Last Time... Geodetic Methods

* Near-Field Measurements

(Good for quantifying local deformation field)

A. Alignment Arrays
B. Trilateration Arrays
C. Leveling Lines
D. Tide Gauges

* Far-Field Measurement

(Good for quantifying plate tectonic scale deformation field)

A. Very Long Baseline Interferometry (VLBI)
B. Global Positioning System (GPS)
C. Synthetic Aperture Radar Interferometry (IntSAR).

** Geodetic methods only directly measure rates over the time of the survey. To extrapolate these geodetic rates to longer timescales and those processes that act over different timescales, one must assume that the rates do not change significantly.*

In Today's Class... Stress in the Earth's Crust and Weak Faults

I. Stress in the Earth's Crust:

A. Measurement techniques.
B. Stress patterns around the world.

II. Weak Faults:

A. Basic mechanical theory of weak faults.
B. Observations of weak faults and implications.

Measuring Stress in the Crust

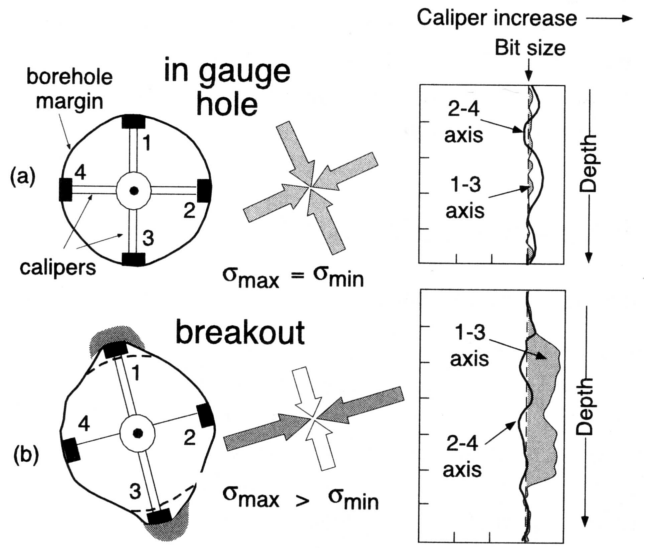


figure taken from Burbank and Anderson (2001) after Plumb and Hickman (1985)

Borehole elongation/ Breakouts

- Differences in principal stresses causes elongation in direction of minimum compression.

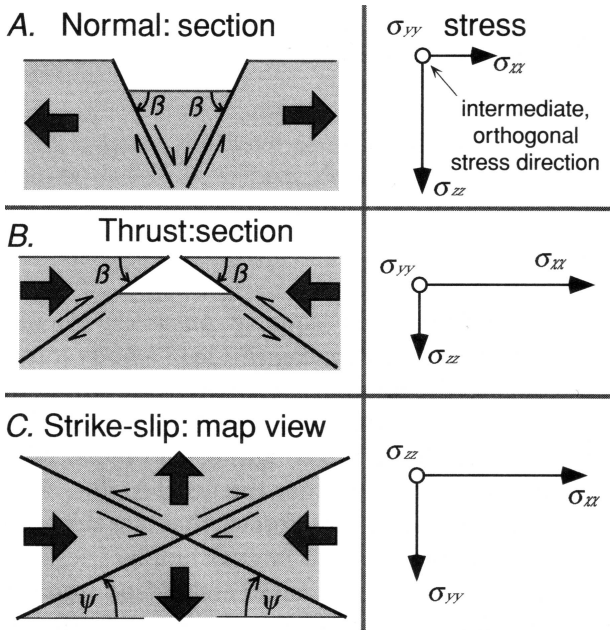
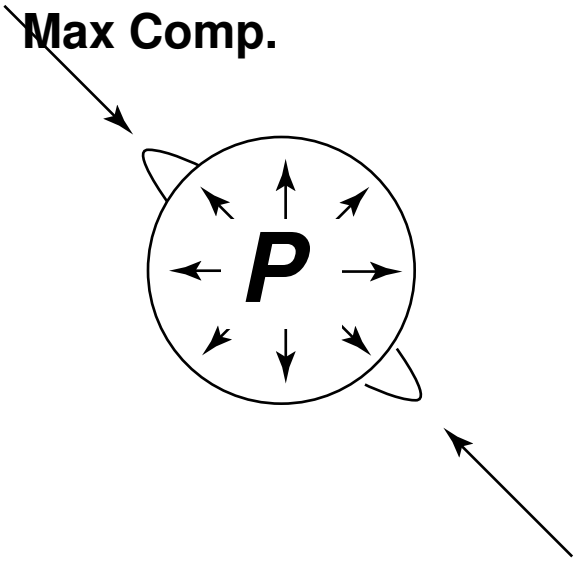


figure taken from Burbank and Anderson (2001) after Turcotte and Schubert (1982)

Geologic Information

- Fault orientations reflect stress field under which they initially formed. Must be cautious of reactivation of preexisting structure.

Stress Measurements



Hydrofracturing

- Pressurized boreholes crack and propagate fractures in direction of greatest compression.

* Fairly reliable stress measurement, but costly.

Earthquake Focal Mechanisms

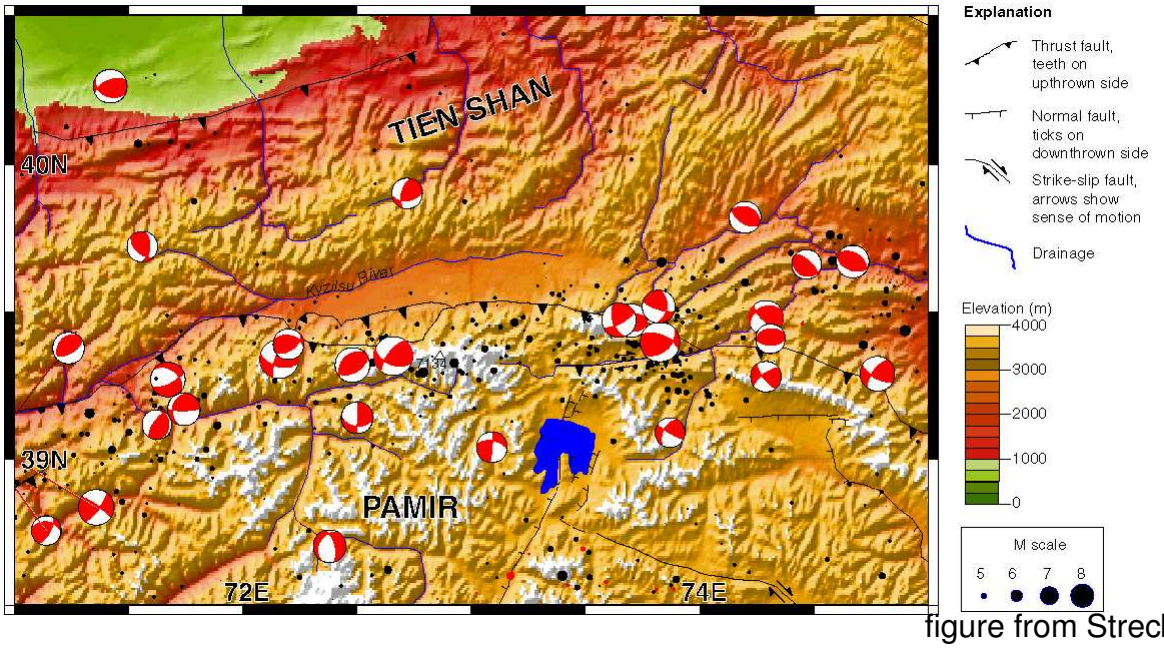
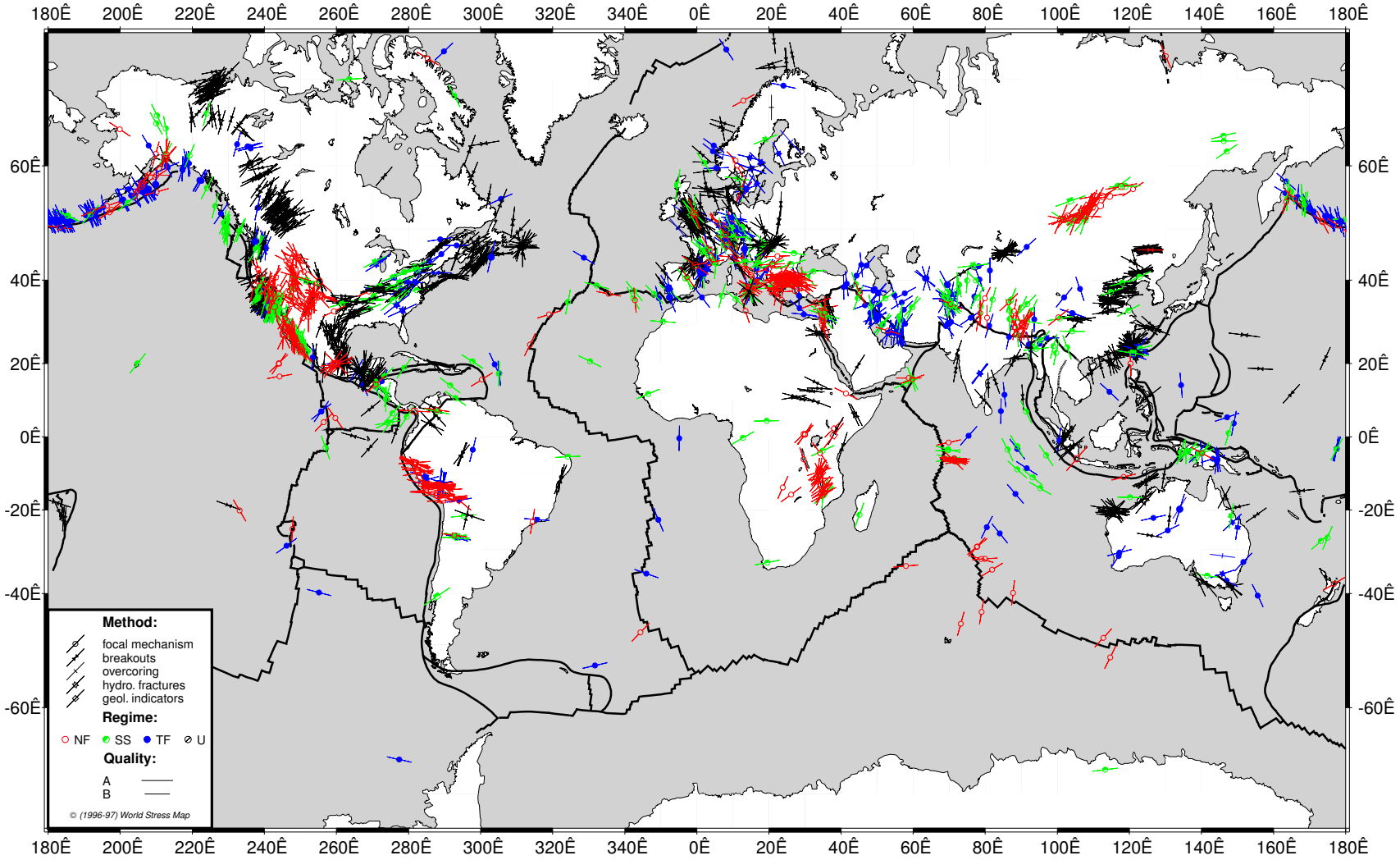


figure from Strecker et al. (in press)

-Focal mechanisms from many earthquakes along structures of known geometry may be inverted for stress field.

- Provides moderately good measures of stress field.

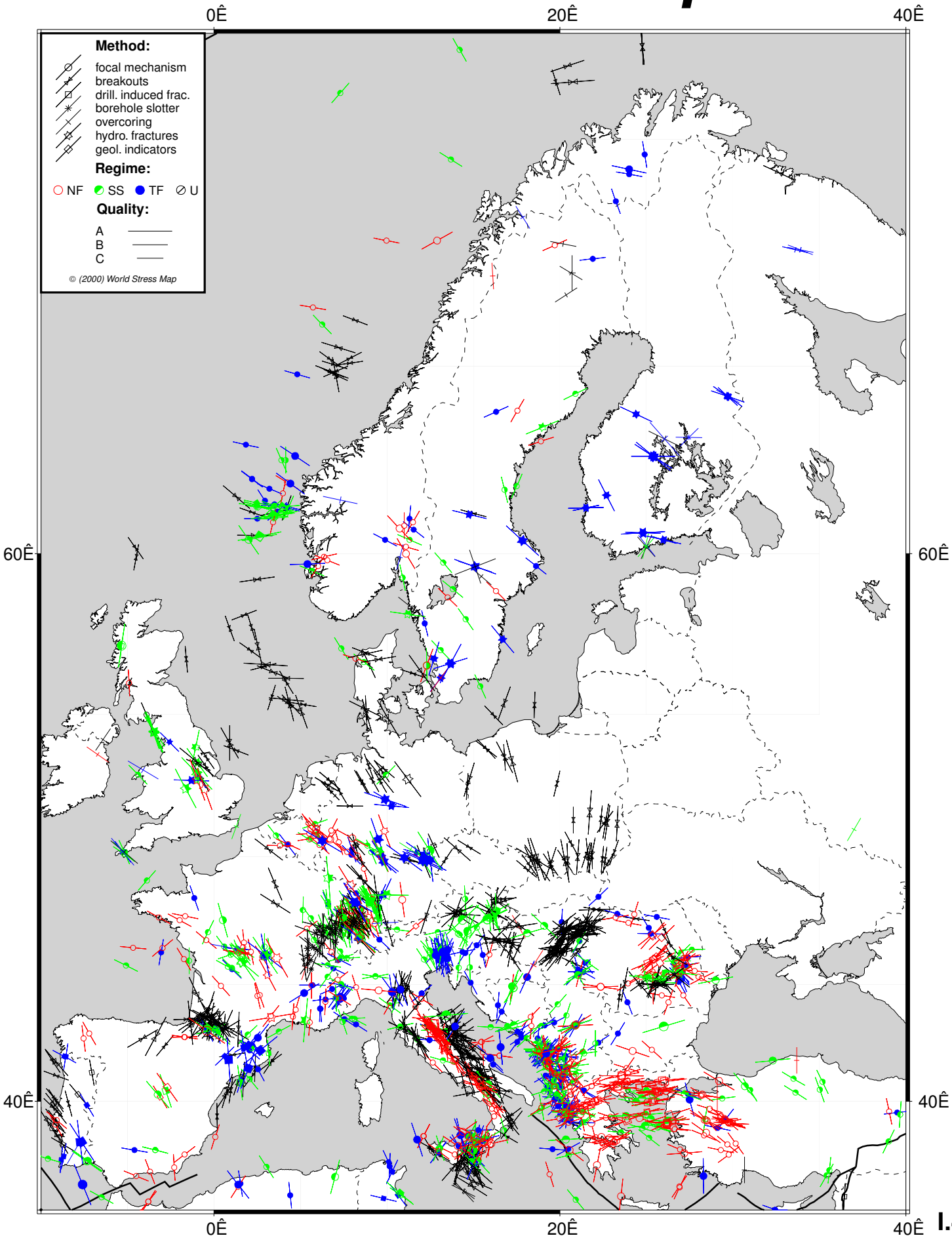
Stress in the Crust Worldwide

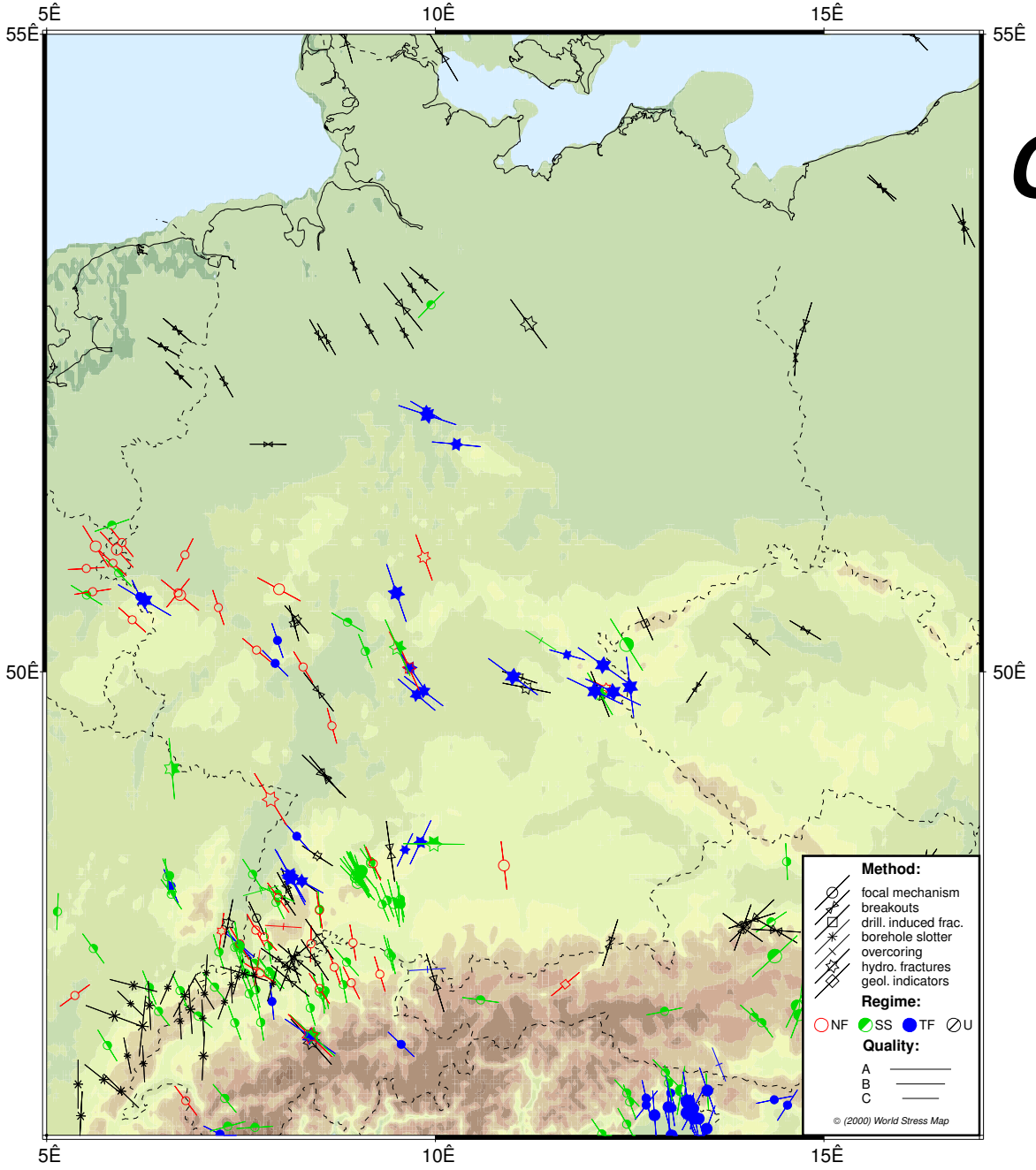


- In most places, stresses are oriented perpendicular to ridges.

- Tectonically active provinces provide important exceptions.

Stresses in Europe





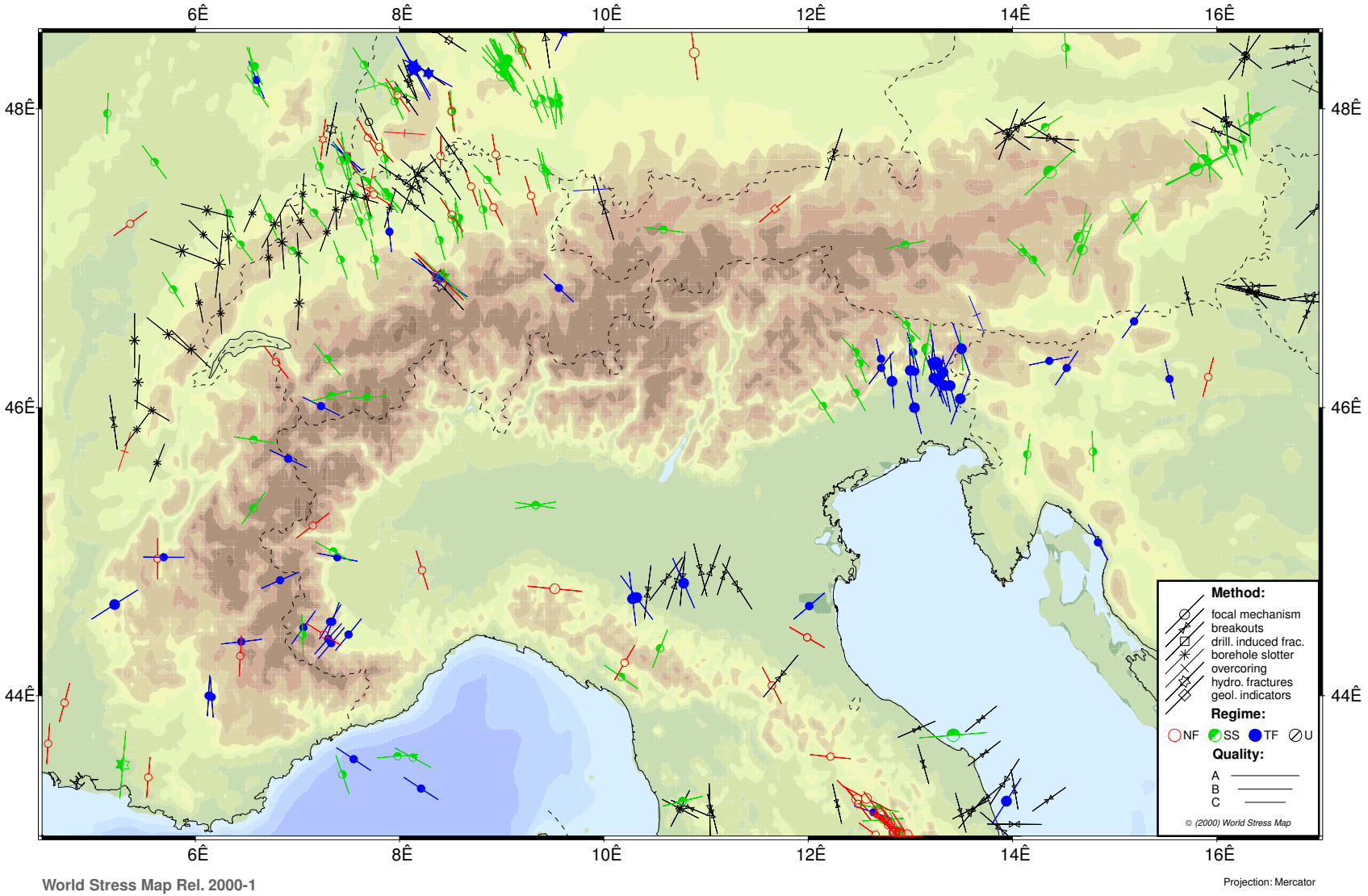
World Stress Map Rel. 2000-1
Heidelberg Academy of Sciences and Humanities
University of Karlsruhe / International Lithosphere Program

Projection: Mercator

Stresses within Central and Southern Germany

Stresses in Germany apparently rotate from N-S in the Alps to WNW-ESE in the central interior.

Stress in the Alps



World Stress Map Rel. 2000-1

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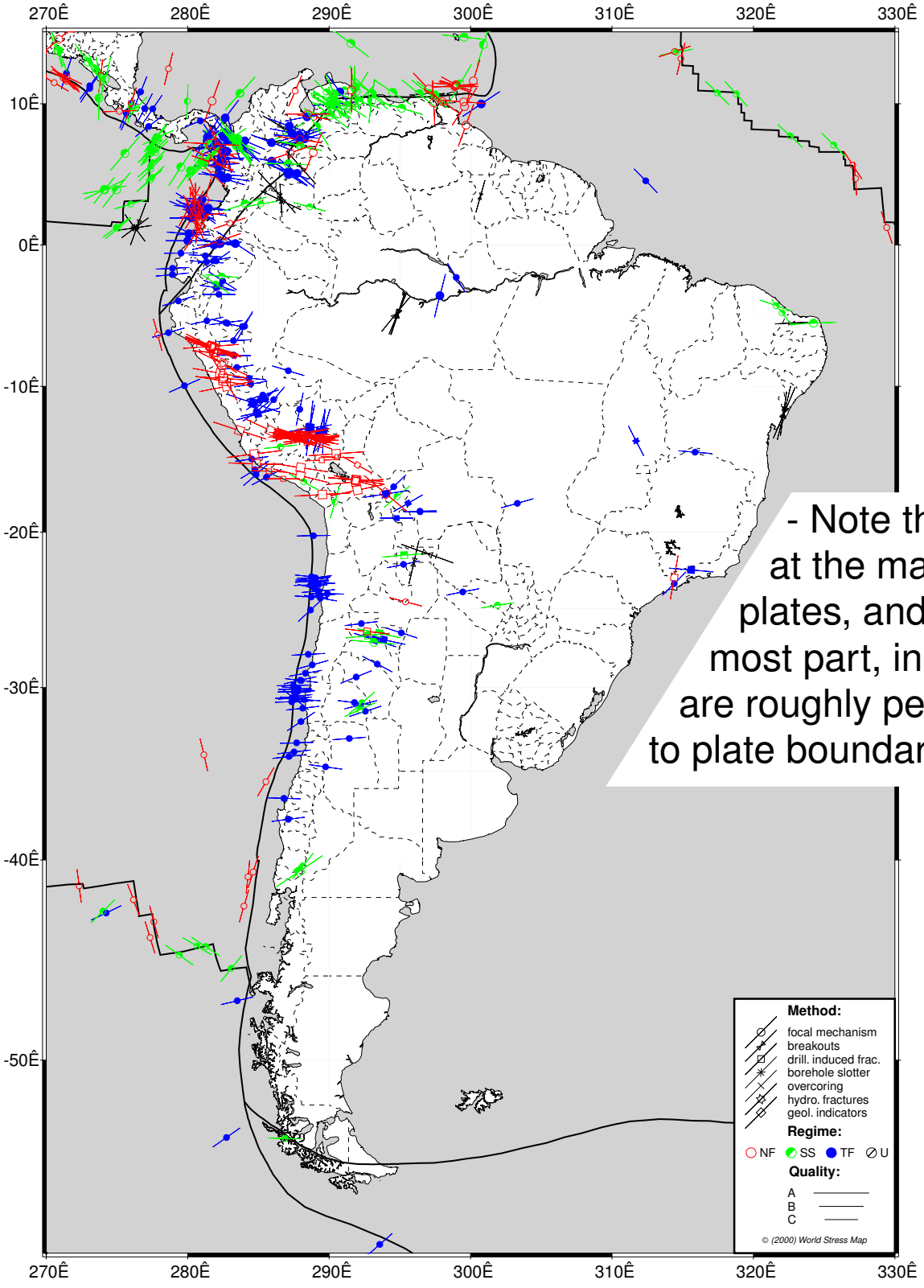
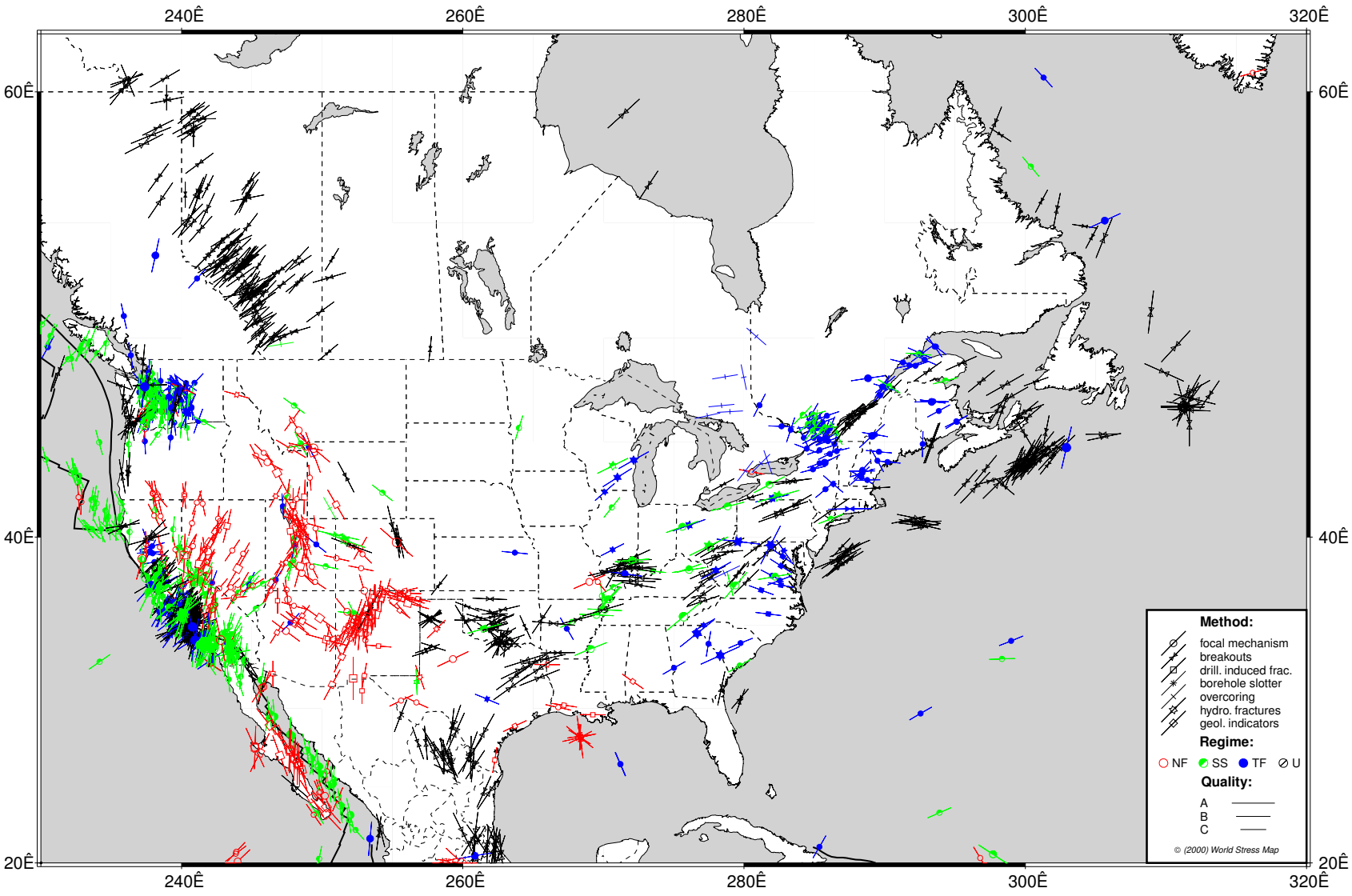
Projection: Mercator

Stresses in South America



- Note that stresses at the margins of the plates, and for the most part, in the iteriors are roughly perpendicular to plate boundaries.

Stresses in North America



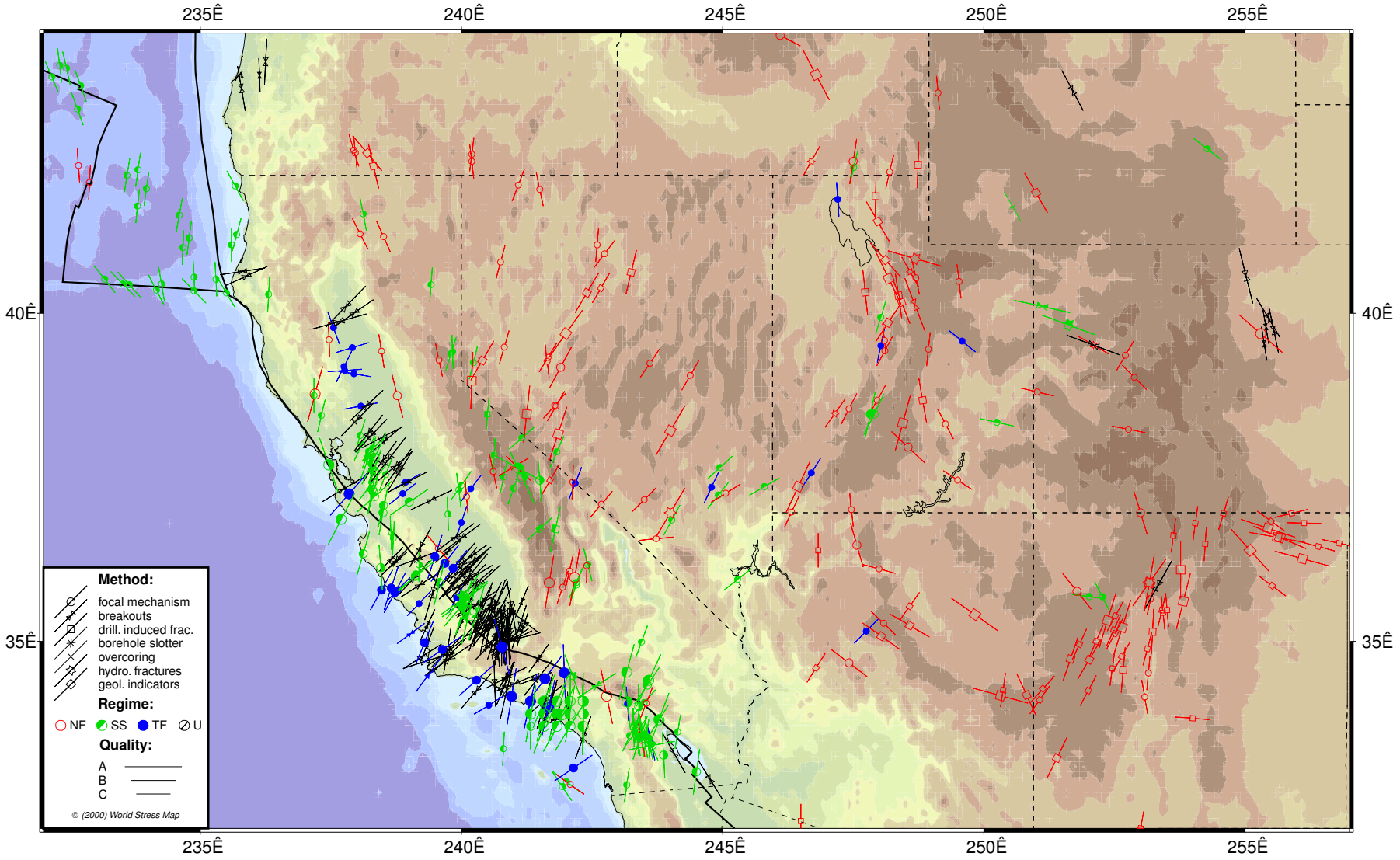
- Within the United States, there seem to be different "stress provinces"

1) Eastern sector more or less seems to strike NE-SW.

2) Basin and Range Area strike NW-SW.

3) Rocky Mountain province stresses strike NW-SE and NE-SW in the north and south, respectively.

Stresses in the Western U.S.



World Stress Map Rel. 2000-1

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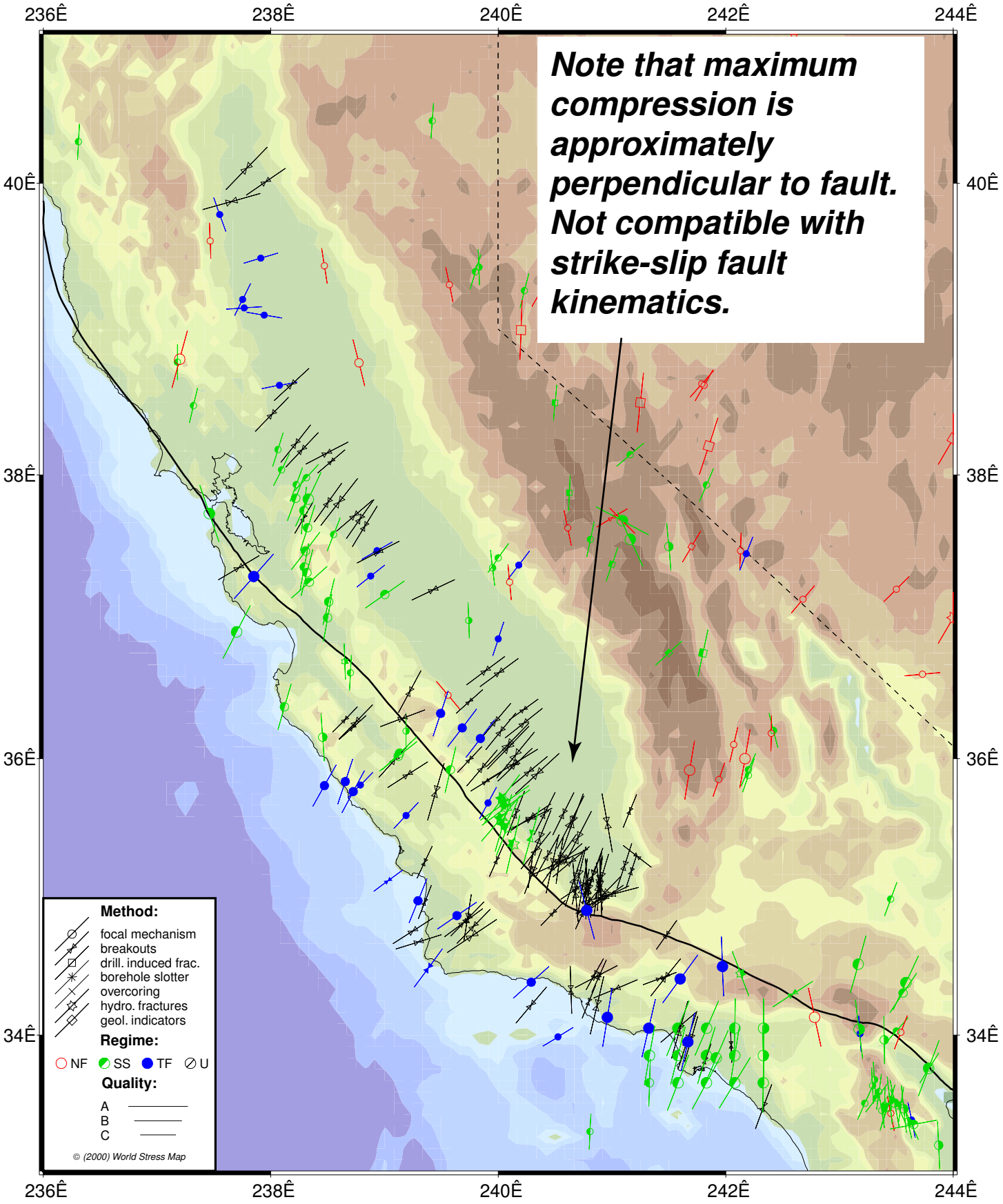
Projection: Mercator

Stresses in California



World Stress Map Rel. 2000-1
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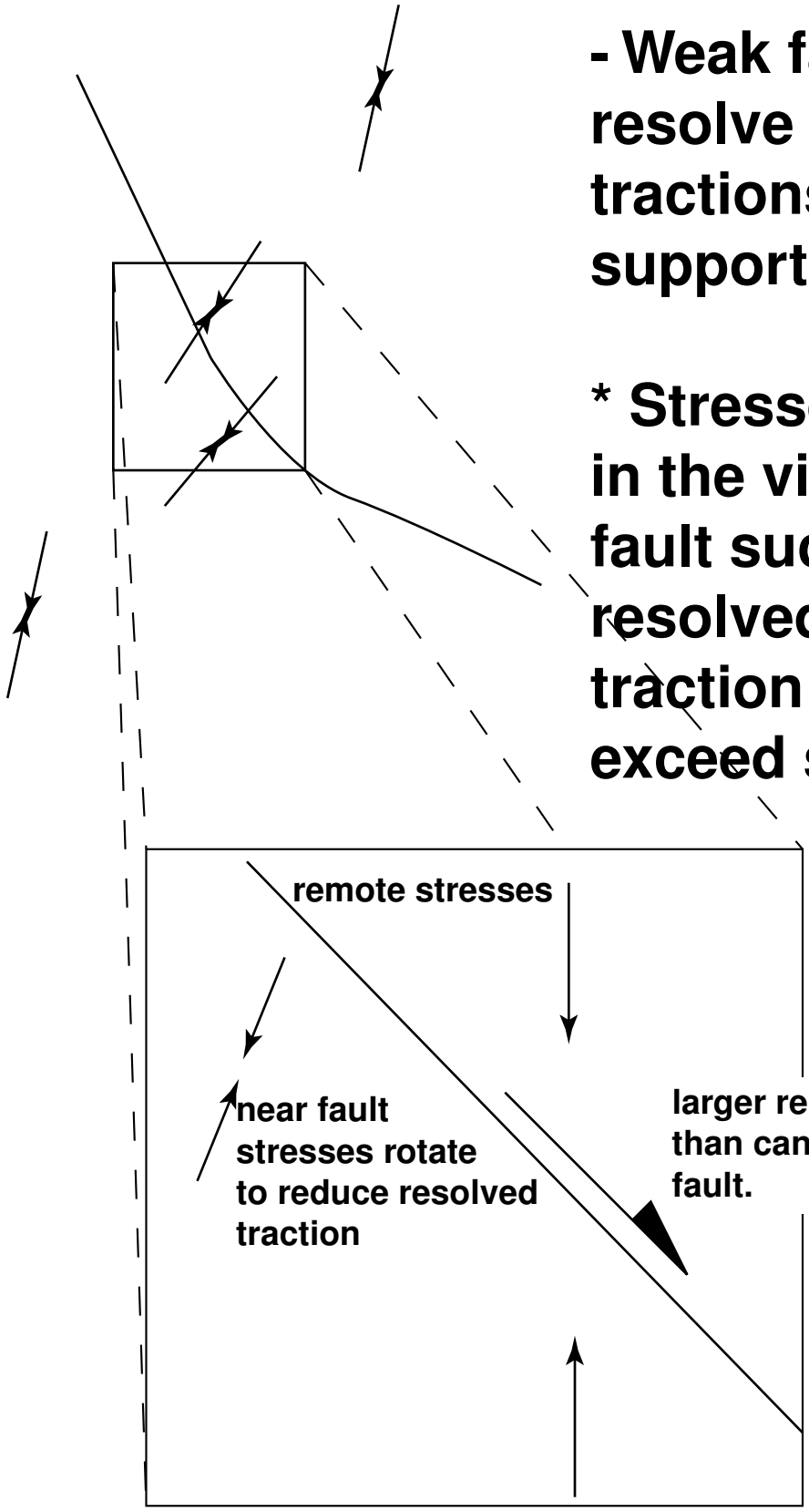
Projection: Mercator

Mechanics of Weak Faults



- Weak faults may resolve greater remote tractions than can be supported by the fault.

*** Stresses must rotate in the vicinity of the fault such that resolved shear traction does not exceed strength of**

When does the resolved shear traction on the fault equal the cohesion along the fault plane?

β ***= far-field angle***
α ***= near-field angle***

Angles are between strike of fault and maximum compression direction

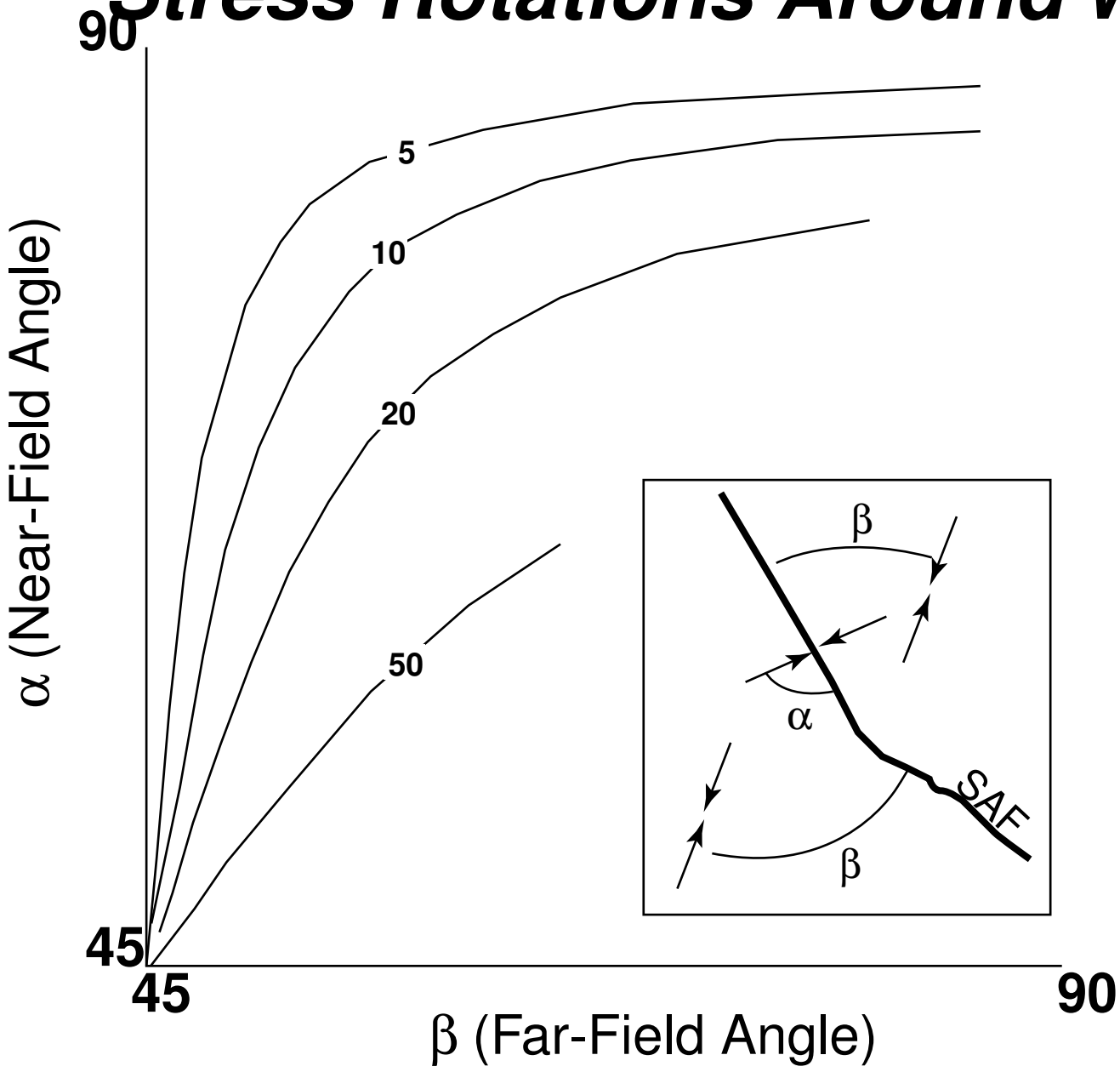
if β ***< 45°***

$$\alpha = \pi/2 - 1/2 \tan^{-1}(2C_o[\sigma_{hmax}-\sigma_{hmin}] \cos[\pi-2\beta])$$

if β ***> 45°***

$$\alpha = 1/2 \tan^{-1}(2C_o / [\sigma_{hmax}-\sigma_{hmin}] \cos[2\beta])$$

Stress Rotations Around Weak Faults



**** Near-field angle is angle between fault strike and max. princ. compressive stress near the fault. Far field angle is this angle between fault and princ. stress far away from fault.***

- As fault becomes stronger in its cohesion, disparity between far and near field angle decreases.

Focal Mechanisms Adjacent to the SAF

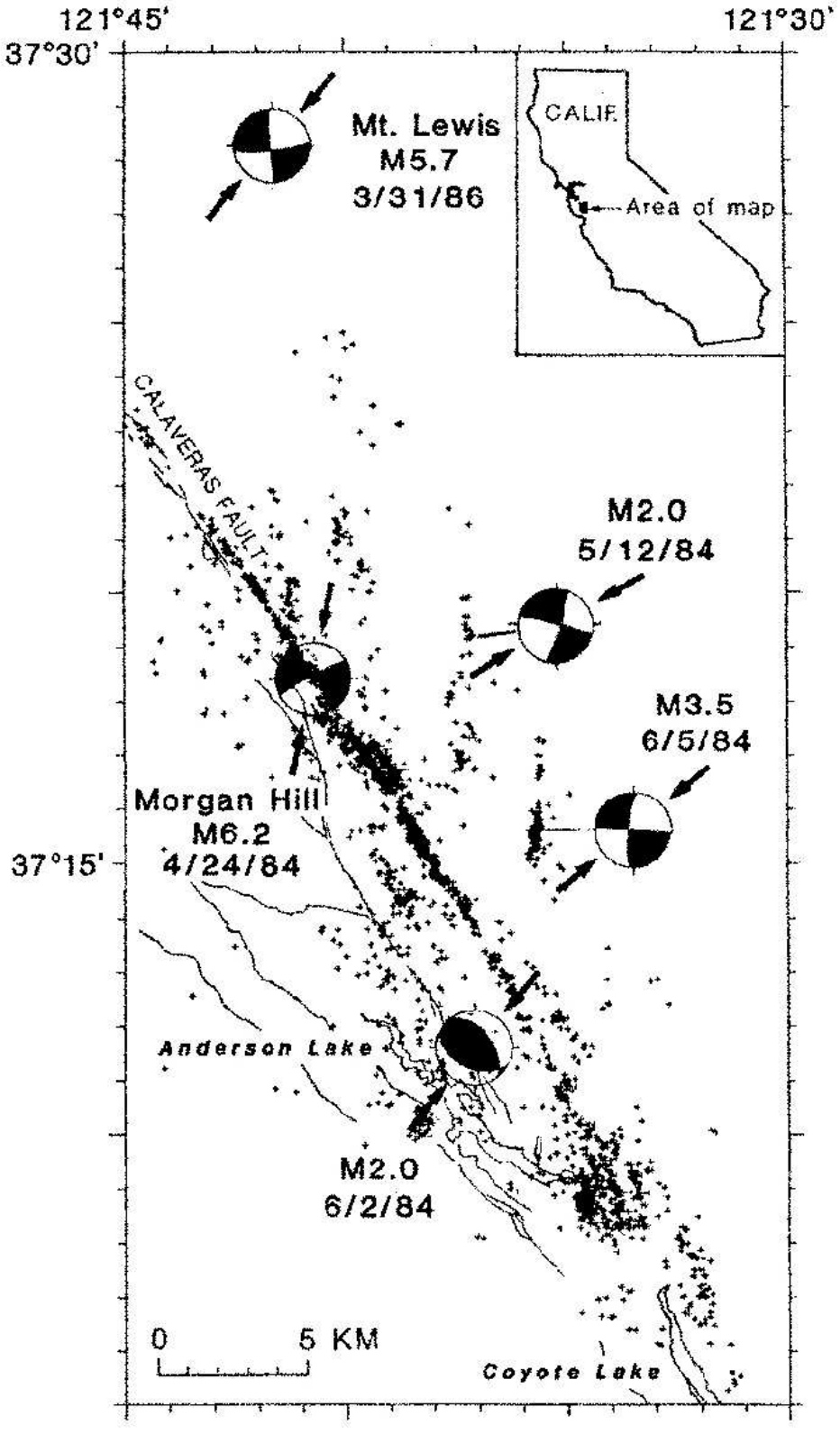
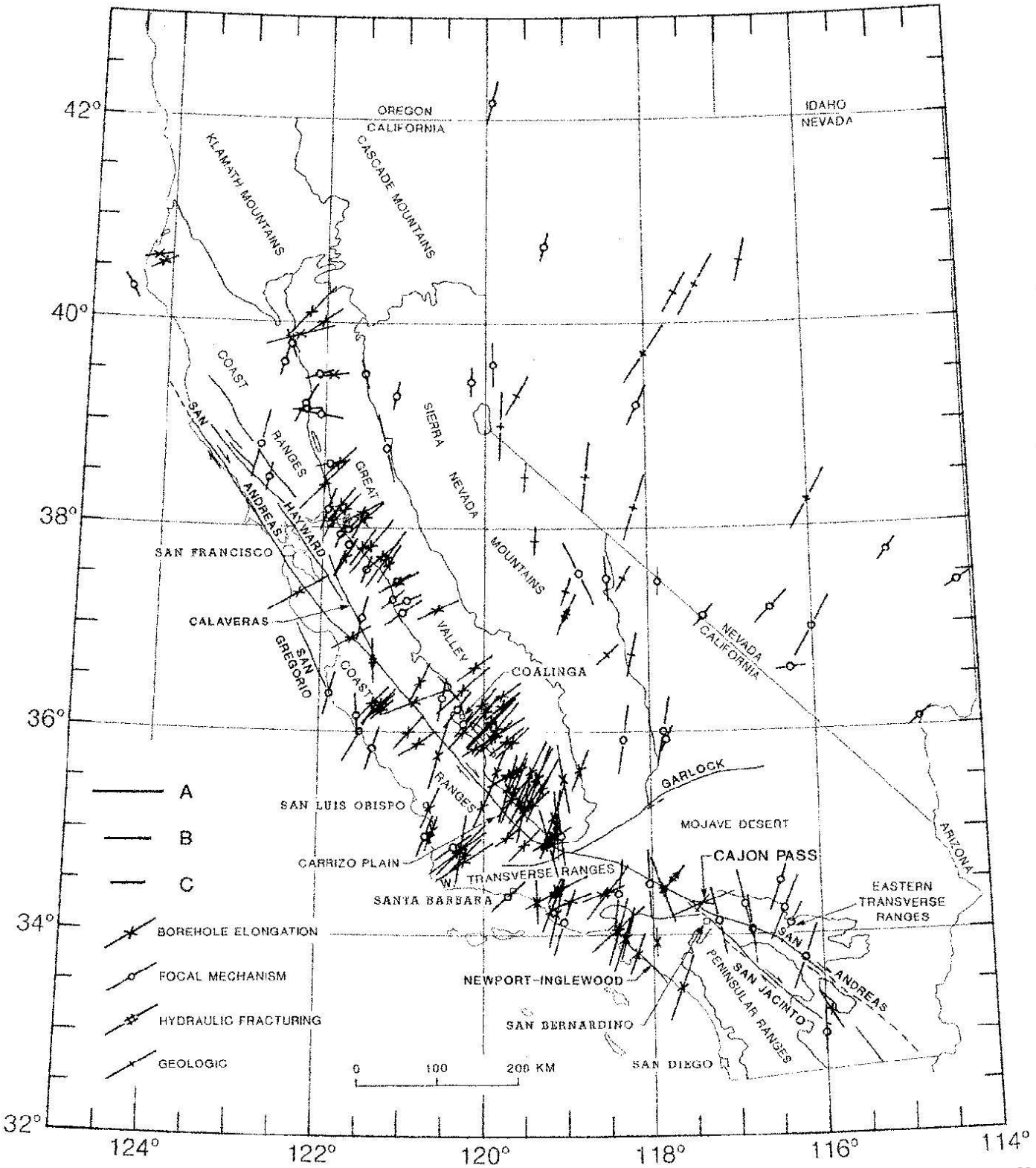


figure from Zoback et al., 1989

* Note focal mechanisms along active structures near the fault imply fault normal compression. However, fault mechanism on the SAF (Morgan Hill EQ) is consistent with motion along the SAF.

Stress Distribution around the SAF



Geologic Structure around the SAF

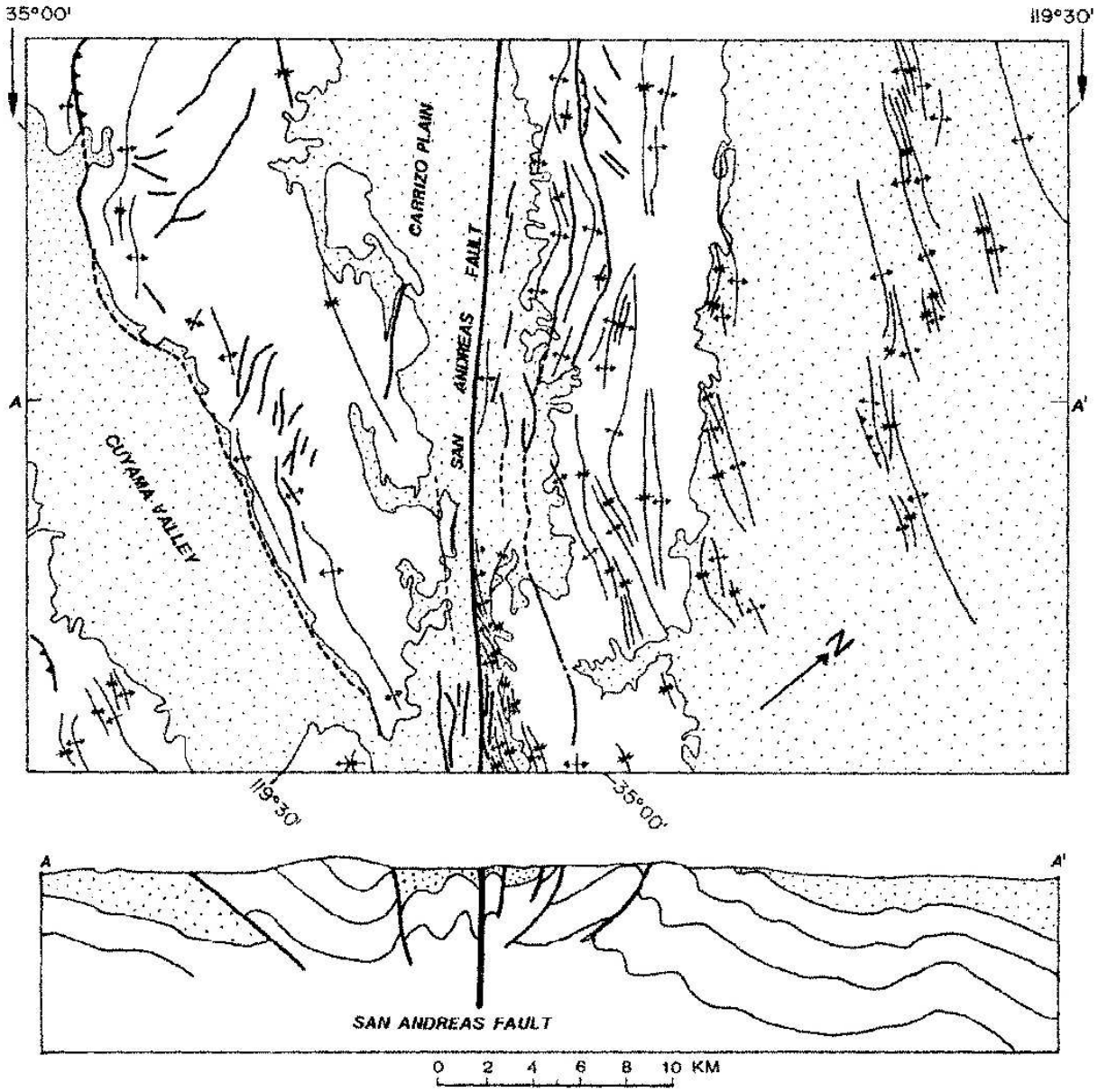


figure from Zoback et al., 1989

Important Points:

- Stress in the Earth's crust seems to be dominated by ridge-push forces.

- This inference is based on the fact that in most areas of the world, maximum horizontal principal compressive stresses are oriented approximately parallel to these spreading directions.

- Tectonic provinces in several parts of the world provide important exceptions to this general observation. For example, Basin and Range and Rocky Mountain Provinces in U. S. reflect combination of forces.

Important Points:

- Theory of weak faults predicts that maximum horizontal principal compressive stress should rotate near the fault to resolve less shear traction on fault surface.

- Earthquake focal mechanisms, geologic structures, and stress measurements around the San Andreas Fault are consistent with the weak fault theory, suggesting that it may have low friction.

Next Time...

Erosion rate measurements and measurement techniques