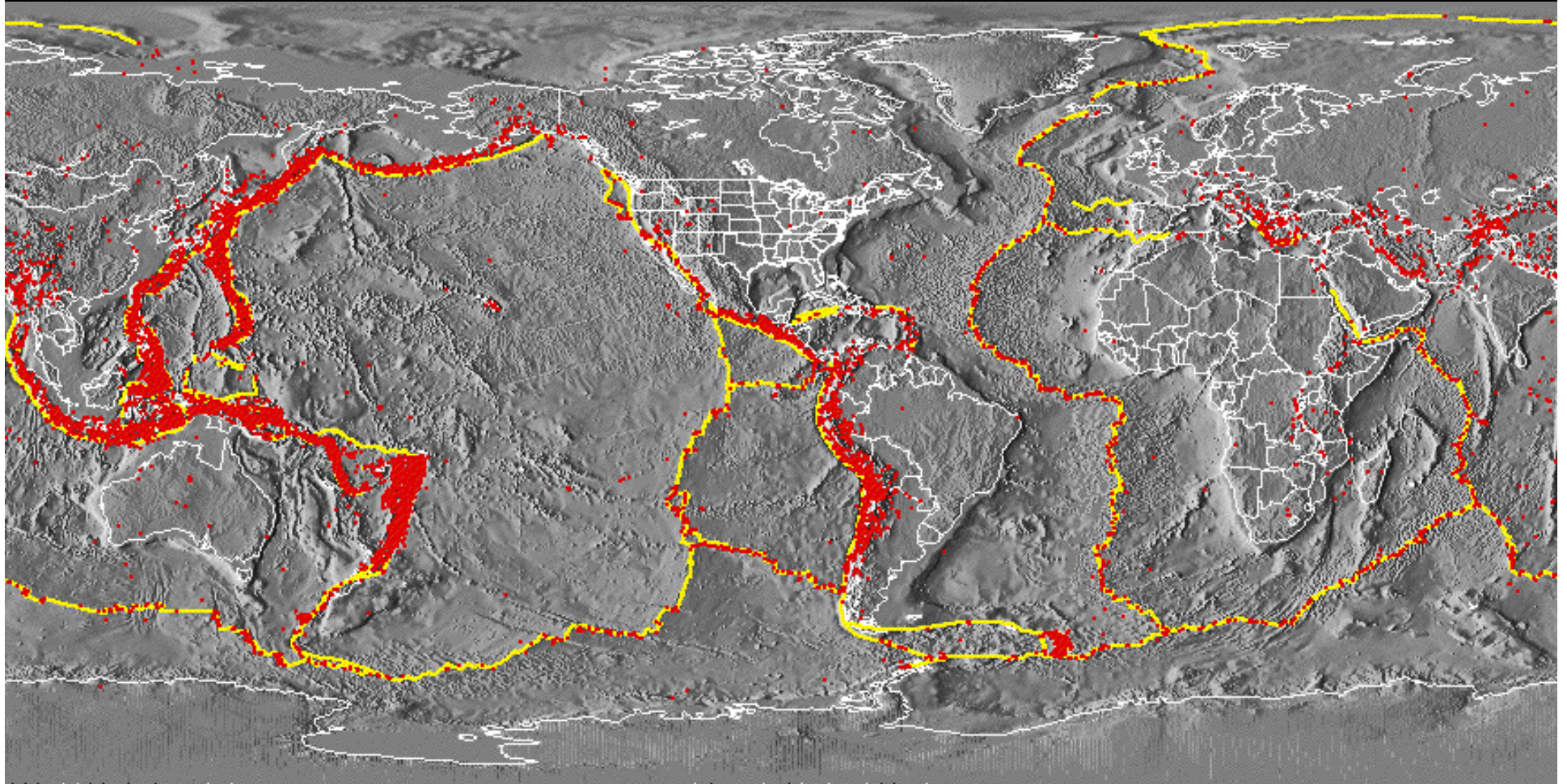
# Present Plate Boundaries and Plate Movements



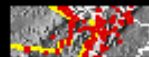


The animation to the left shows a crack where hot molten rock escapes from the interior and pushes apart the surface in opposite directions from the crack. The image on the right shows how such a crack, a "mid-oceanic ridge", runs right down the center of the Atlantic Ocean and powers the spreading of the ocean floor to separate the Americas from Europe and Africa.

# Distribution of Earth Quakes

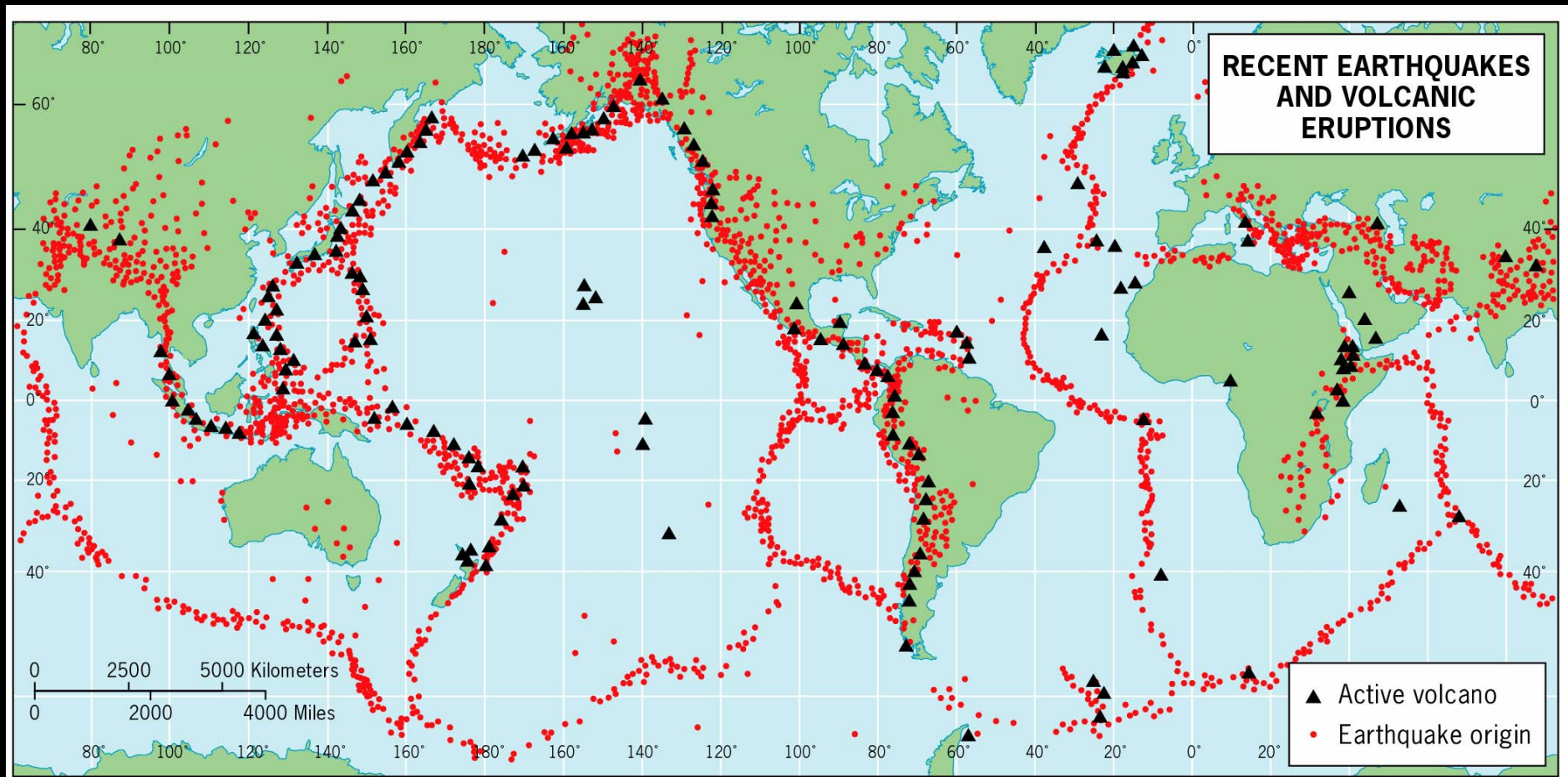


Crustal Plate Boundaries

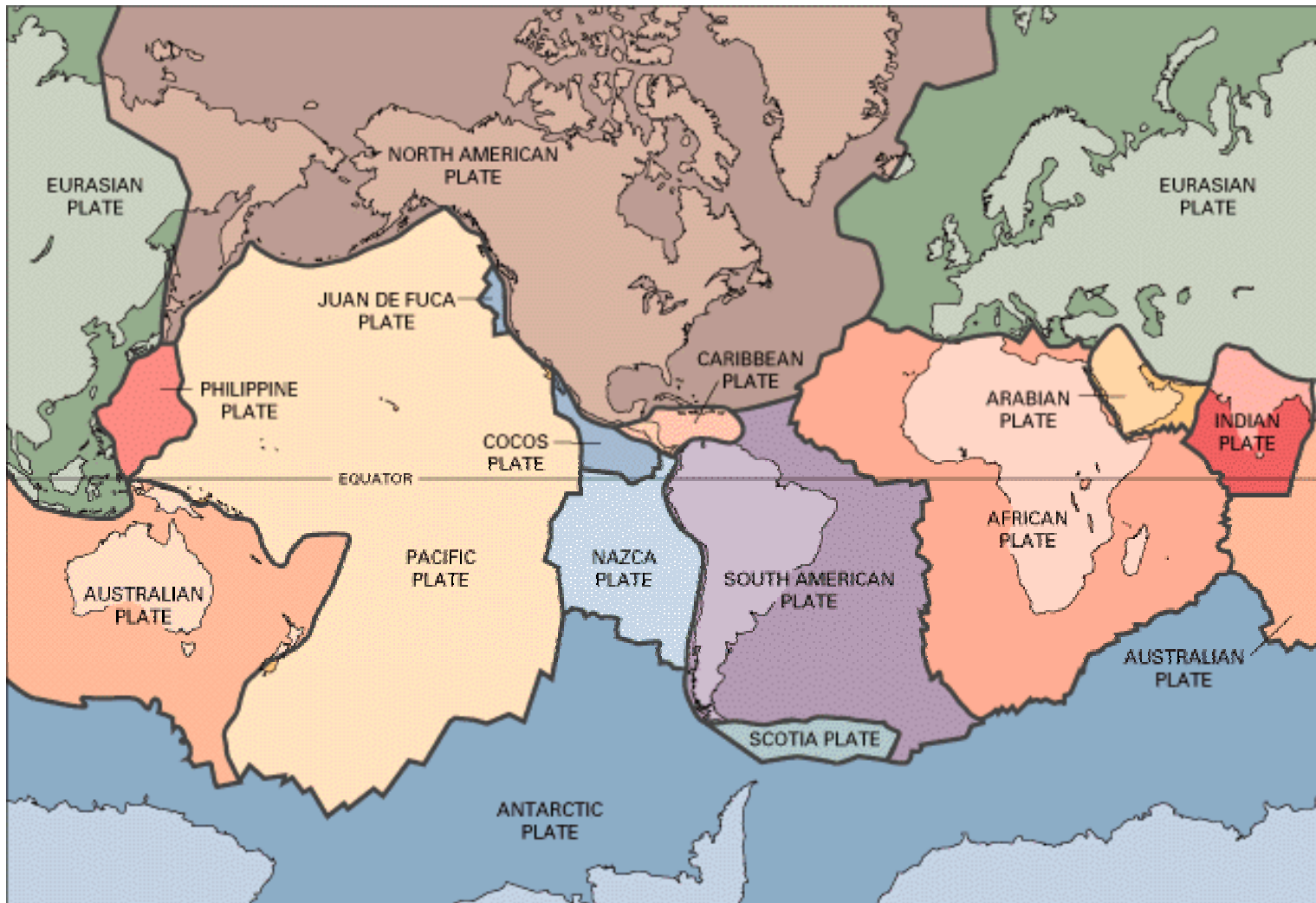


Earthquake Epicenters,  $M > 5$ , 1980-1990  
Coastlines, Political Boundaries

# Distribution of Volcanoes



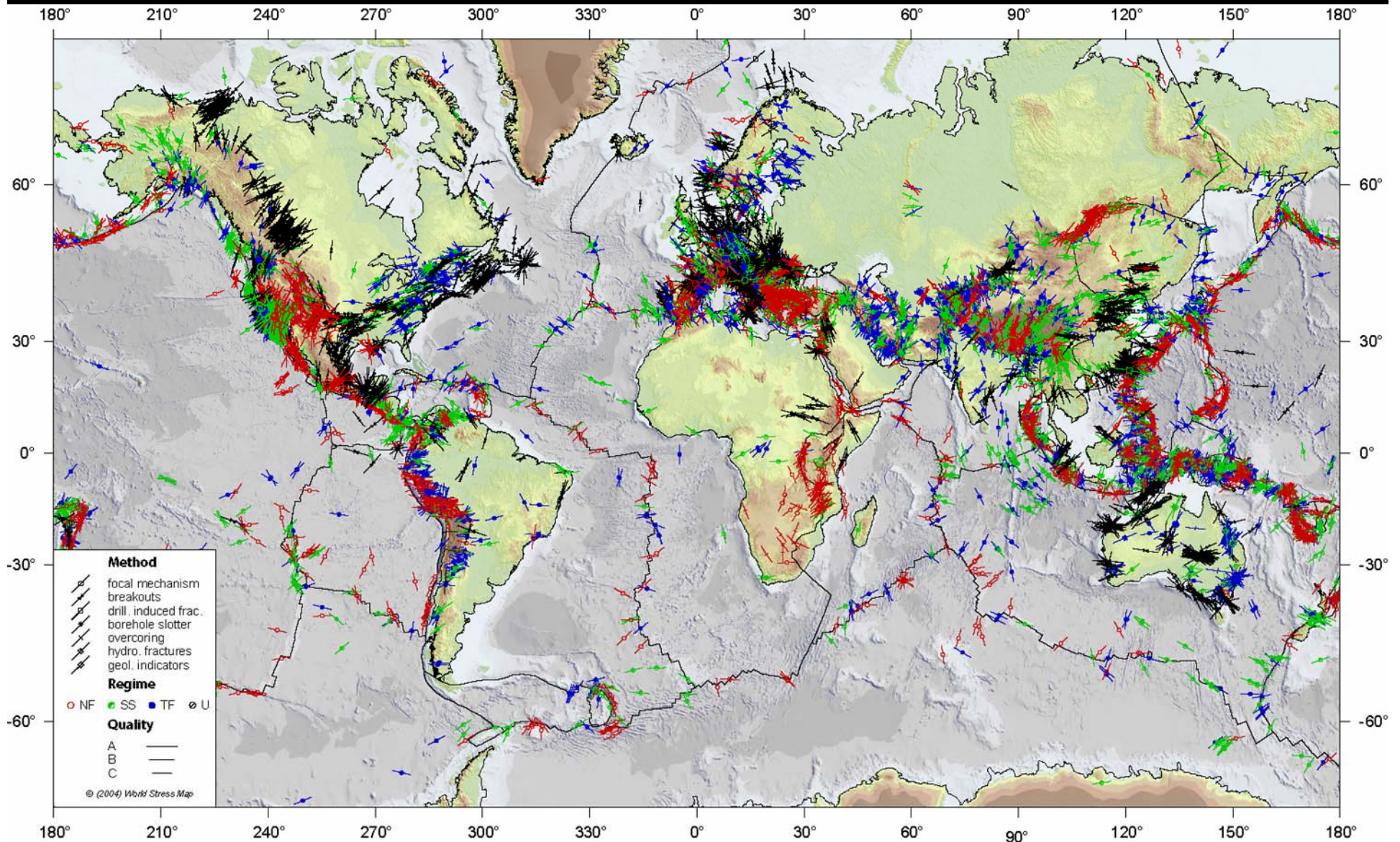
# The Earth's Modern Plates



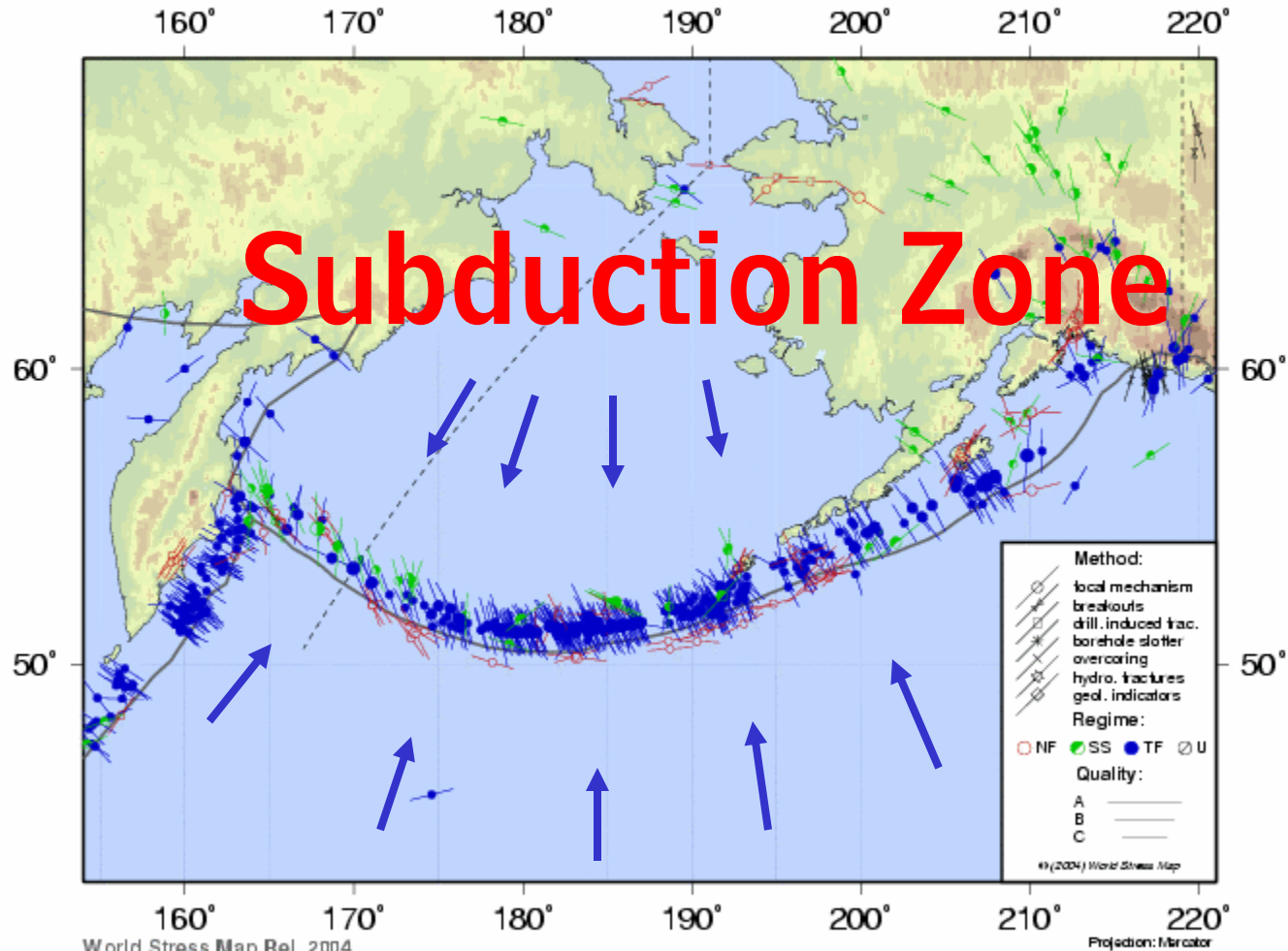
*But, like everything else, nothing stays the same for long. Plates are always changing: appearing, growing, transforming, and disappearing. Remember, though that while ocean basins subduct and disappear, continents do not.*



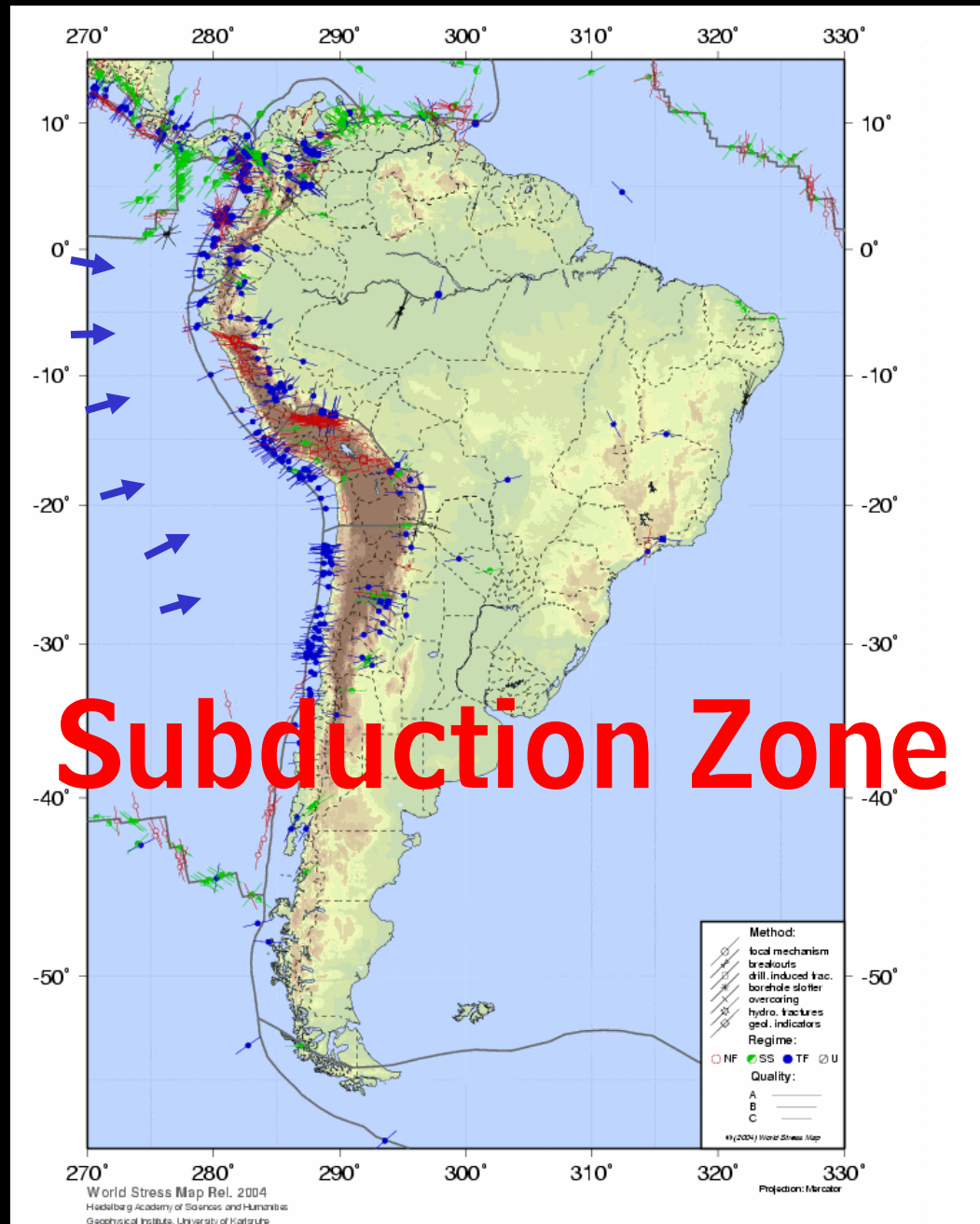
# Look at some of the World's Active Zones



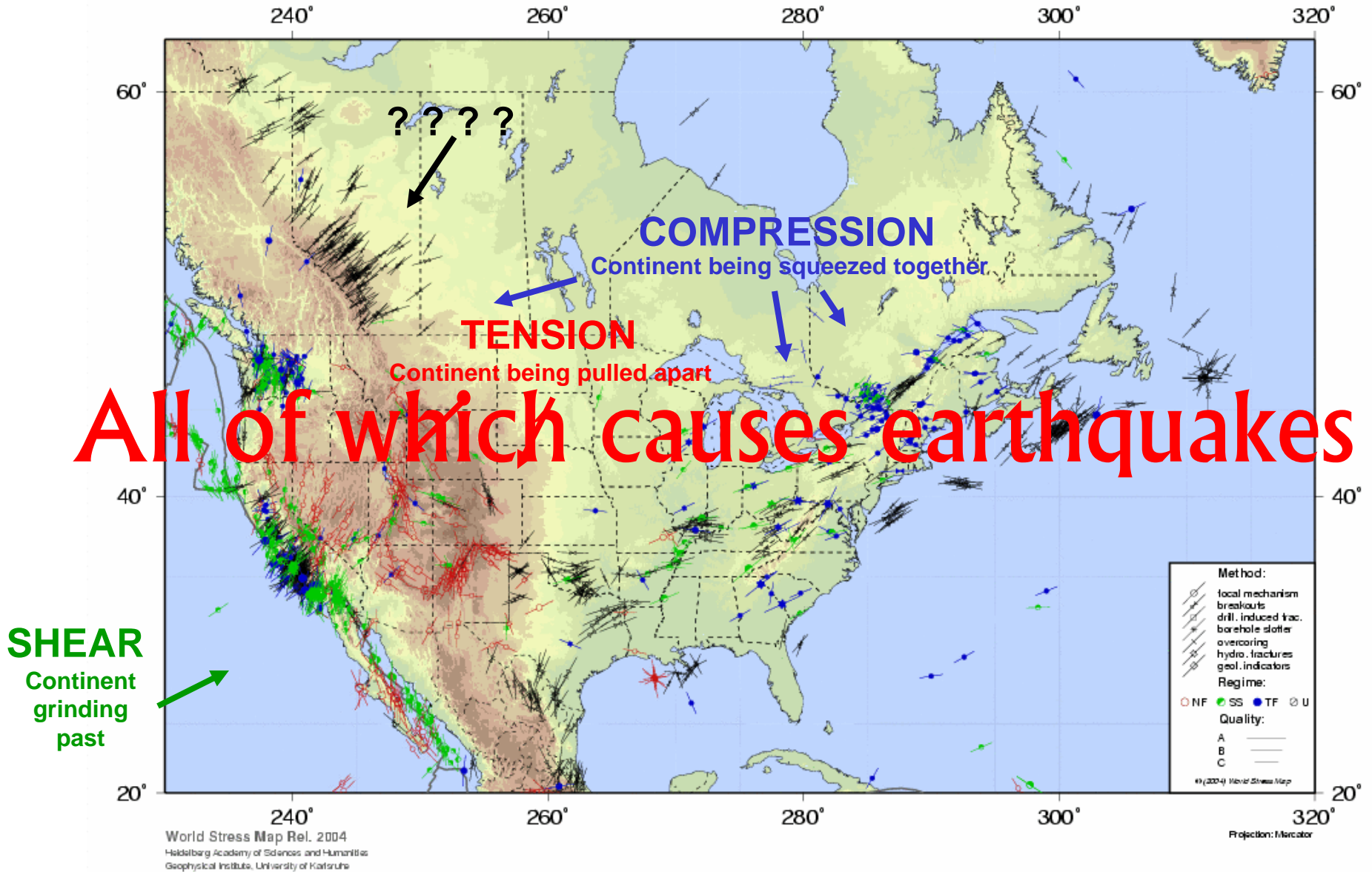
# Aleutian Stress Patterns



# South American Stress Patterns



# North American Stress Patterns



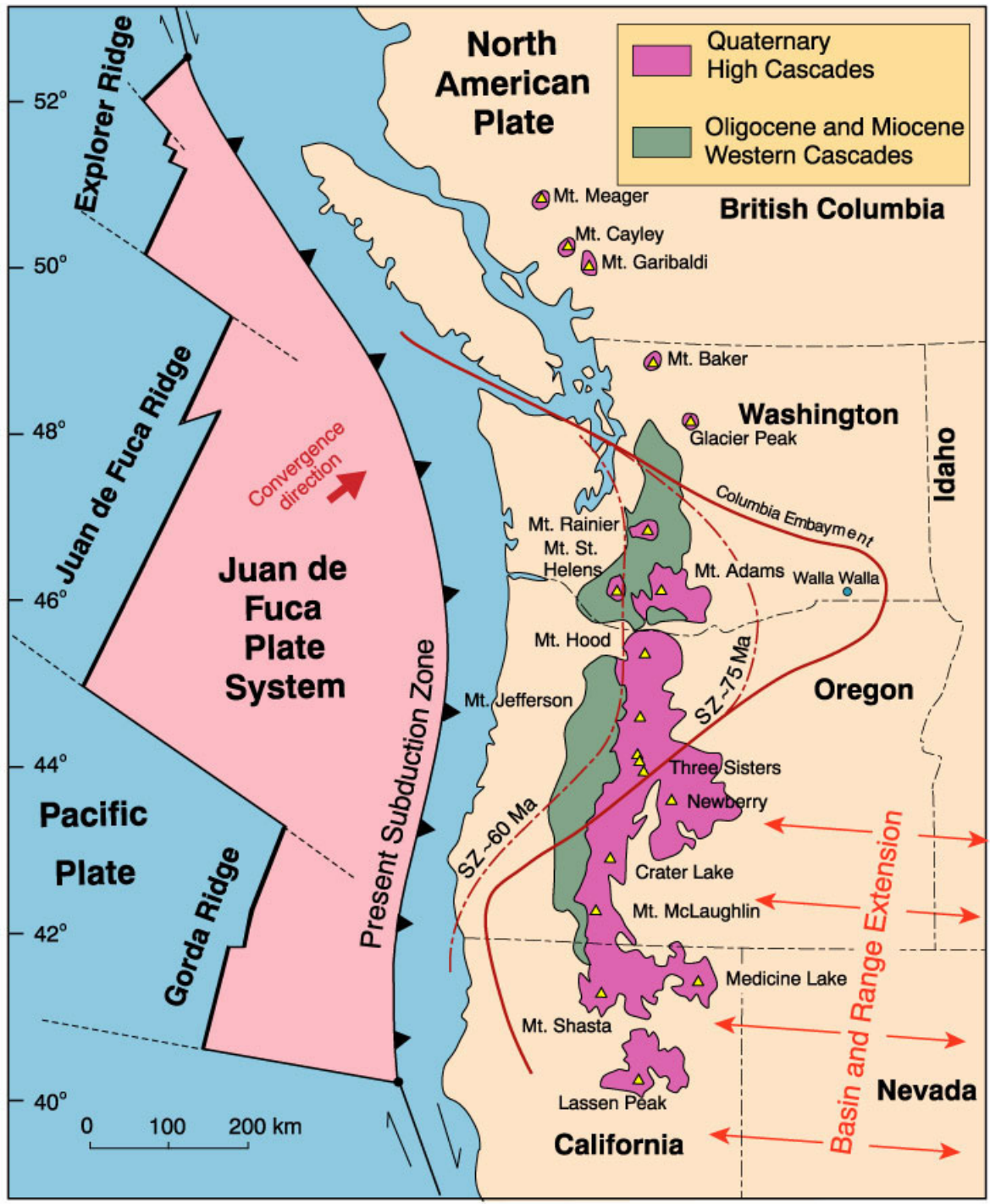
# Why is the Western United States so Geologically Active?

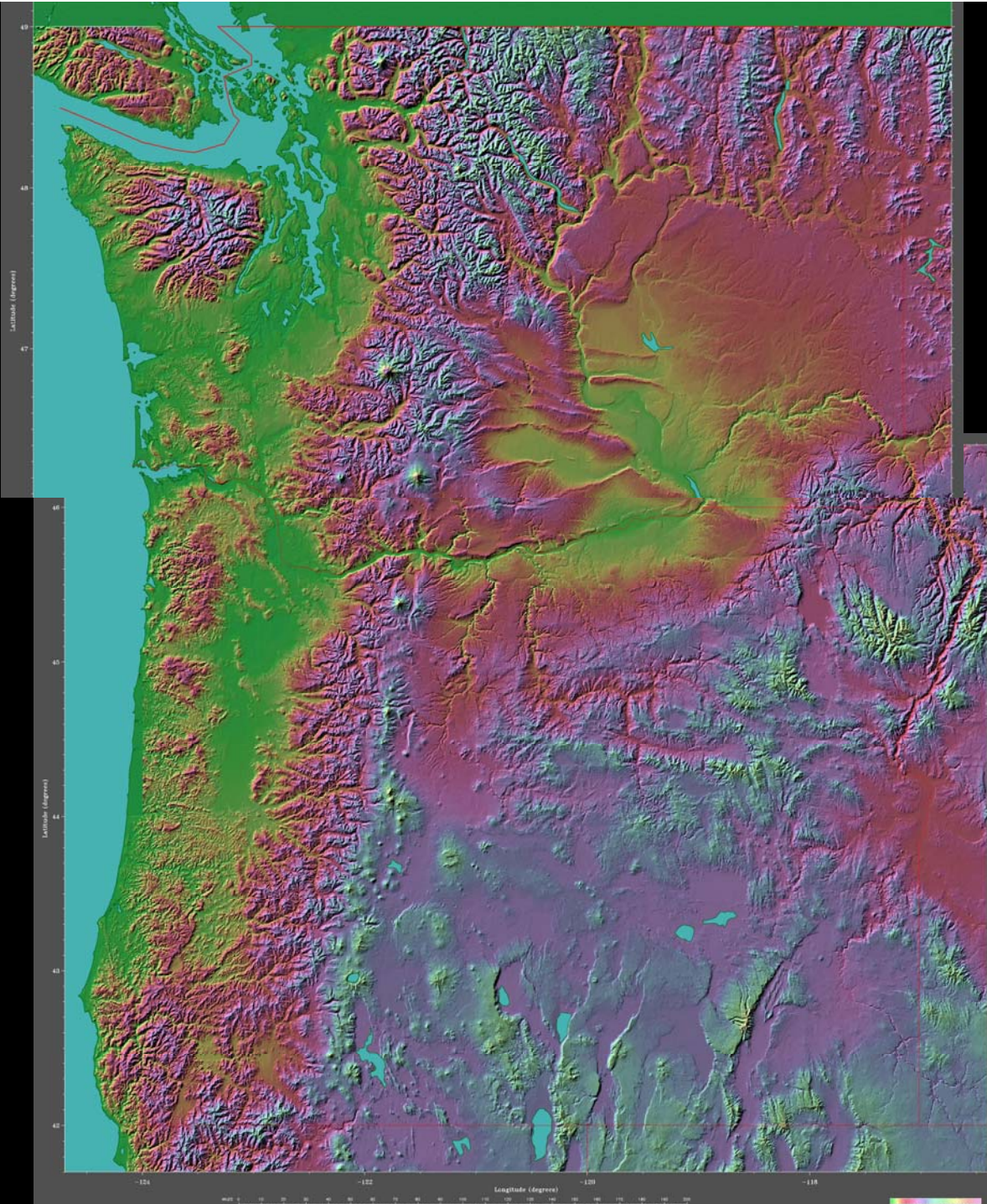
Convergent



Transform  
Plates slide past each other

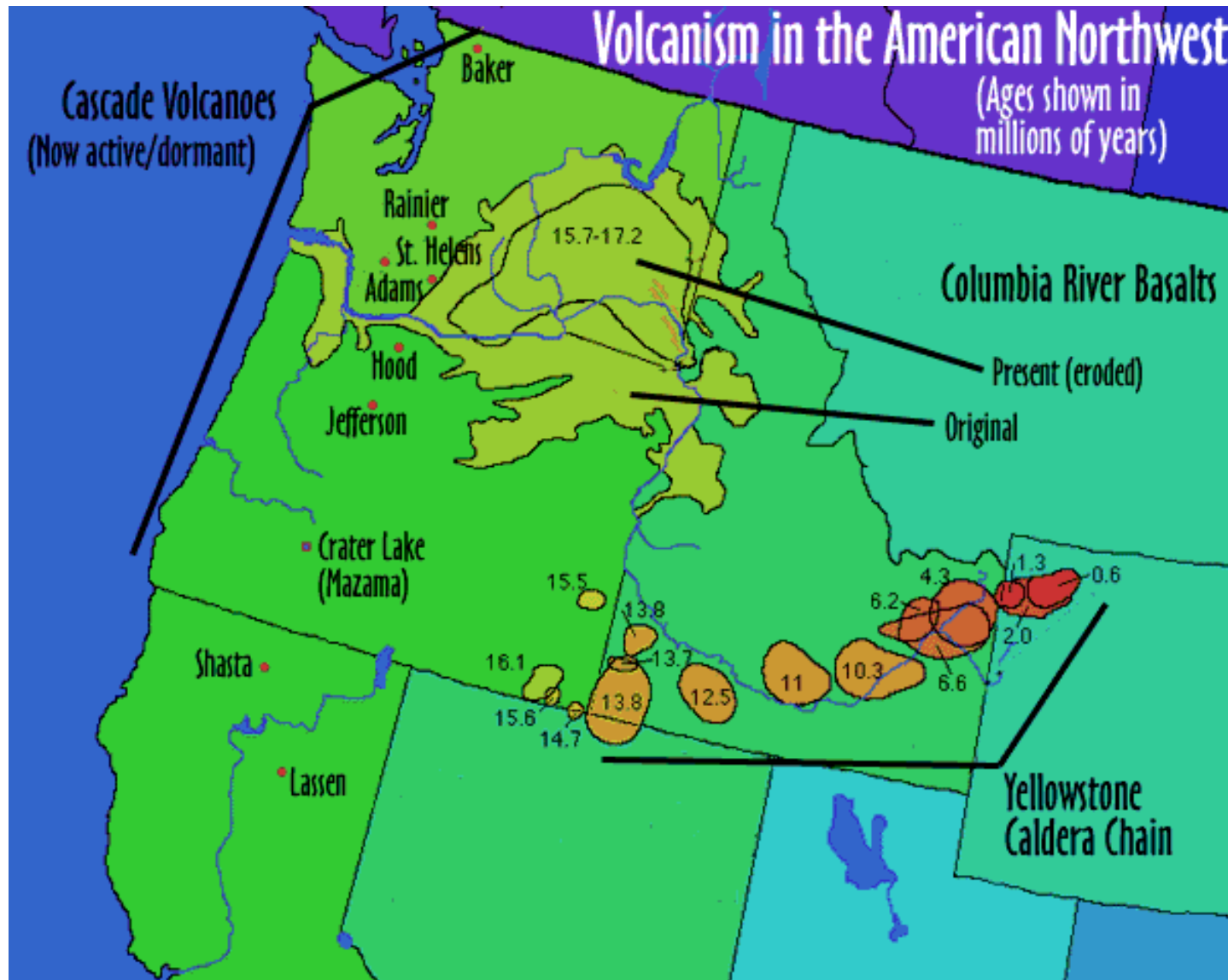
Divergent





relief\_maps/washington\_map\_400.gif

# YELLOWSTONE CALDERA – WYOMING, U.S.A.





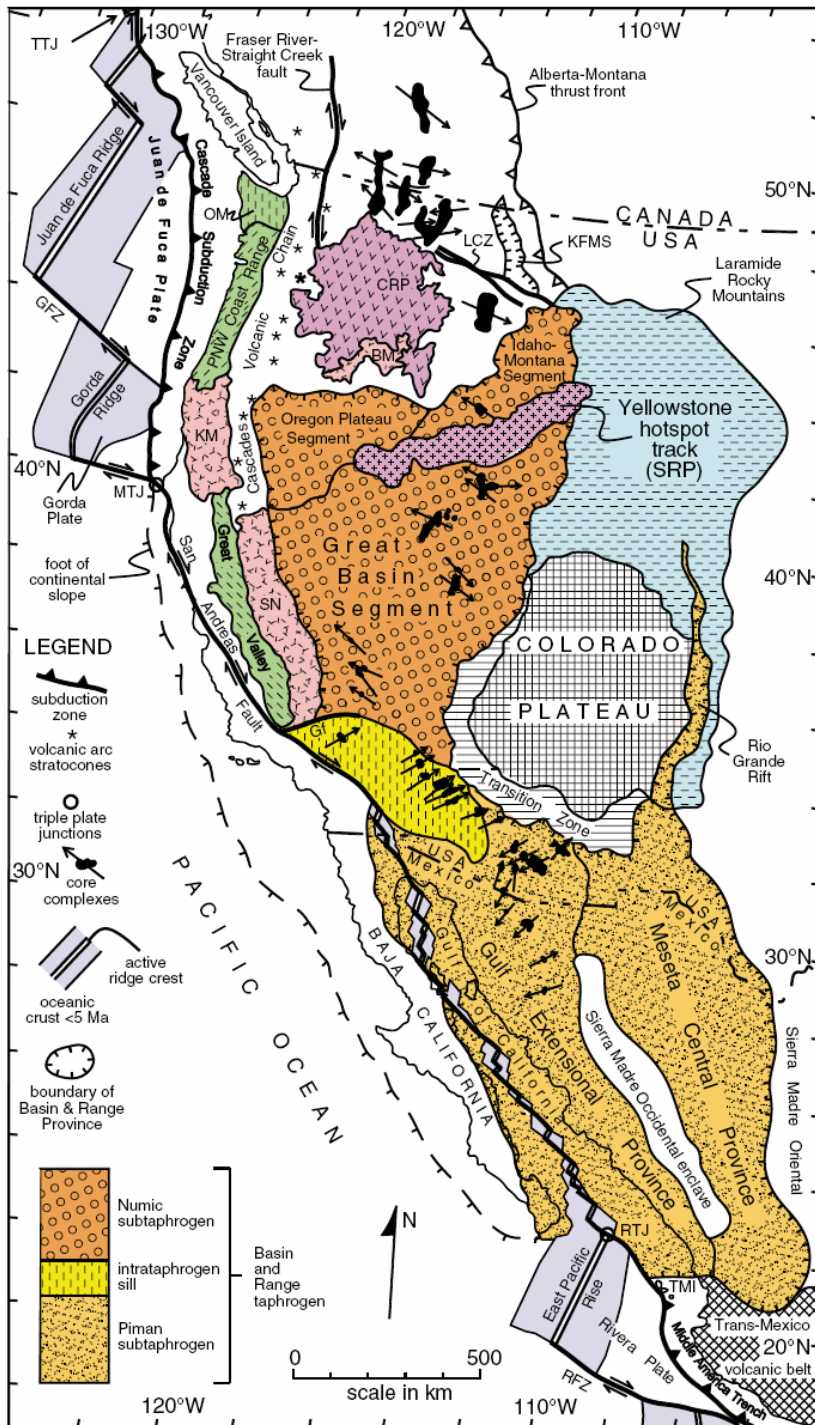
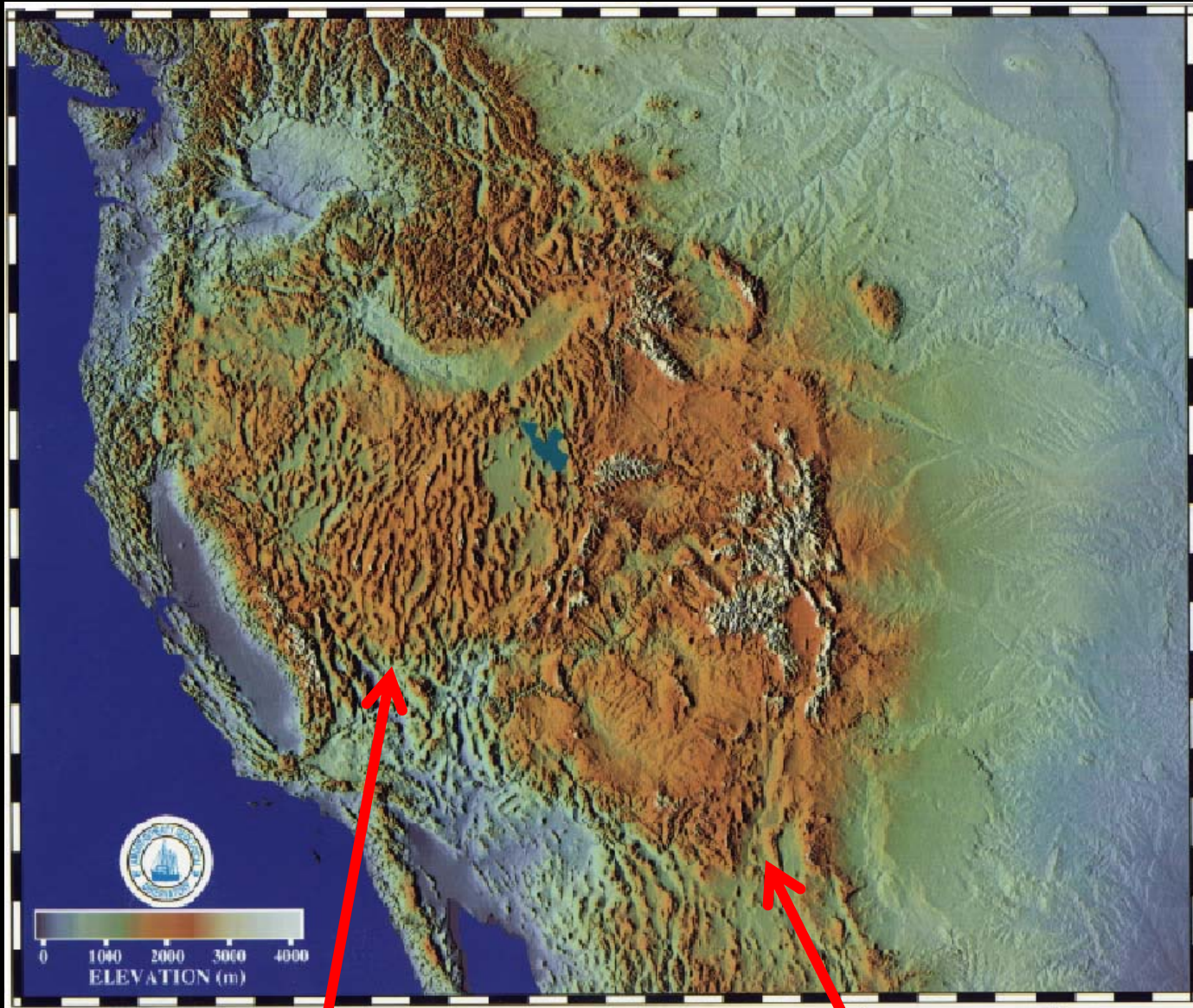


Figure 1. Position of the Great Basin in the western Cordillera (adapted after Dickinson, 2002). Modern triple plate junctions: MTJ—Mendocino; RTJ—Rivera; TTJ—Tofino. Other abbreviations: BM—Blue Mountains; CRP—Columbia River Plateau (check pattern and red color denote extent of Columbia River Basalt lavas); KFMS—Kisenehn-Flathead-Mission-Swan extensional Paleogene basins; KM—Klamath Mountains; LCZ—Lewis and Clark fault zone; PNW—Pacific Northwest; RFZ—Rivera Fracture Zone; SN—Sierra Nevada; SRP—Snake River Plain; TMI—Tres Marias Islands (cross pattern and red color denote extent of bimodal volcanic suite).

- *Continental extension (western U.S.)*



Basin and Range

Rio Grande rift



# Why Does Rocky Mountain Building Penetrate So Far into the Interior of N.A.?

Convergent

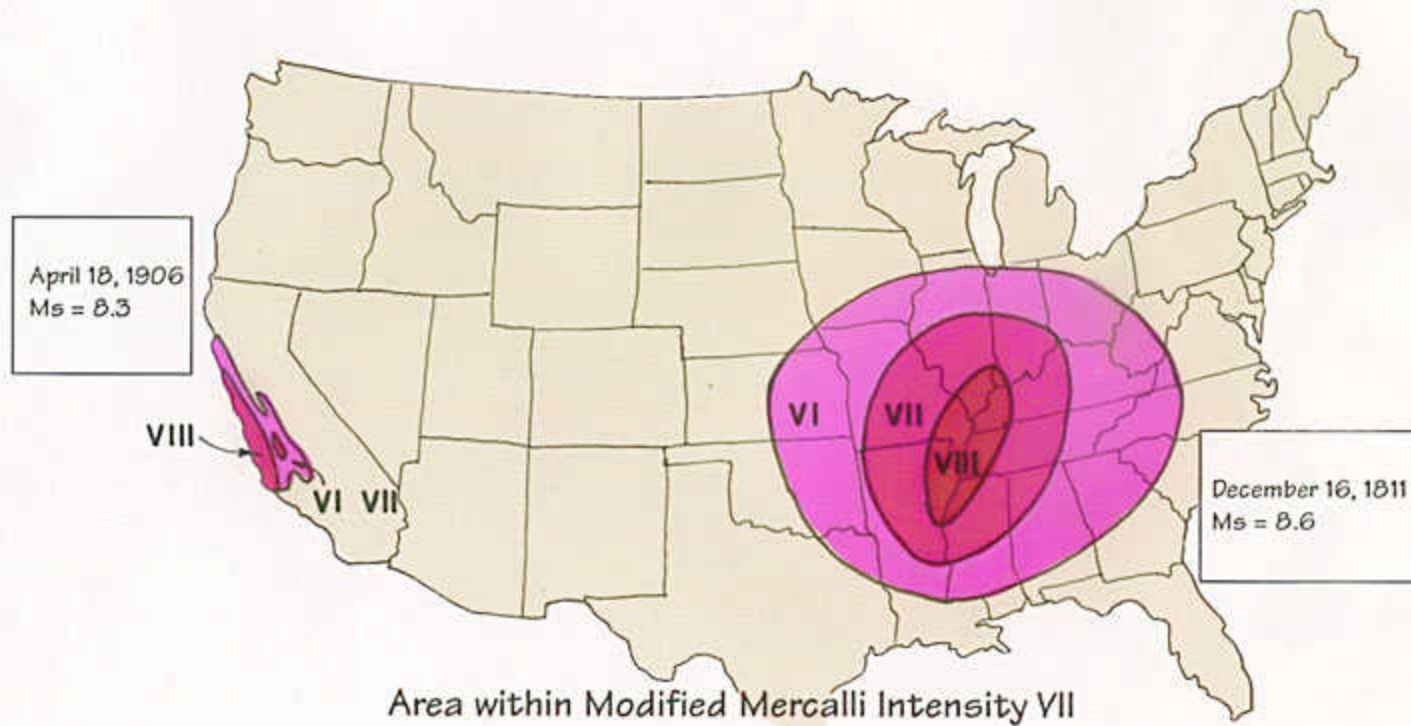


Transform  
Plates slide past each other

Divergent

# But areas that do not look geologically active may be

COMPARISON OF AREAS OF DAMAGE  
FROM THE NEW MADRID AND SAN FRANCISCO EARTHQUAKES

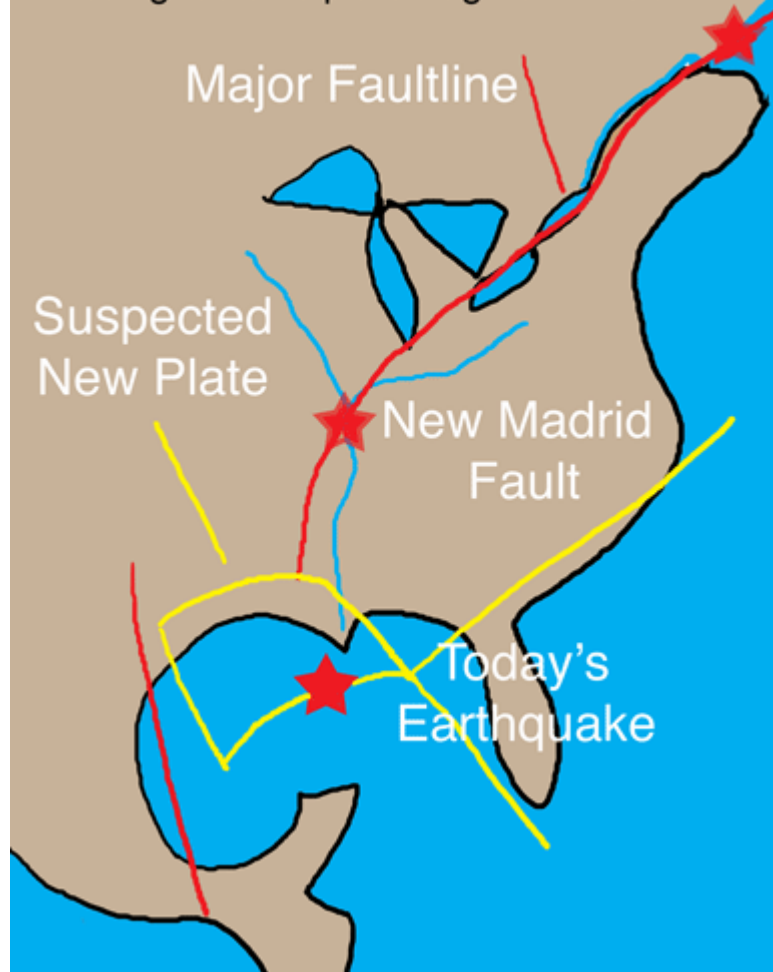


New Madrid ~ 600,000 km<sup>2</sup>

San Francisco ~ 30,000 km<sup>2</sup>

# Jack Reed's Theory

Missing tectonic plate fragment in Gulf

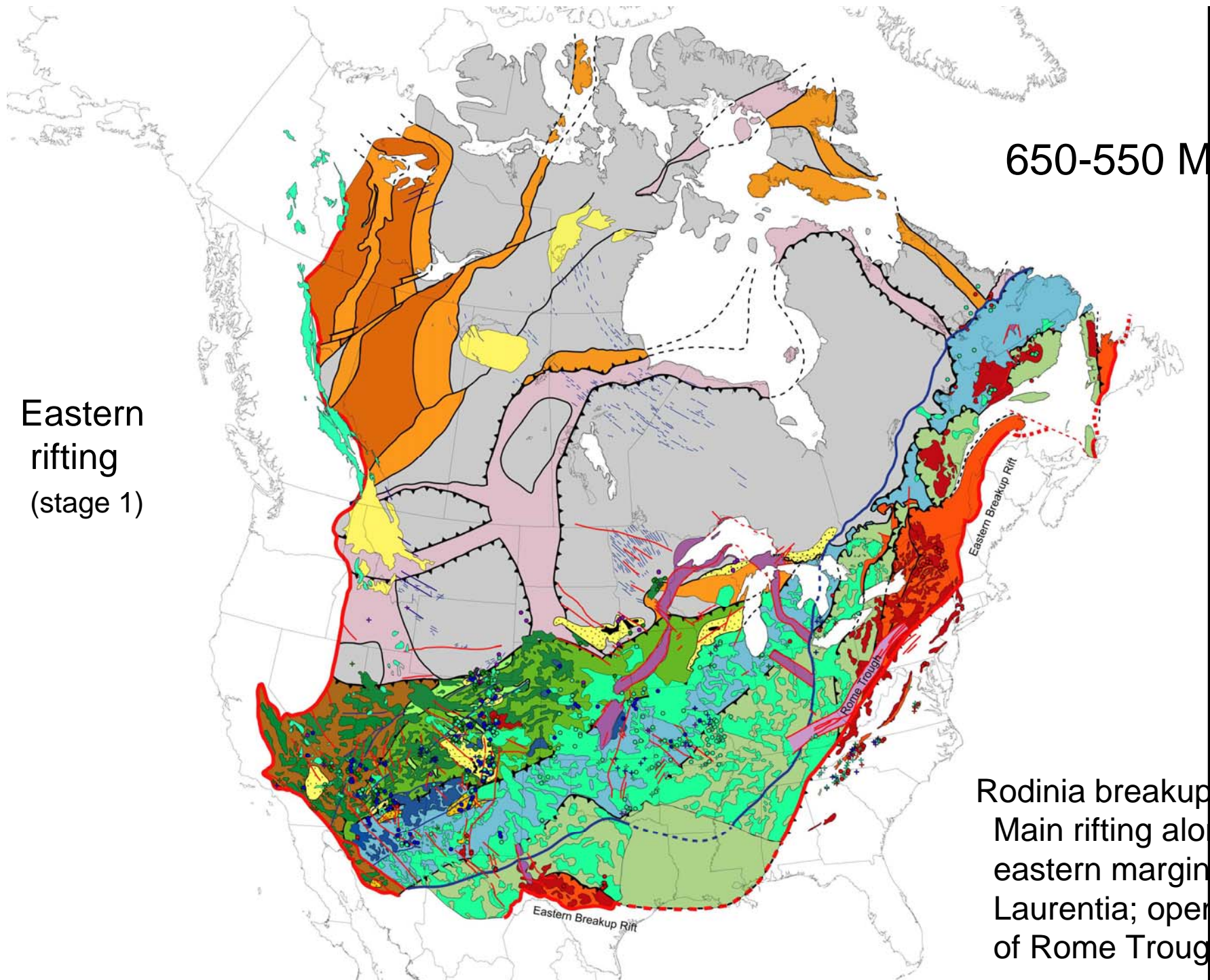


Major Faultline

Suspected  
New Plate

New Madrid  
Fault

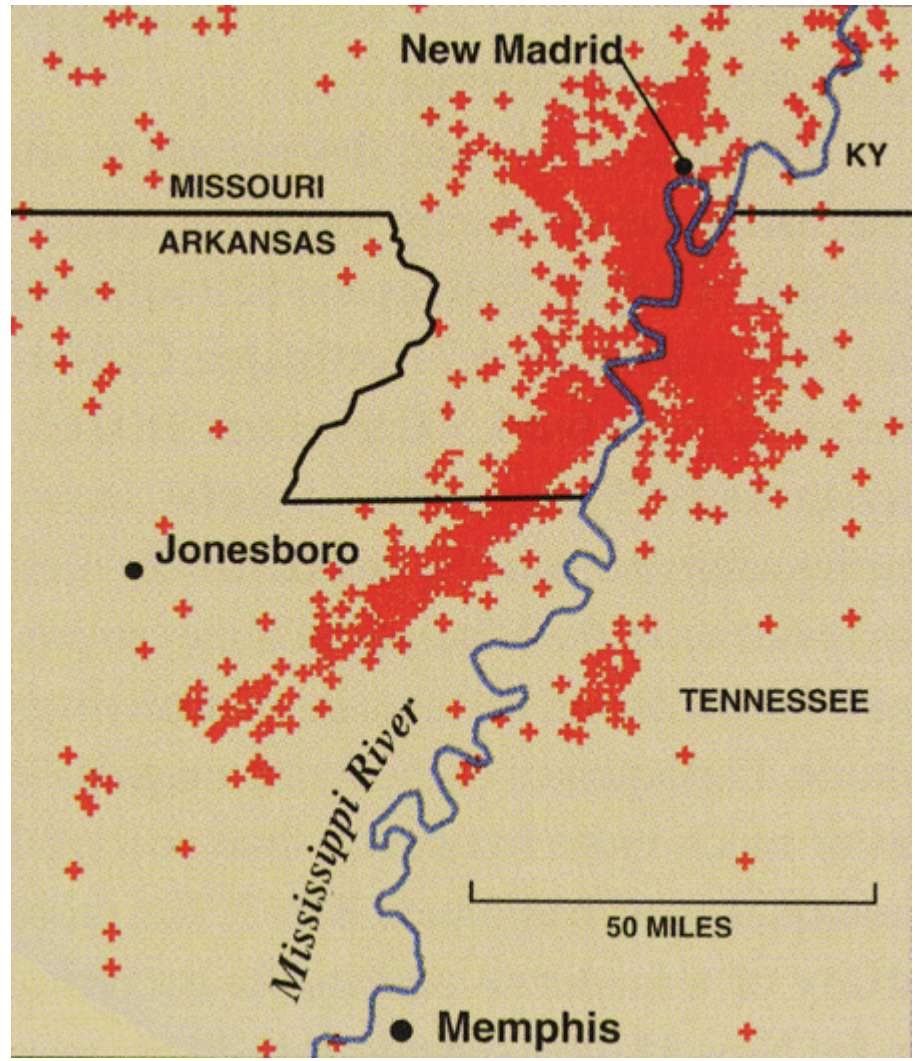
Today's  
Earthquake



Eastern rifting (stage 1)

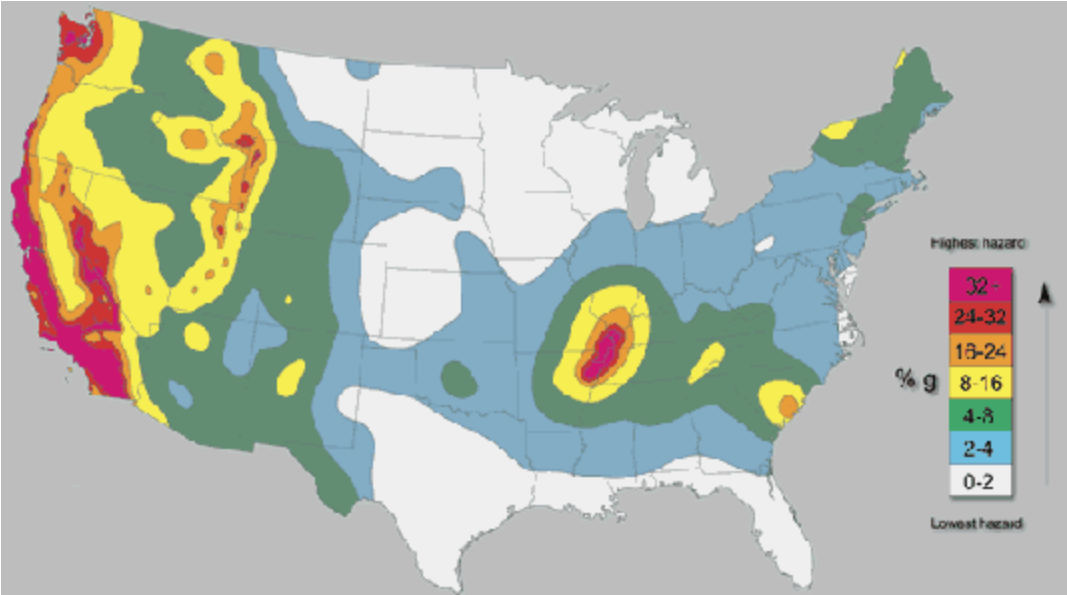
650-550 M

Rodinia breakup  
Main rifting along eastern margin of Laurentia; opening of Rome Trough

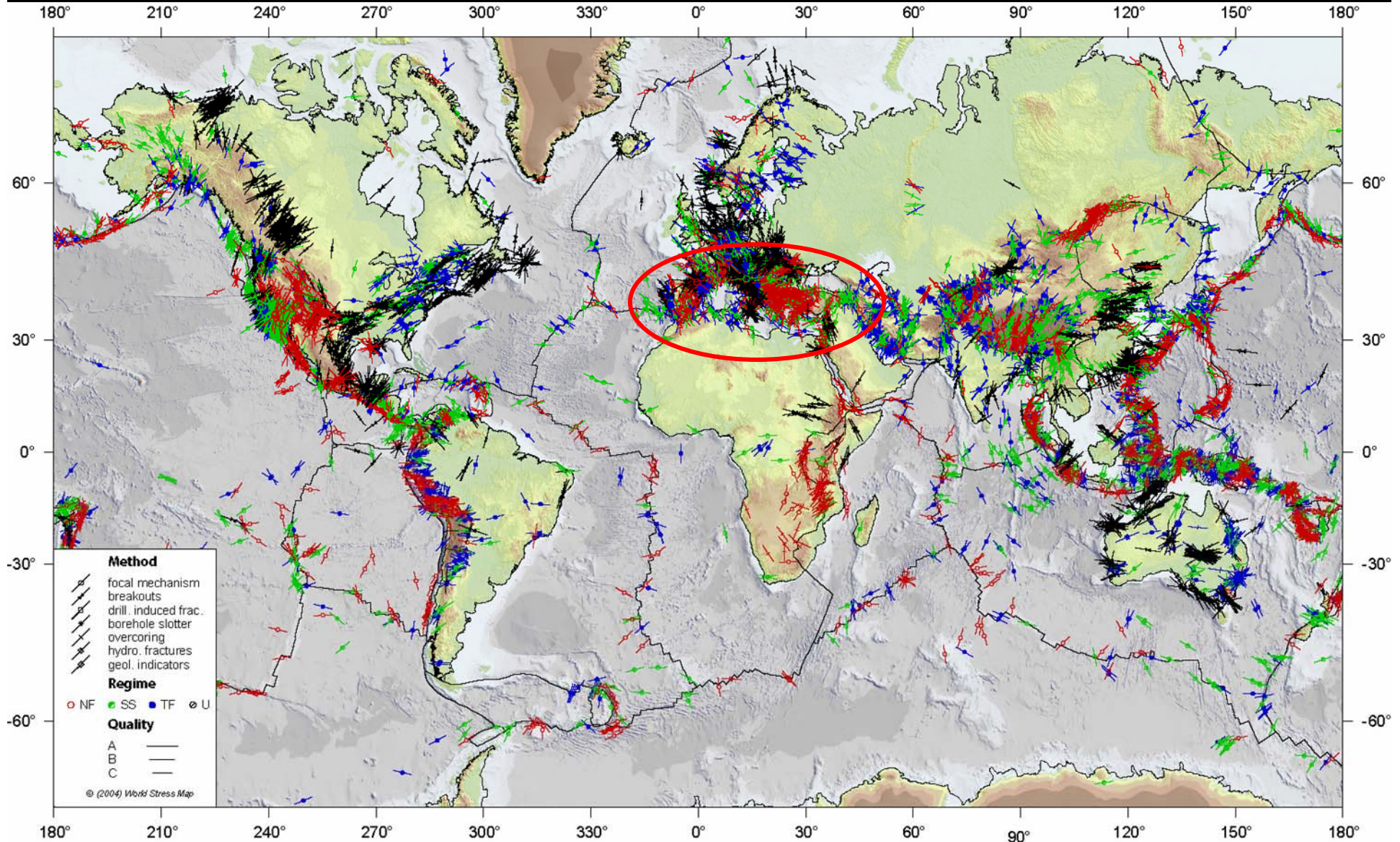




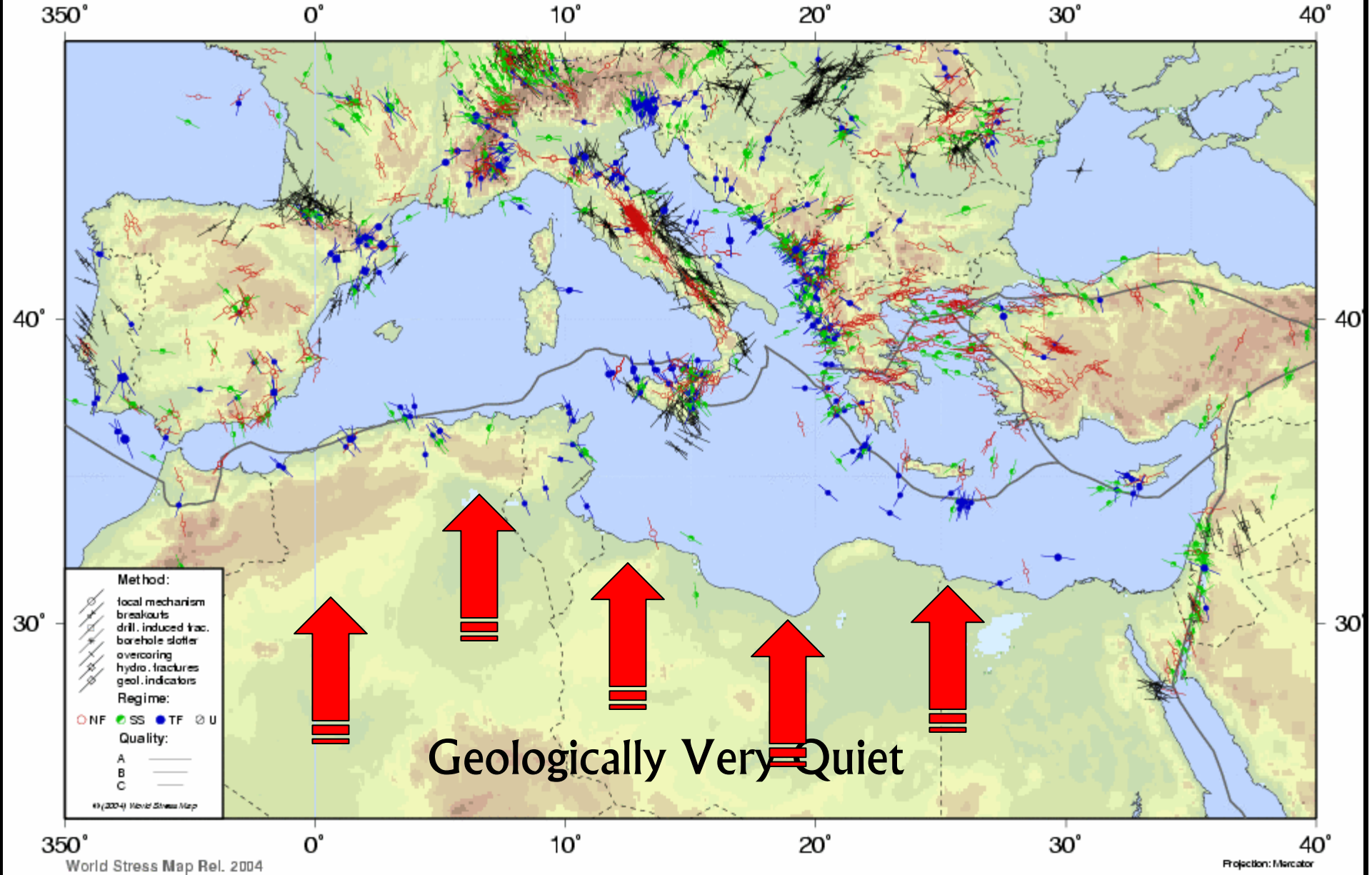


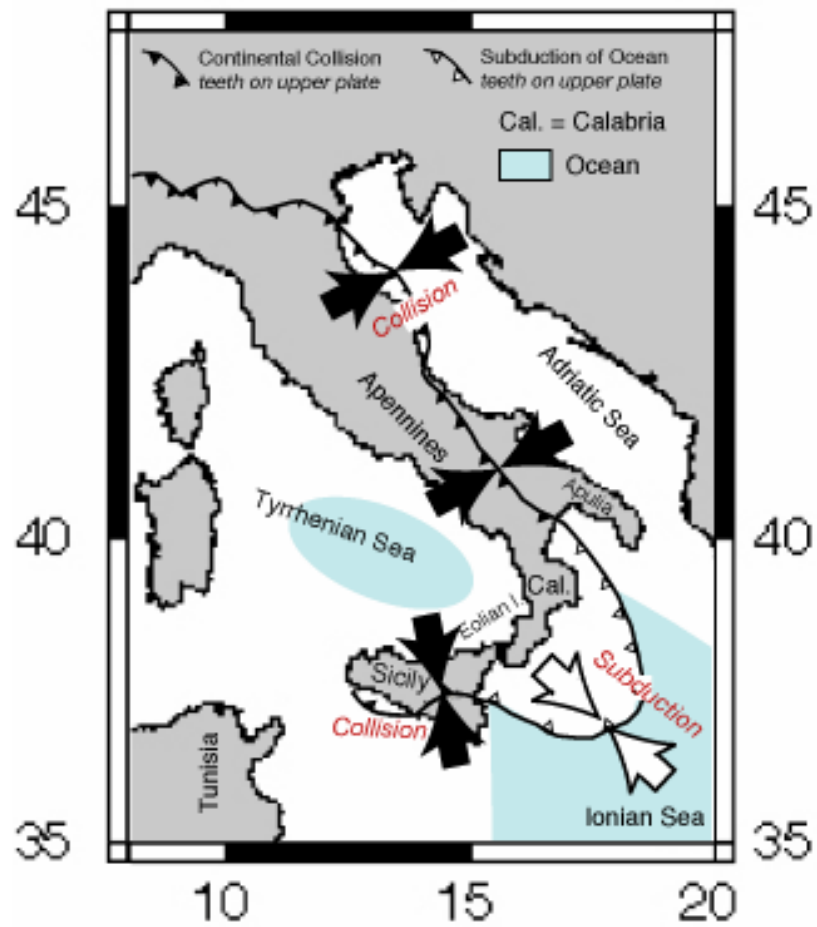


# Others Areas of High Stress in the World



# Mediterranean Stress Patterns





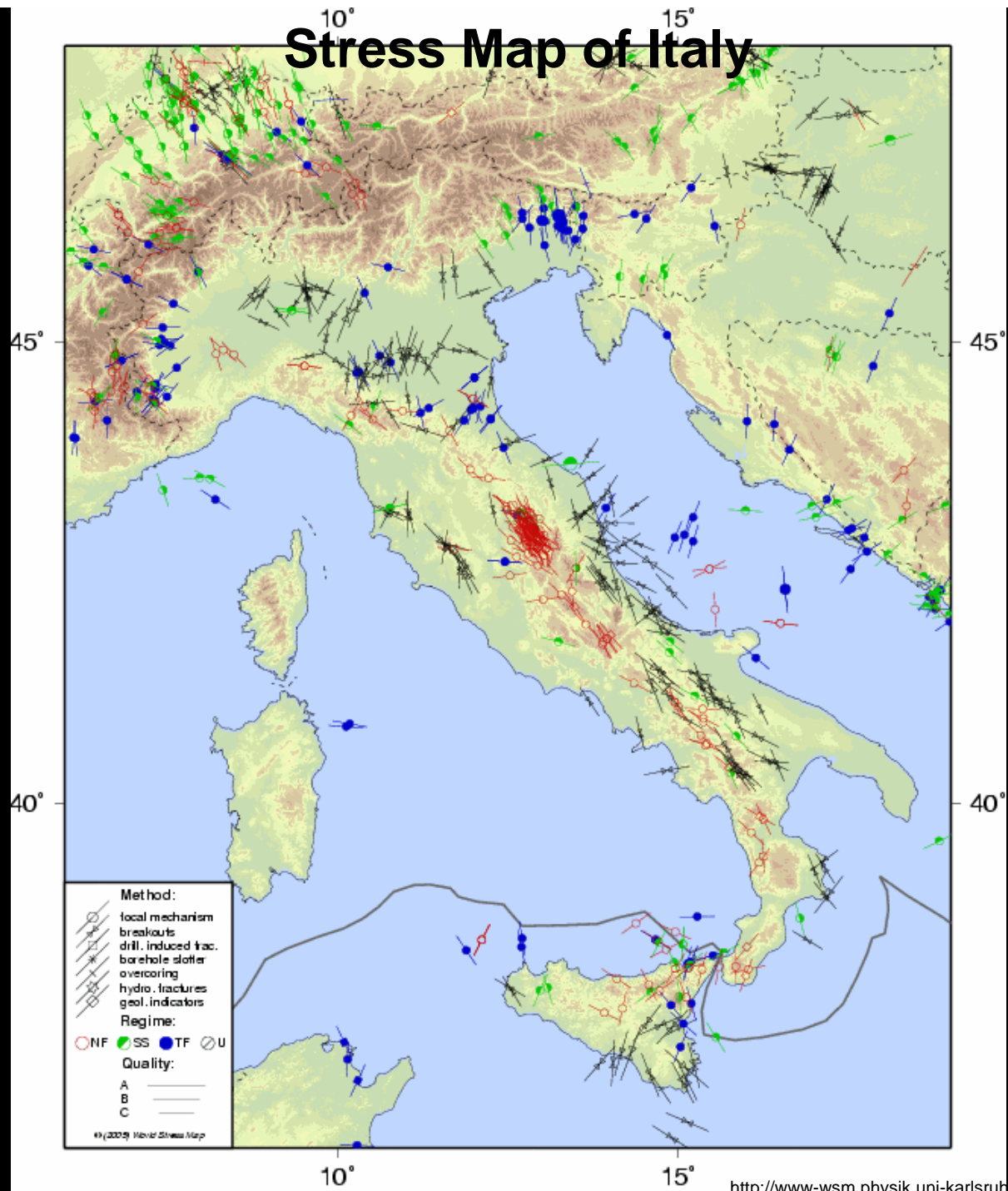
### The cause of the Izmit earthquake



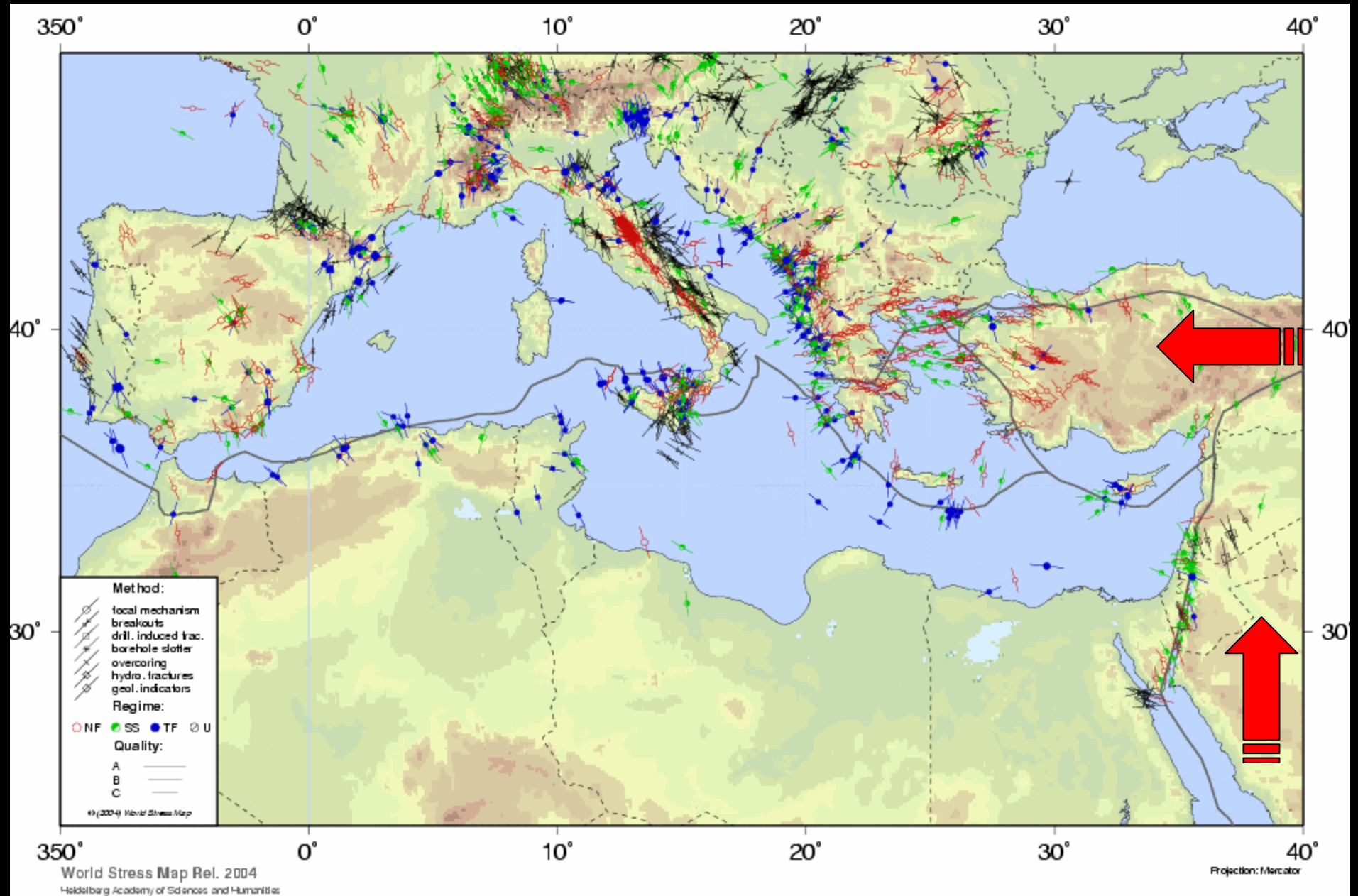
The Arabian/African and Eurasian plates are moving north and south towards each other. As a result, Turkey is being squeezed out westwards. The latest movement in this process took place on the North Anatolian fault, causing the Izmit earthquake.

Key:  
North Anatolian fault ■ East Anatolian fault ■ Aegean fault ■

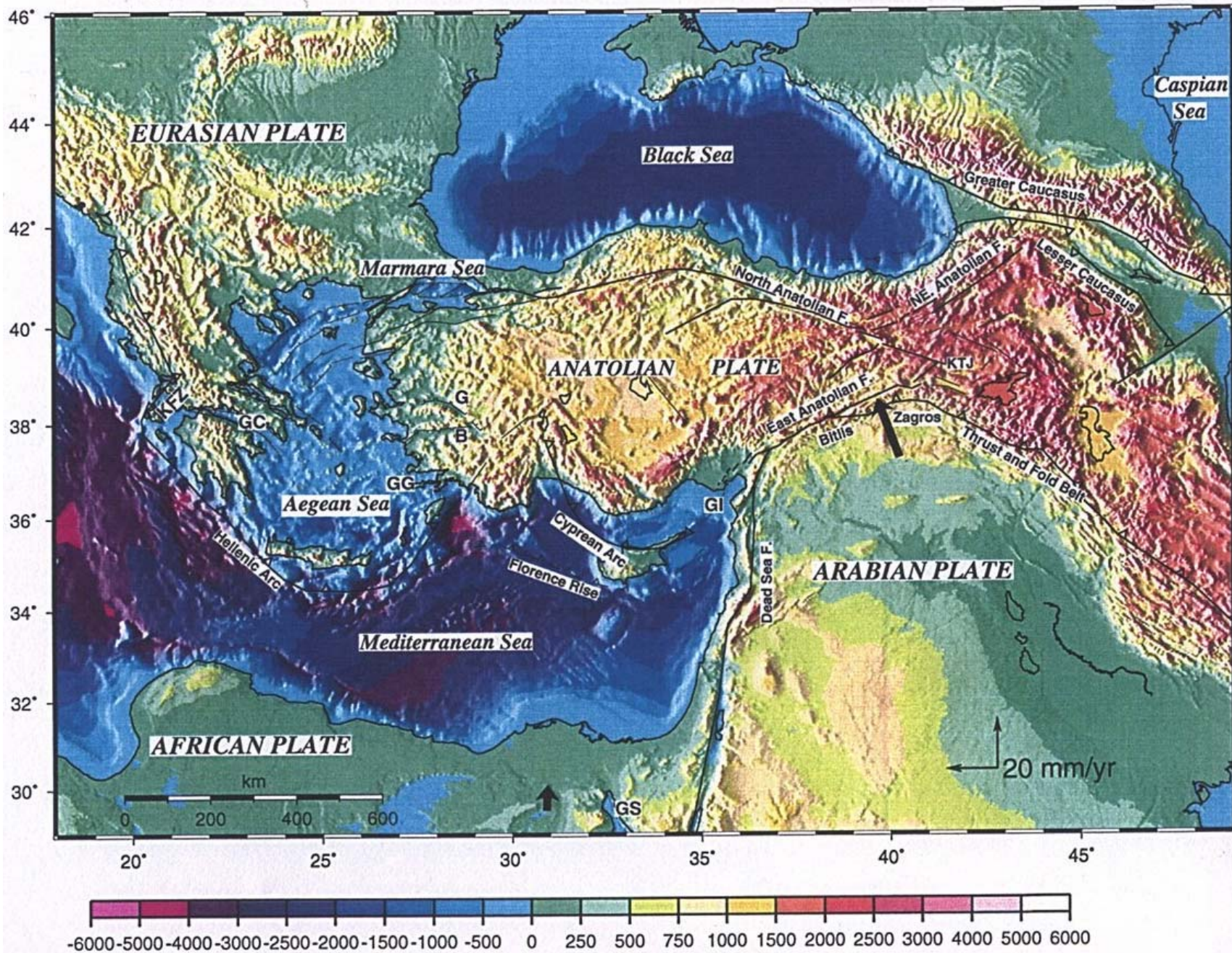
# Stress Map of Italy



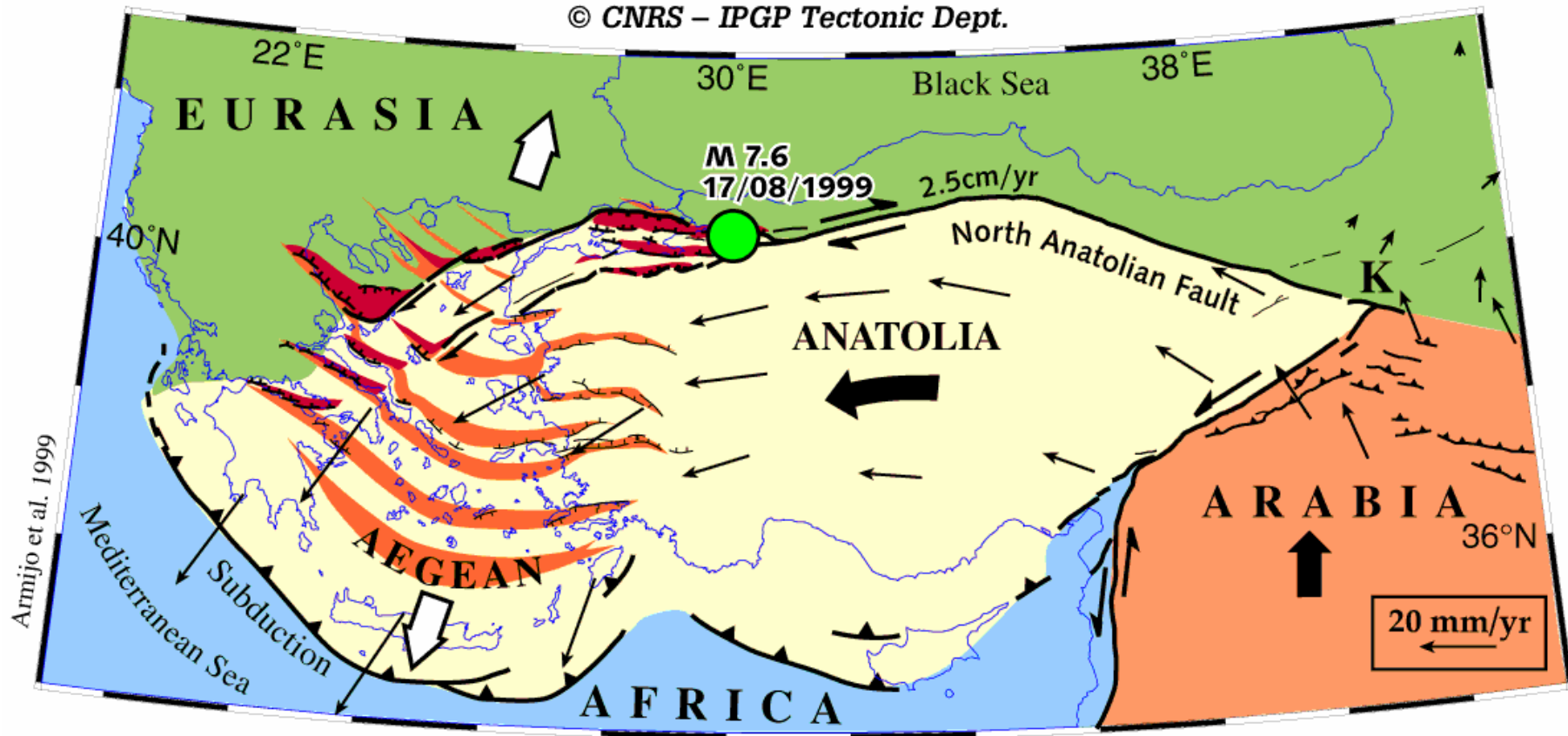
**Northern Africa is quiet, but Europe is not.  
Turkey is being squeezed in the middle.**



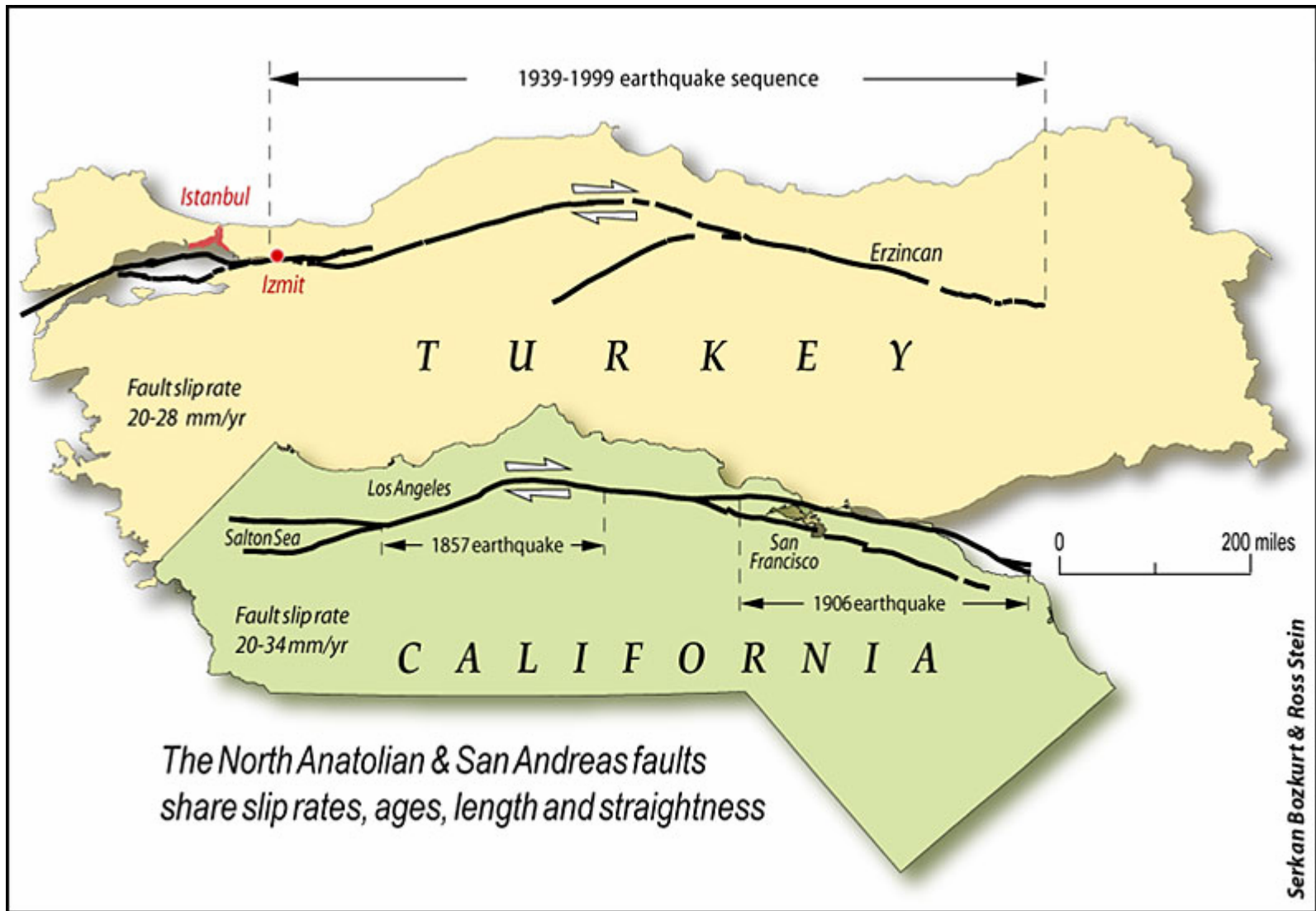




© CNRS – IPGP Tectonic Dept.

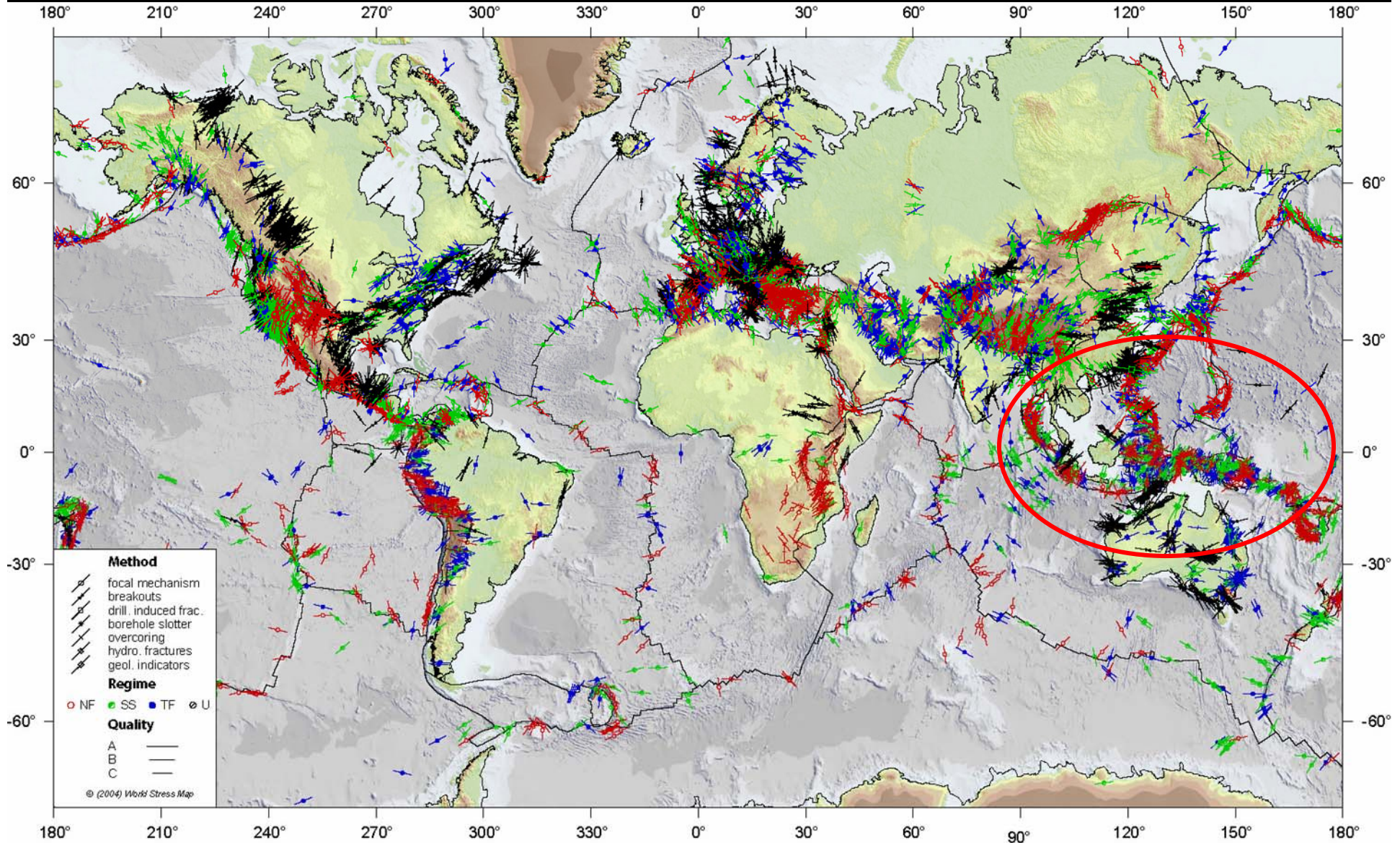


Armijo et al. 1999

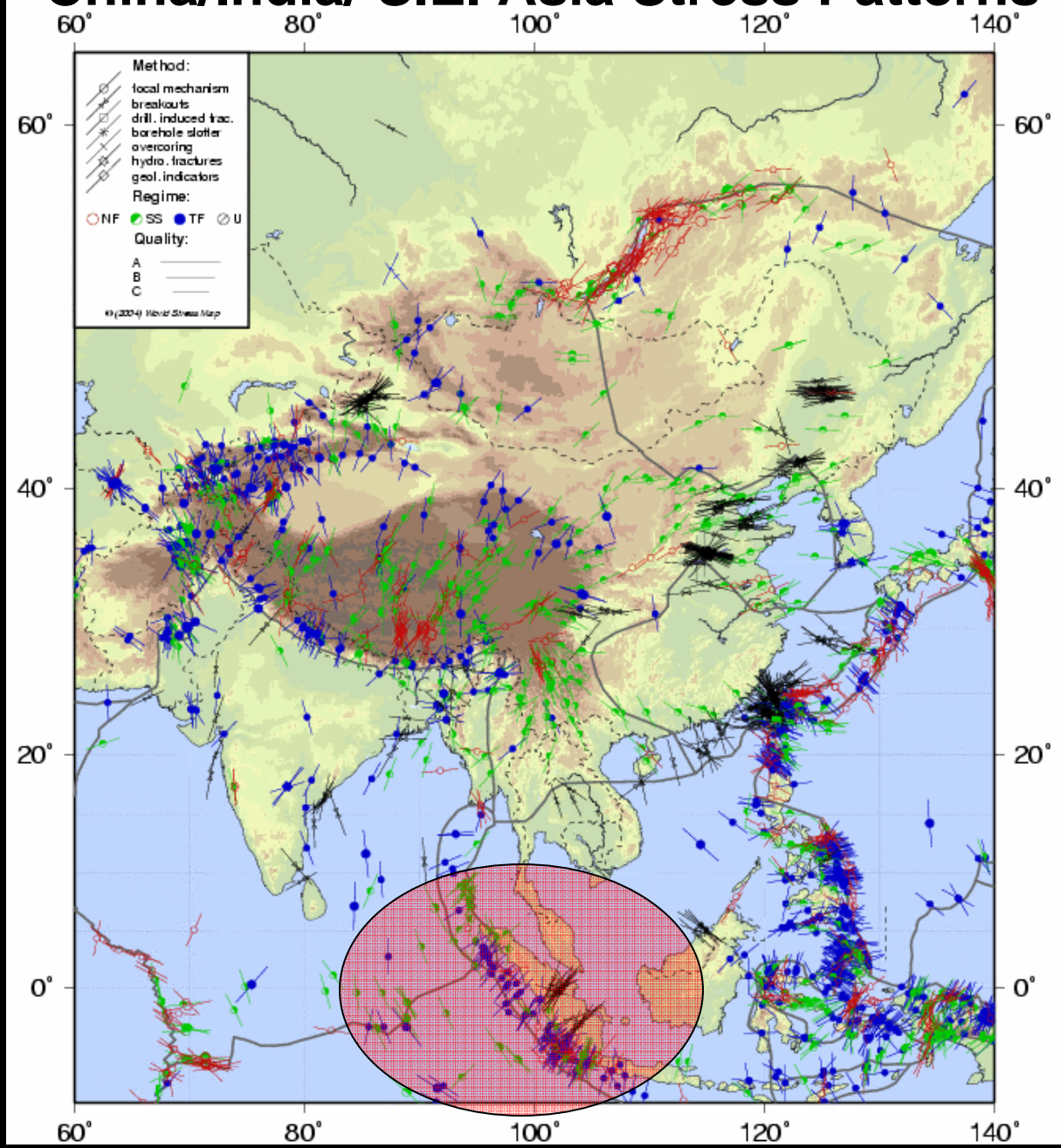




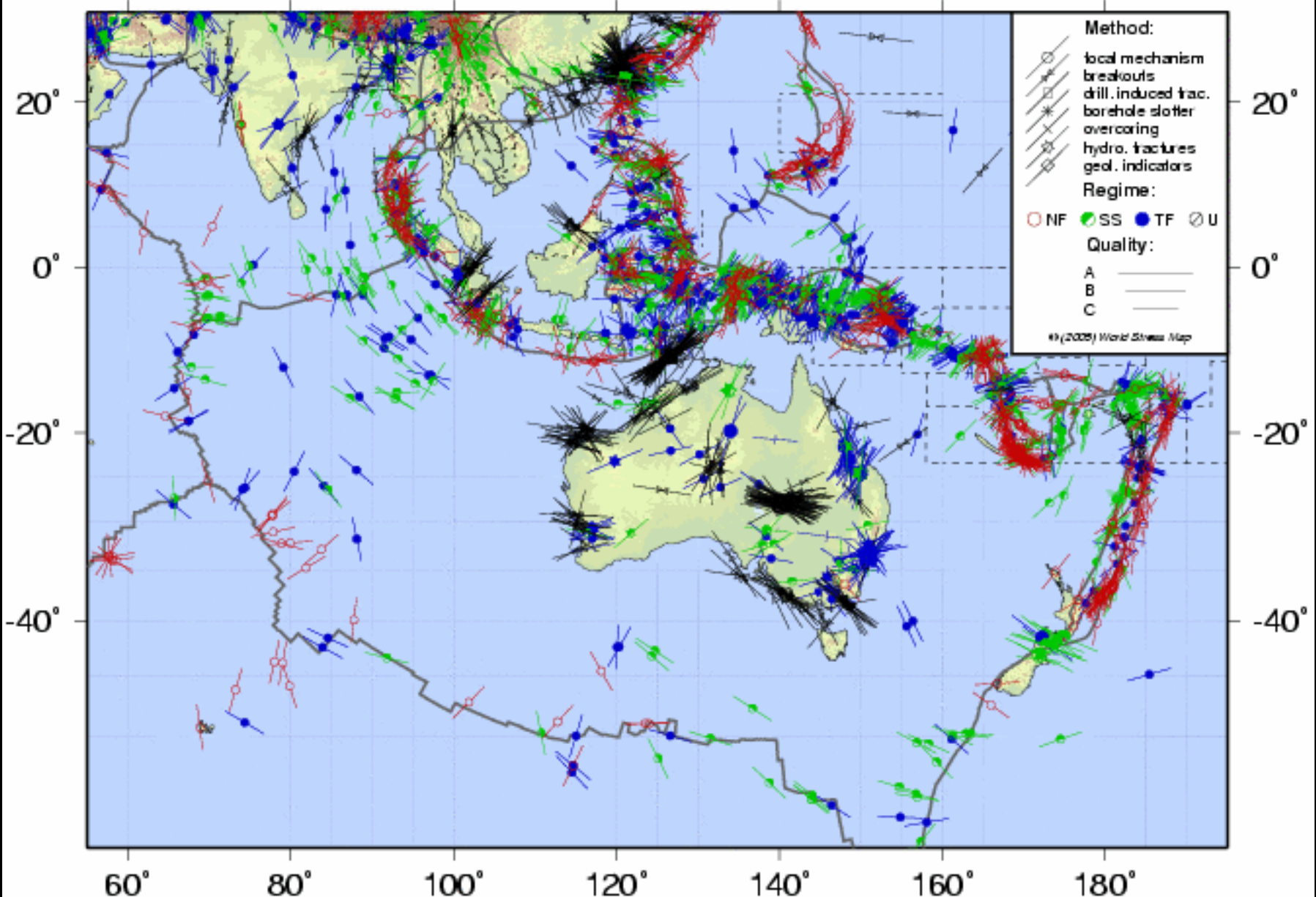
# Others Areas of High Stress in the World



# Global Stress Patterns



# Stress Map on the Australian Plate

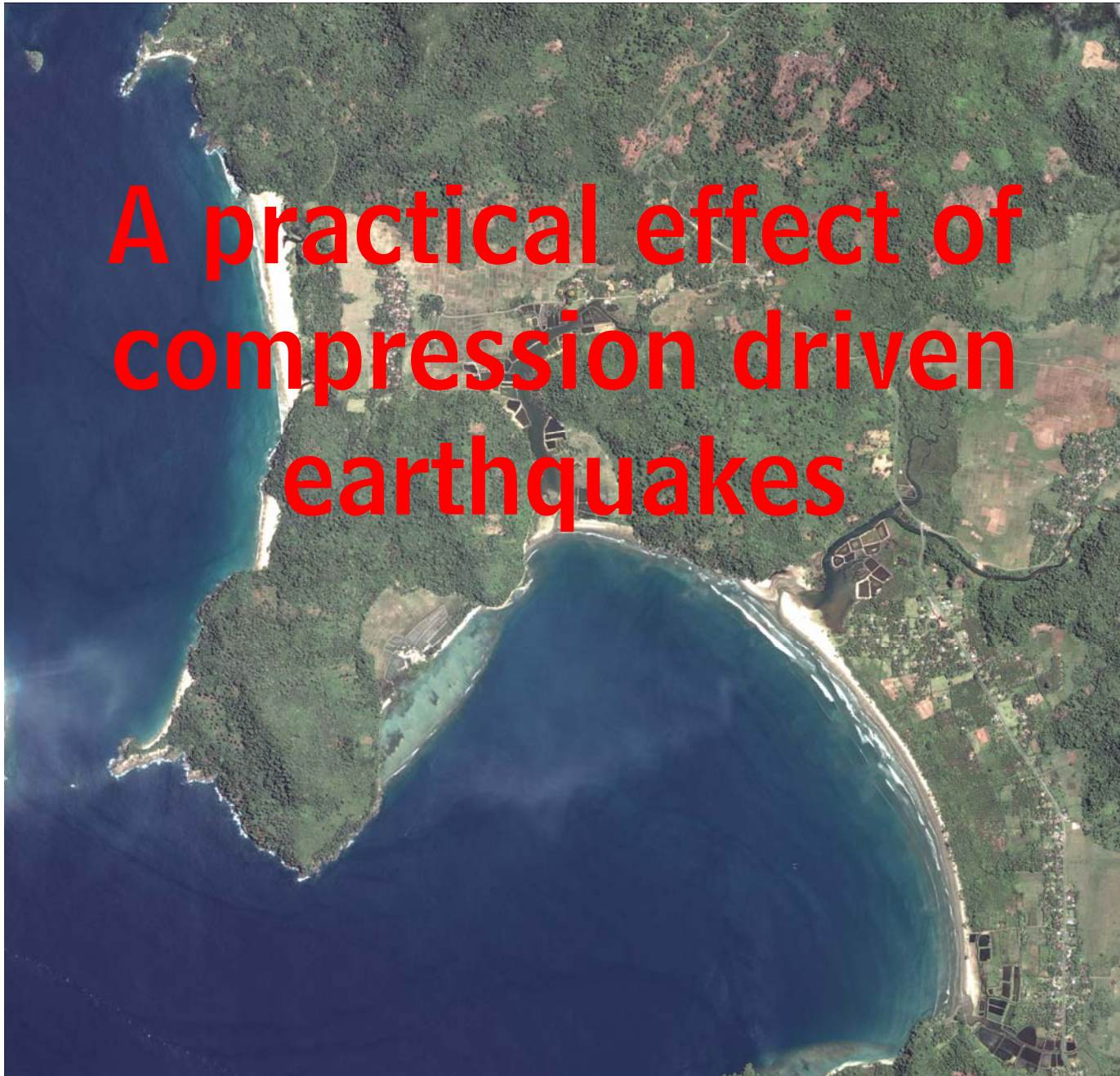


World Stress Map Rel. 2005  
 Heidelberg Academy of Sciences and Humanities  
 Geophysical Institute, University of Karlsruhe

Projection: Mercator

## Banda Ache Tsunami, Indonesia

**A practical effect of  
compression driven  
earthquakes**





# Banda Aceh Tsunami, Indonesia





# Banda Ache Tsunami, Indonesia



# Banda Ache Tsunami, Indonesia

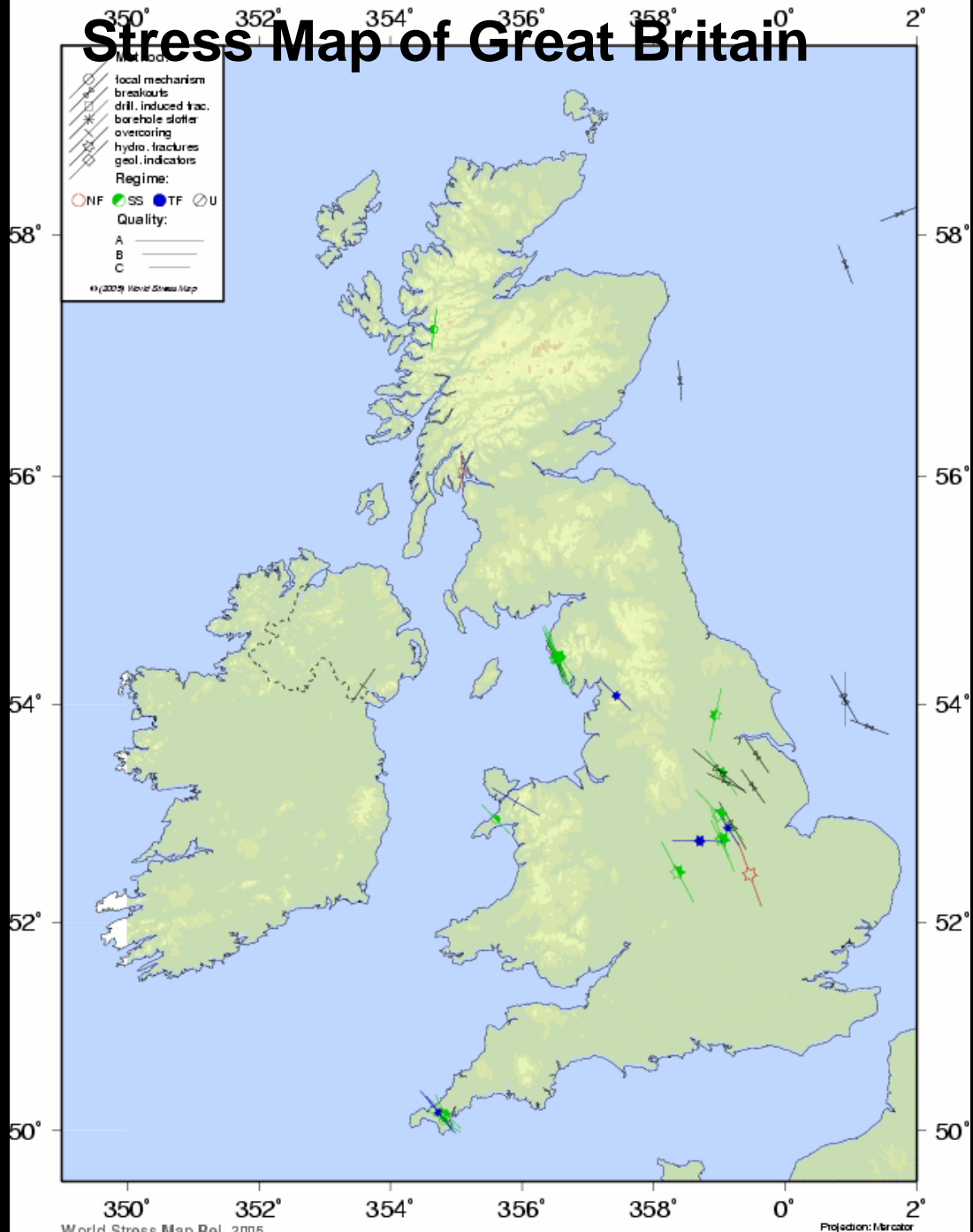


# Banda Ache Tsunami, Indonesia

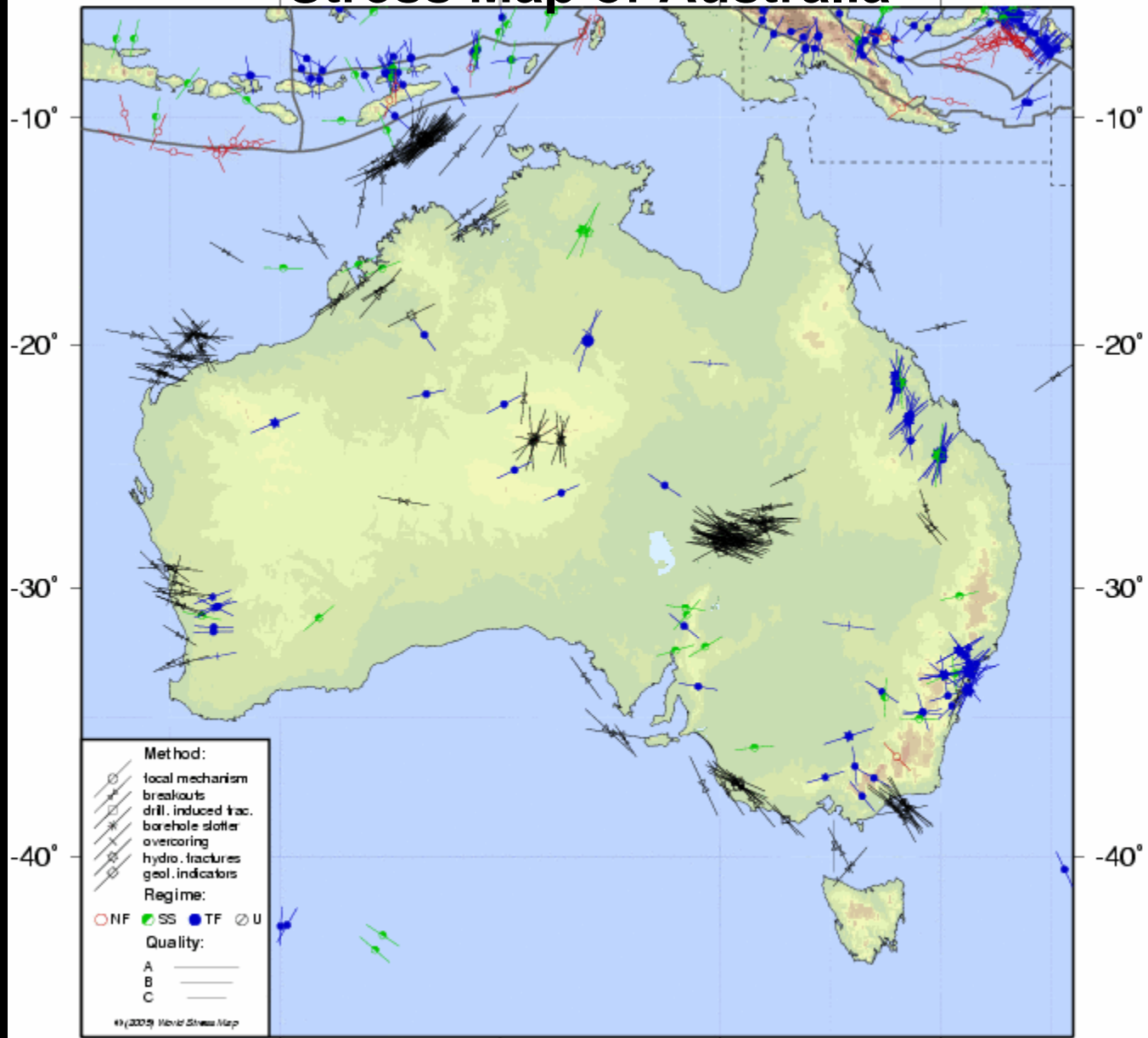


**Geologically  
Quiet Places to  
Live**

# Stress Map of Great Britain



# Stress Map of Australia



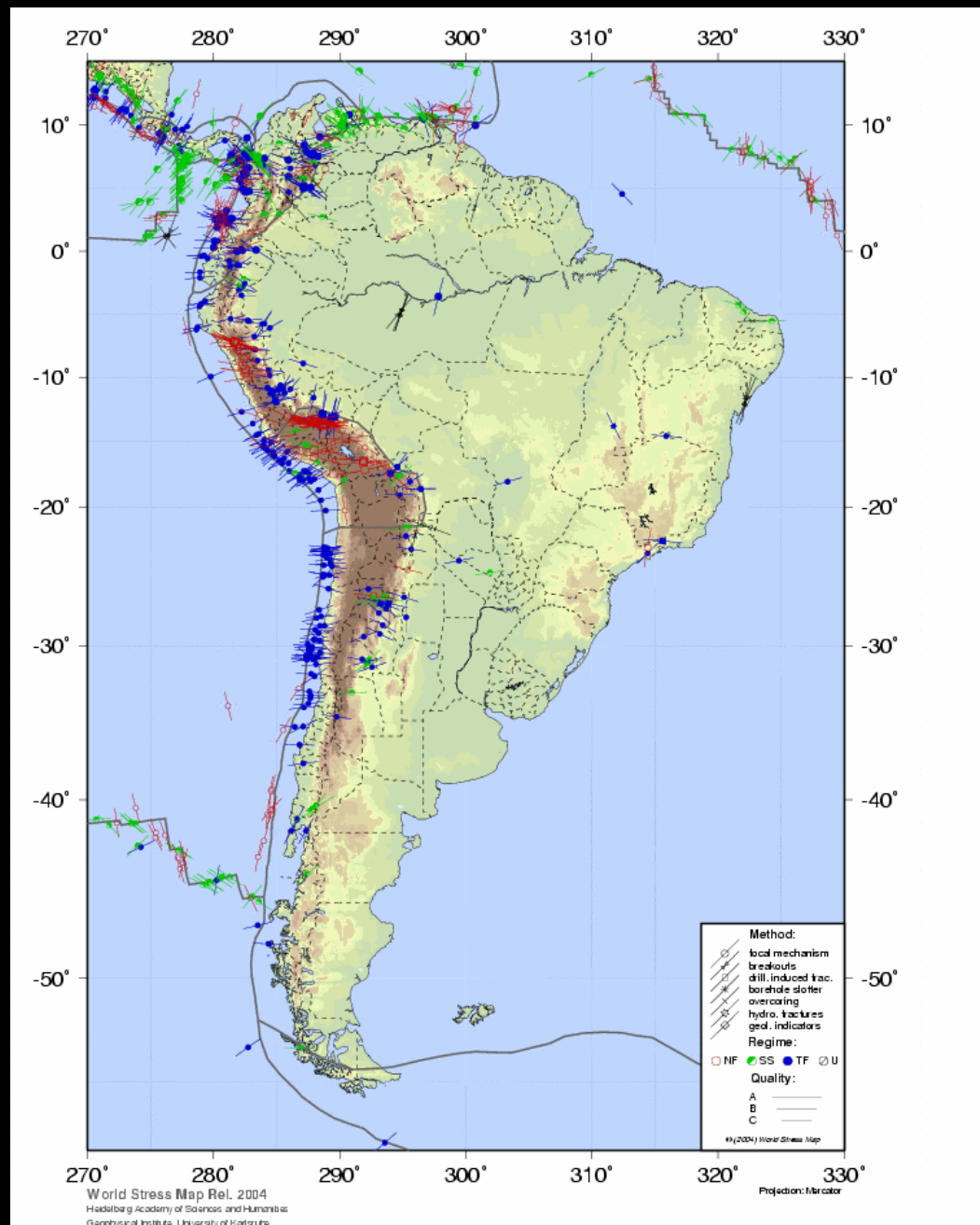
World Stress Map Rel. 2005  
 Heidelberg Academy of Sciences and Humanities  
 Geophysical Institute, University of Karlsruhe

Projection: Mercator

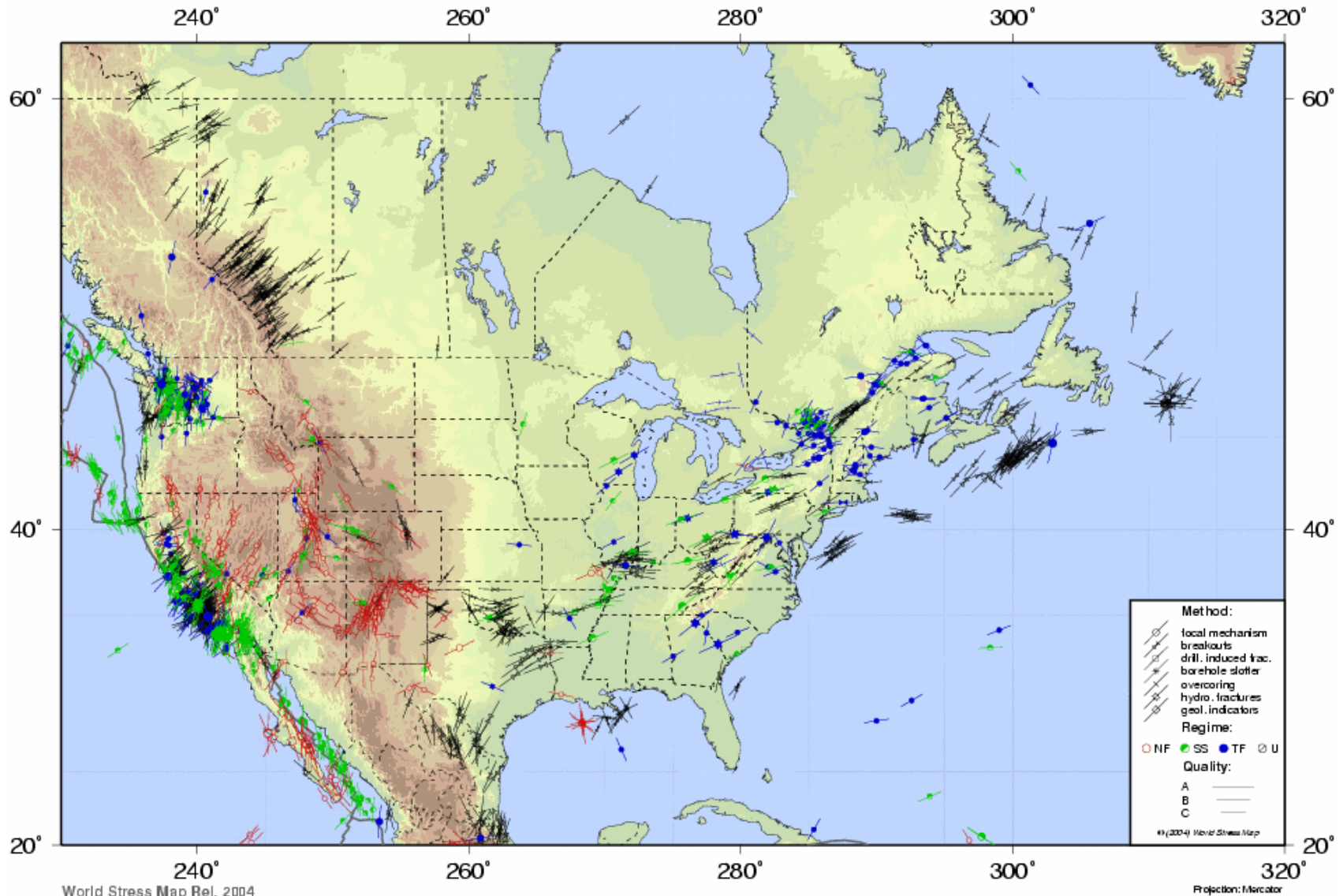
<http://www.wcm.physik.uni-karlsruhe.de/en>



# South American Stress Patterns



# North American Stress Patterns



# Others Low Stress Areas to Live

