Advanced Structural Geology, Fall 2022

Andersonian Faulting Theory and World Stress Map

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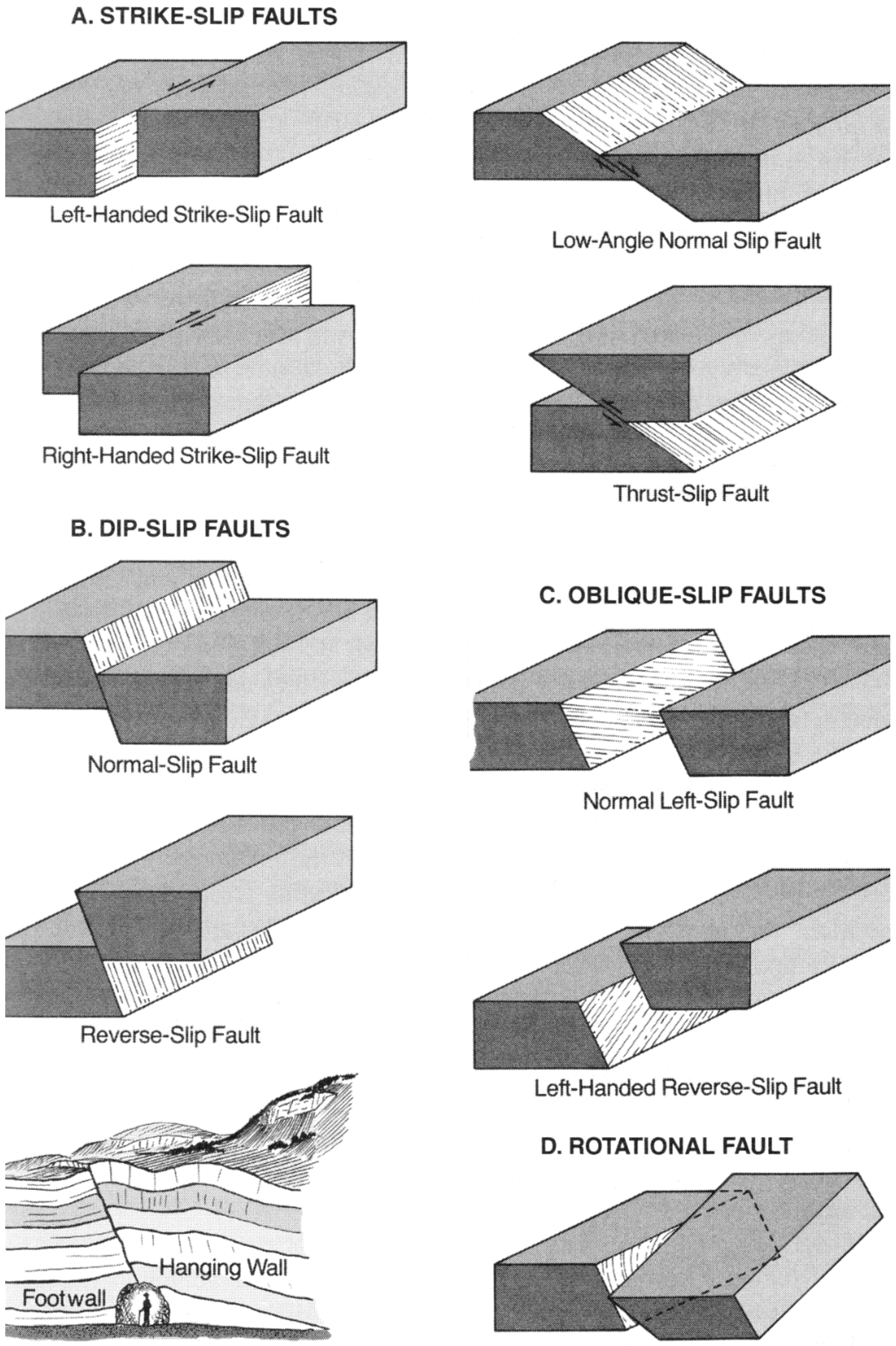
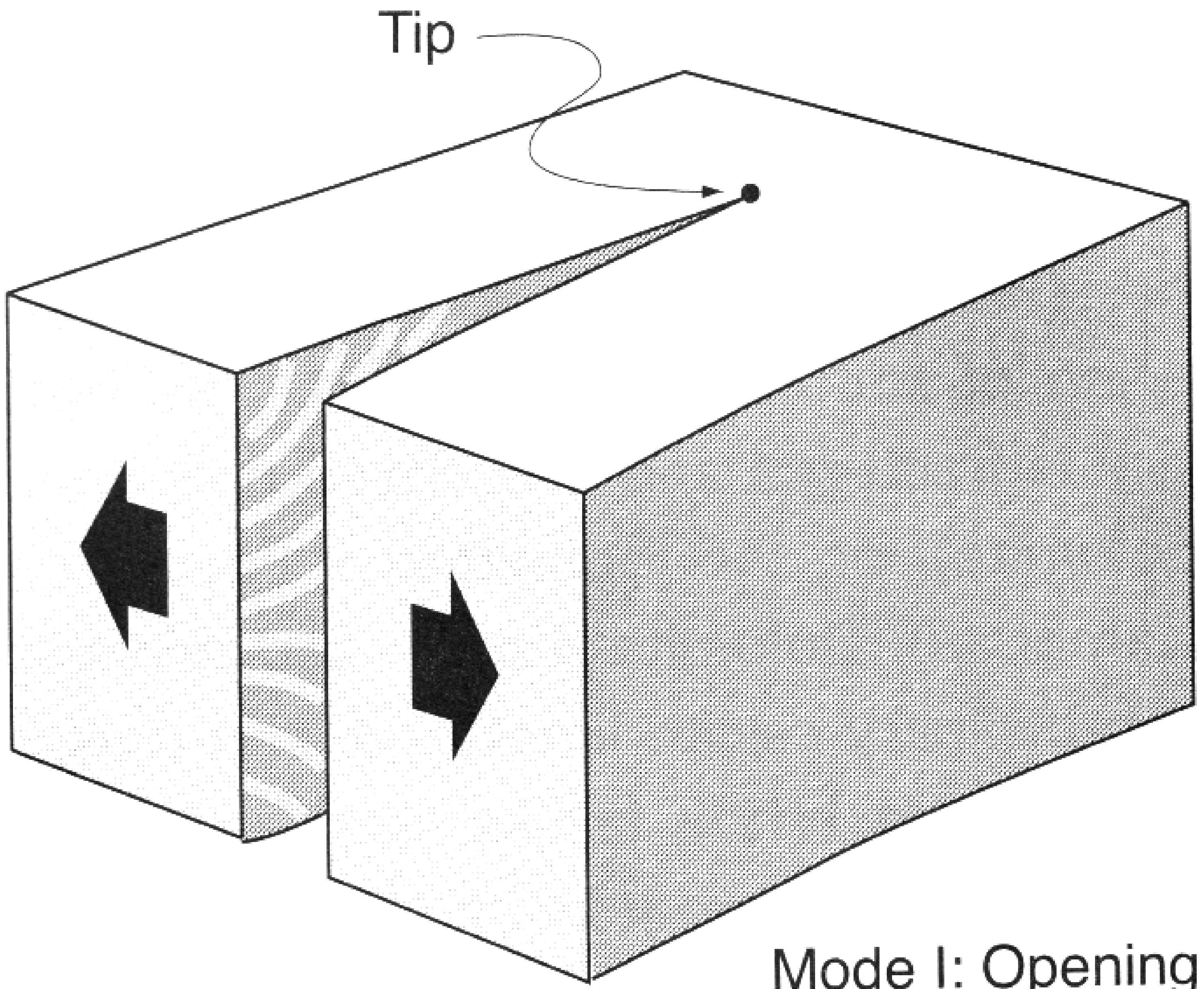
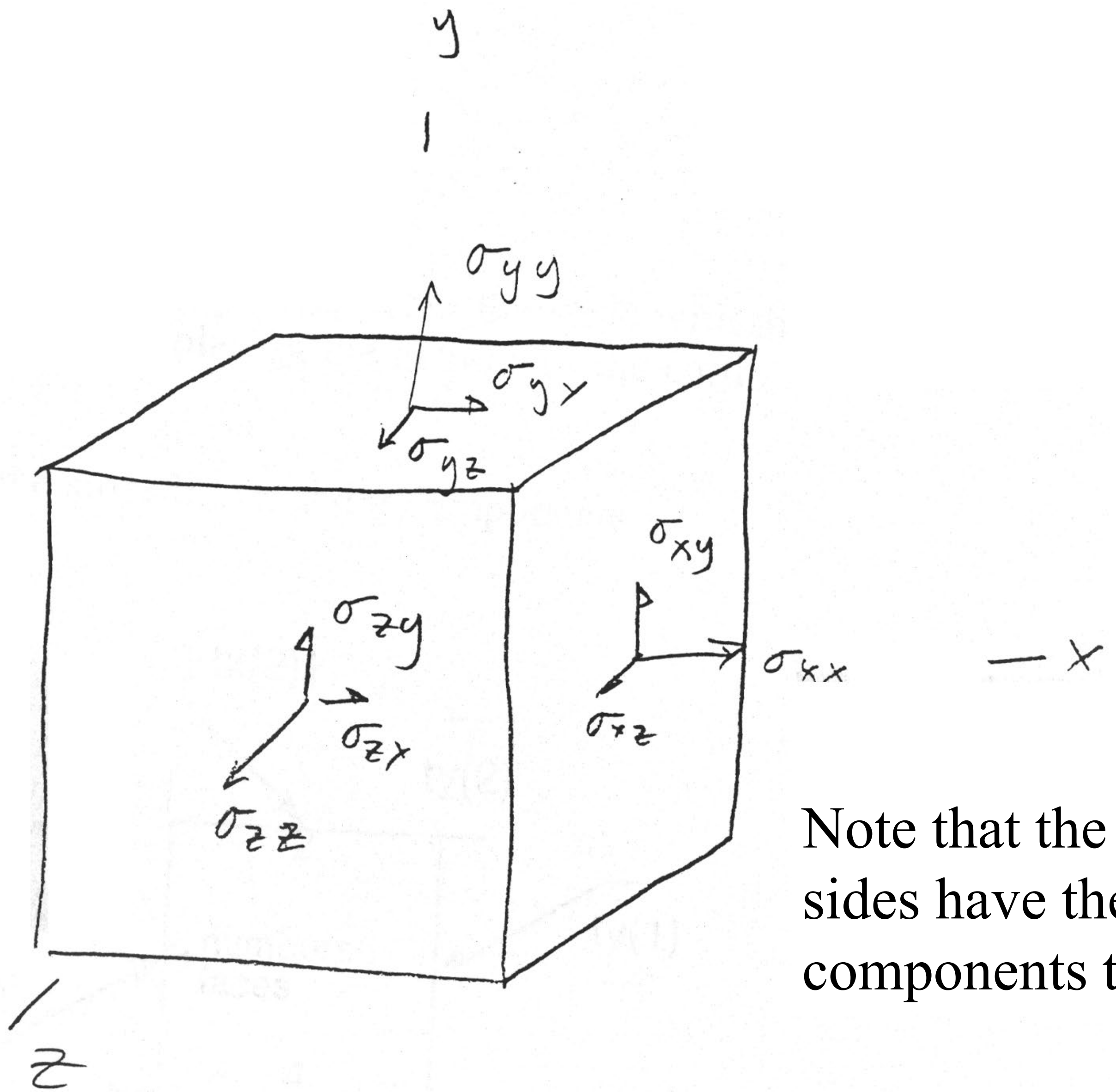
Classification of faults



Fracture



3D Stress tensor



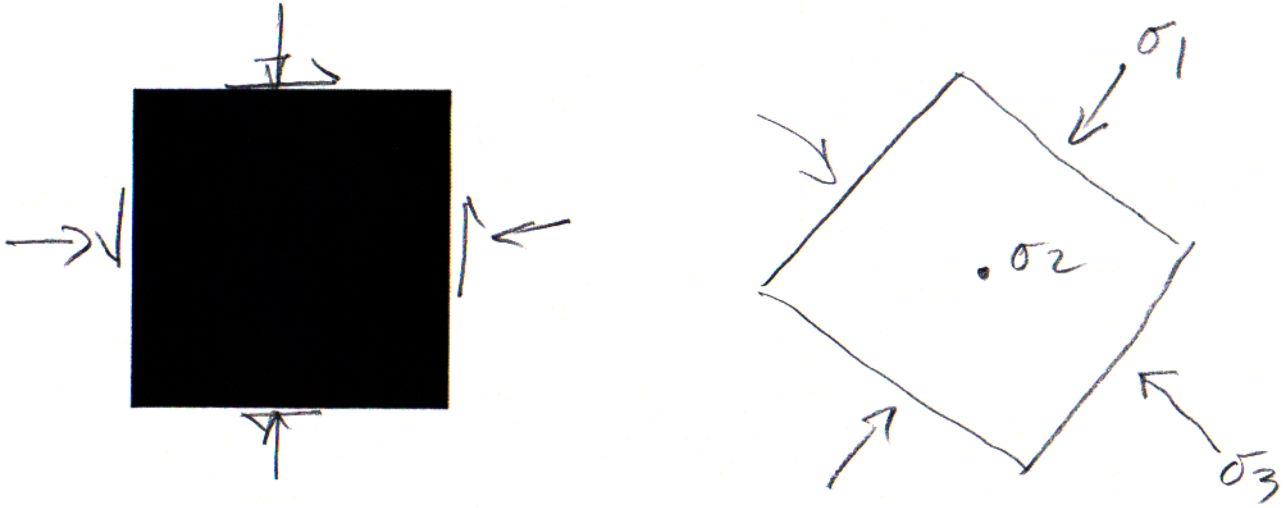
Note that the opposite sides have the stress components too!

Recall:

Stress tensor

Principal stresses

We can always find orientations of a cubic element such that the shear shress components are zero on all sides and in that case, the normal stress components are calle the <u>principal stresses</u>.



$\sigma_1 > \sigma_2 > \sigma_3$

σ_1 = max compression

σ_3 = min compression

Recall:

Tractions and stress

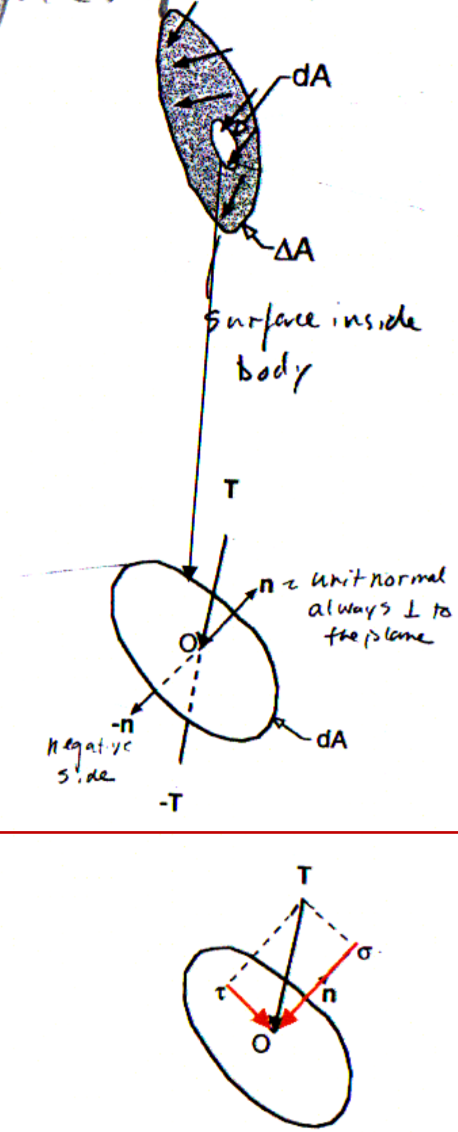
traction as a function of orientation of surface defined by normal vector

$$\vec{T}(\vec{n}) = \lim_{\Delta A \to 0} \frac{\Delta \vec{F}}{\Delta A} = \frac{d\vec{F}}{dA}$$

$$\vec{T}(\vec{n}) + \vec{T}(-\vec{n}) = 0$$

σ_n or σ is normal component

σ_s or τ is shear component



(a) "Traction" or "Stress vector"

(b) Equilibrium "Cauchy's relationship

(c) Components of the Traction Vector

Andersonian Faulting Theory

- Key assumptions:
  - Earth's surface is a free surface (so it has no shear tractions acting along it). Therefore, σ_1, σ_2, σ_3 must be either parallel or perpendicular to it.
  - A fault will slip in the direction of maximum resolved shear traction

Andersonian Faulting Theory

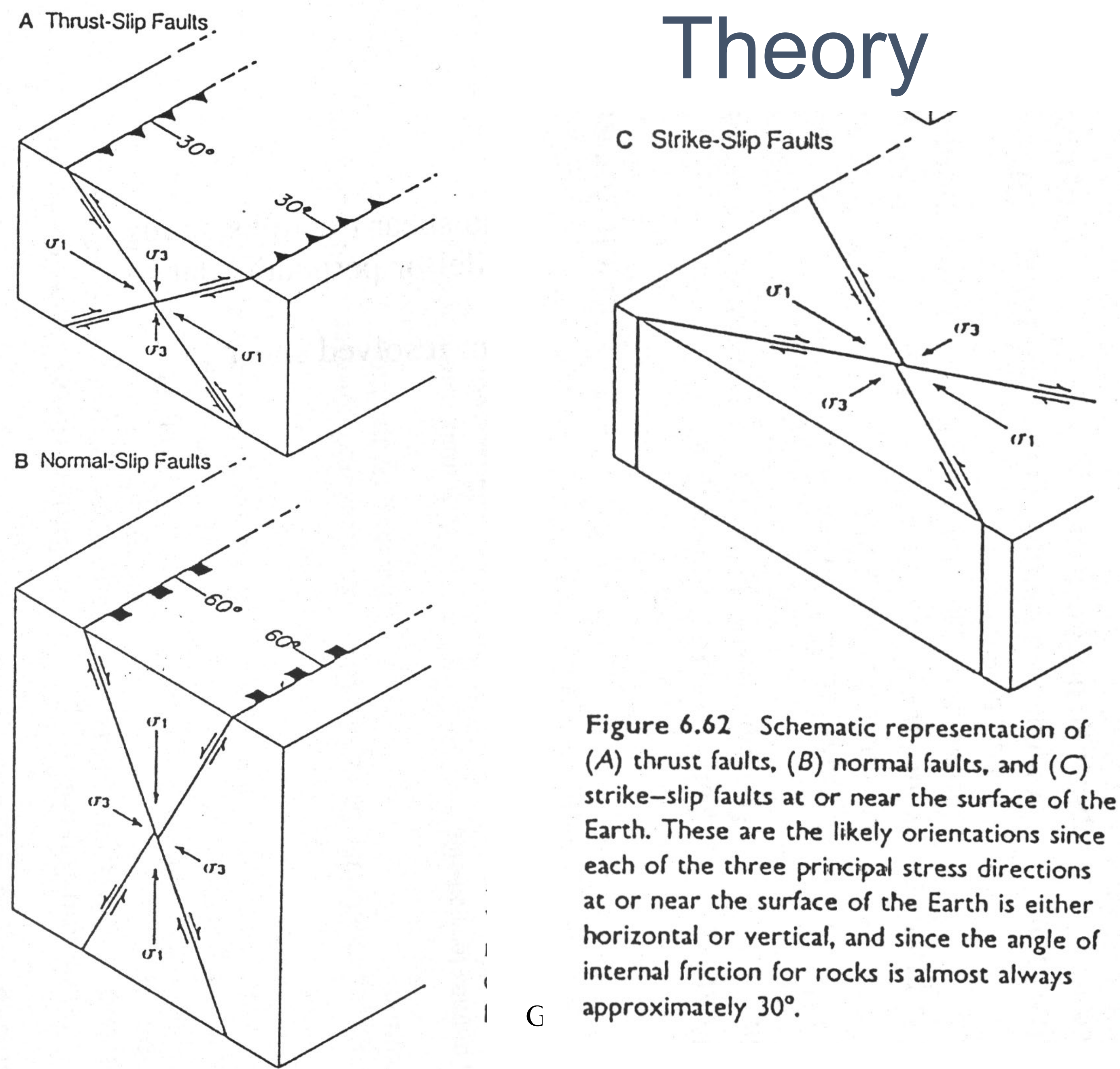


Figure 6.62 Schematic representation of (*A*) thrust faults, (*B*) normal faults, and (*C*) strike–slip faults at or near the surface of the Earth. These are the likely orientations since each of the three principal stress directions at or near the surface of the Earth is either horizontal or vertical, and since the angle of internal friction for rocks is almost always approximately 30°.

Davis and Reynolds, p. 306

Andersonian Faulting Theory

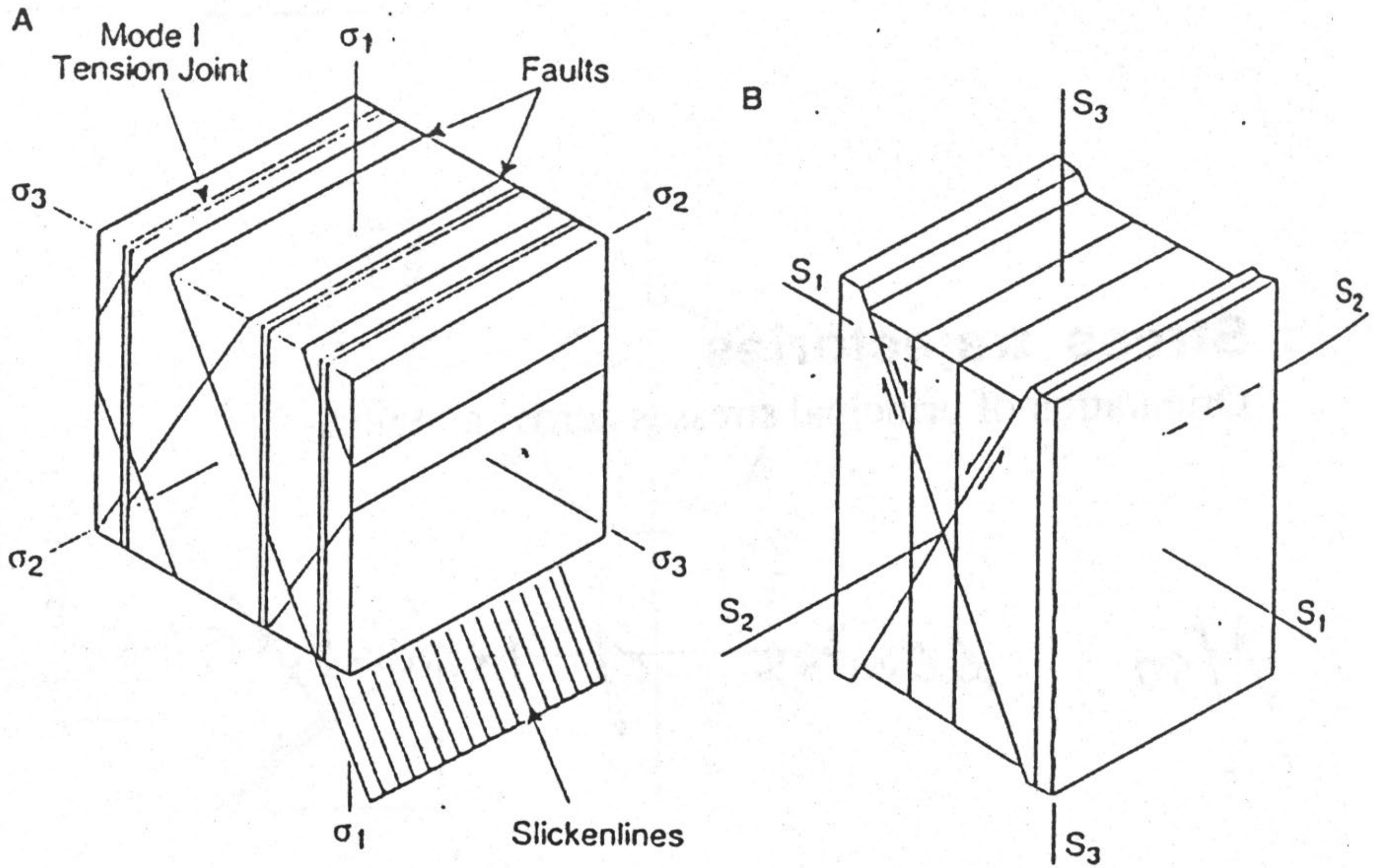


Figure 6.63 Drawings of conjugate faults as well as mode I tension fractures in a block of rock that had been subjected to length-parallel shortening. Note the orientations of the principal stress directions with respect to the orientations of faults, slickenlines, and mode I joints. Referenced with respect to (*A*) principal stress directions, (*B*) principal strain directions.

Davis and Reynolds, p. 306

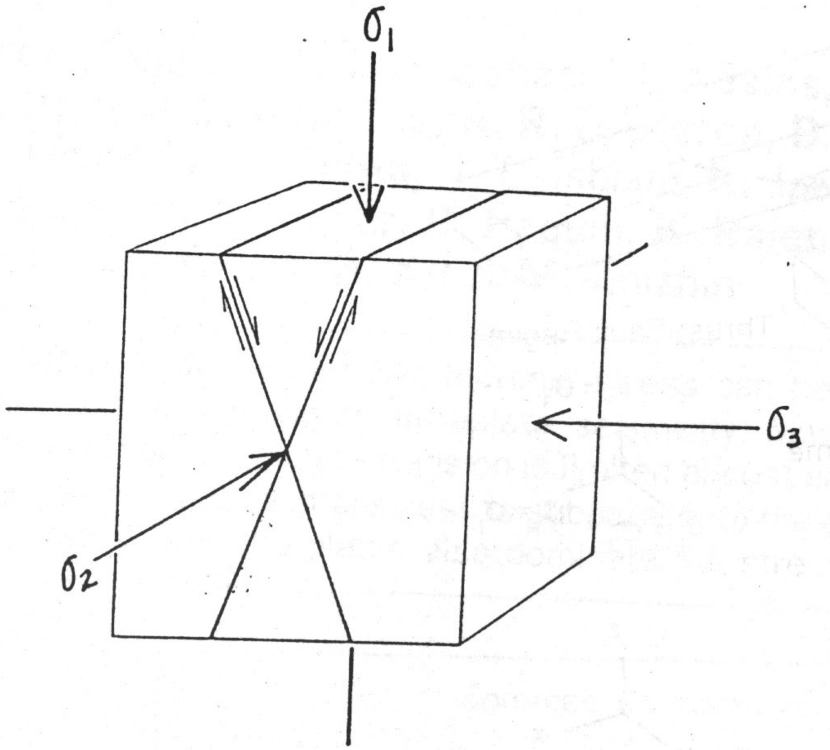
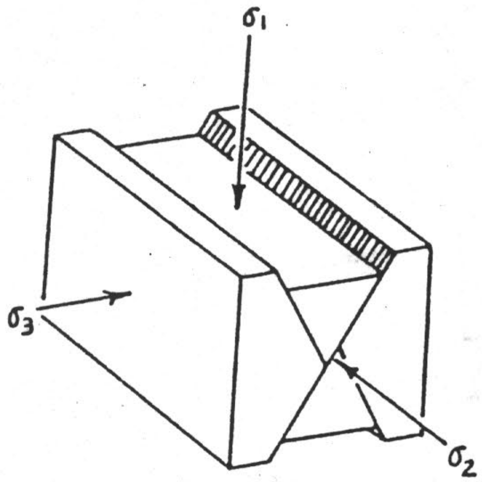
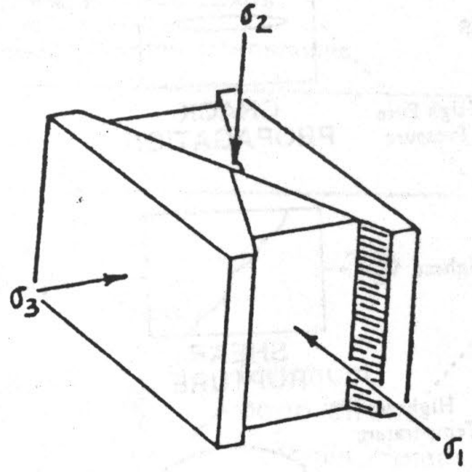


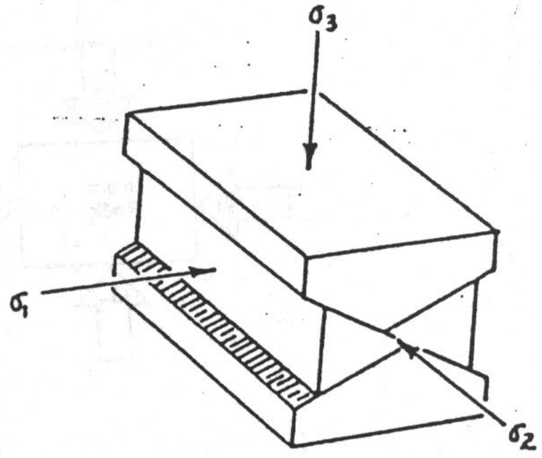
Fig. 10.6 Relationship between principal stresses and conjugate shear surfaces.

Andersonian Faulting Theory

Rowland and Duebendorfer







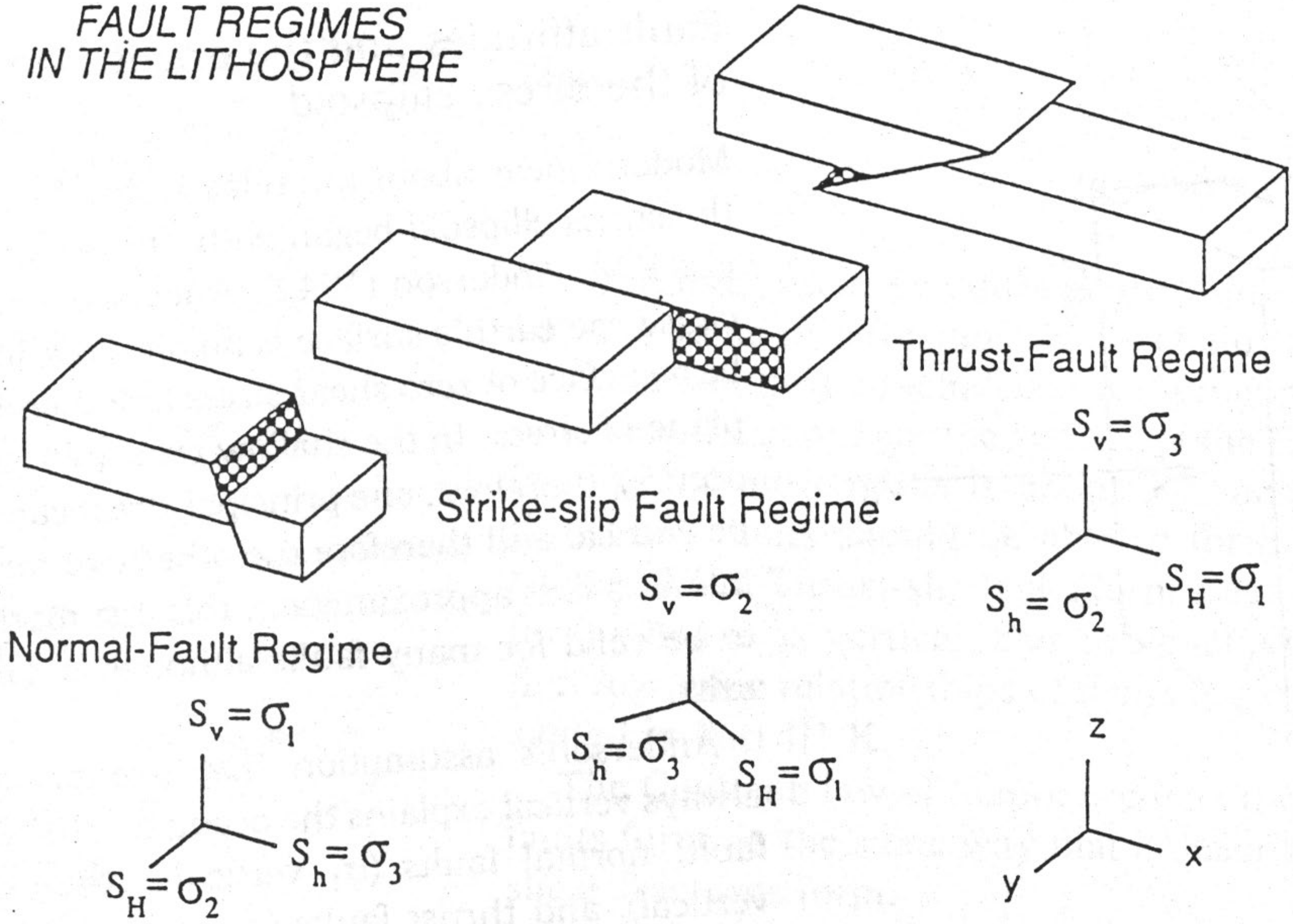


Fig. 1–3. The three states of stress associated with thrust, strike-slip, and normal faulting. These three stress states, known as the Andersonian stress states, are referred to as the thrust-fault, strike-slip-fault, and normal-fault regimes, respectively.

-Engelder, 1993, Stress regimes in the lithosphere, Princeton Univ. Press

Relative stress magnitudes and faulting regimes

Regime	Stress		
	S_1	S_2	S_3
Normal	S_v	S_{Hmax}	S_{hmin}
Strike-slip	S_{Hmax}	S_v	S_{hmin}
Reverse	S_{Hmax}	S_{hmin}	S_v

(from Reservoir Geomechanics by Zoback--http://www.amazon.com/Reservoir-Geomechanics-Mark-D-Zoback/dp/0521770696)

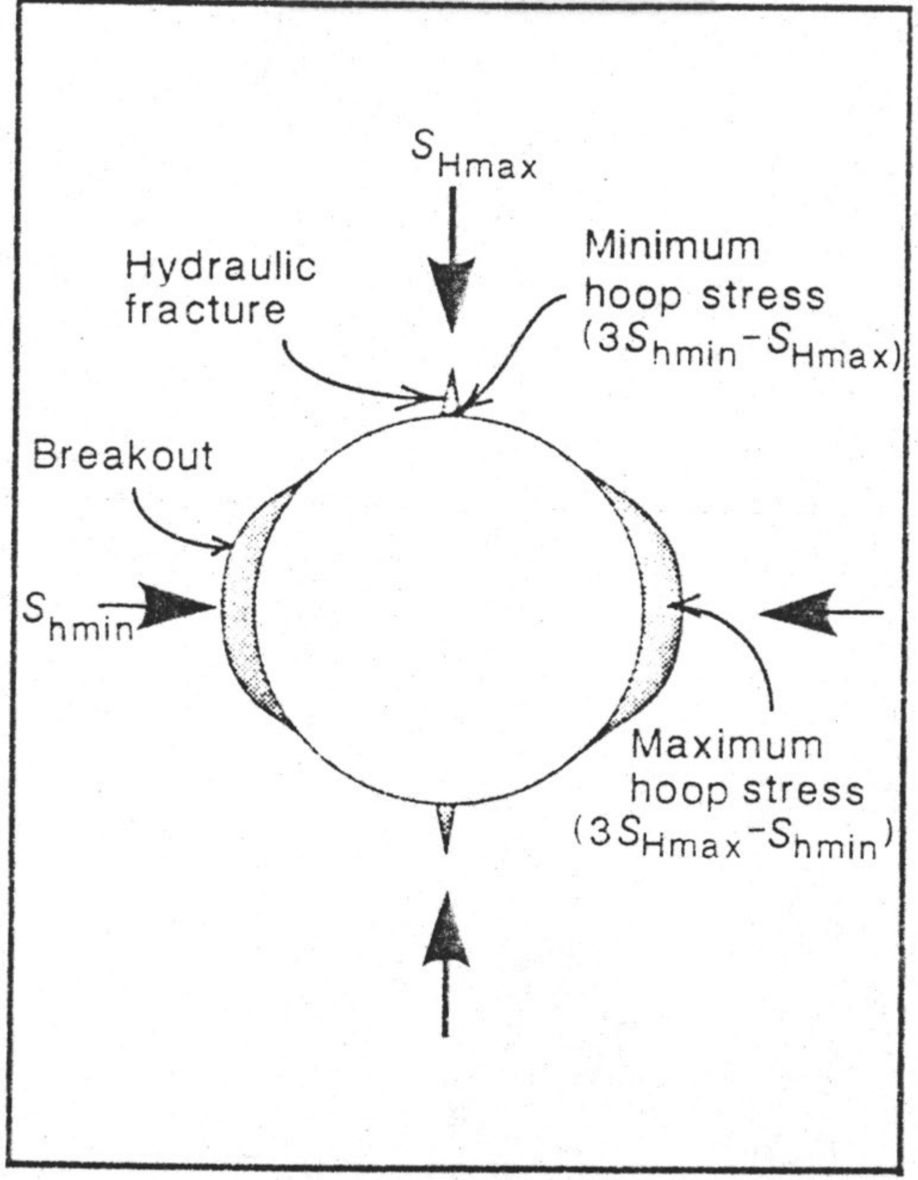
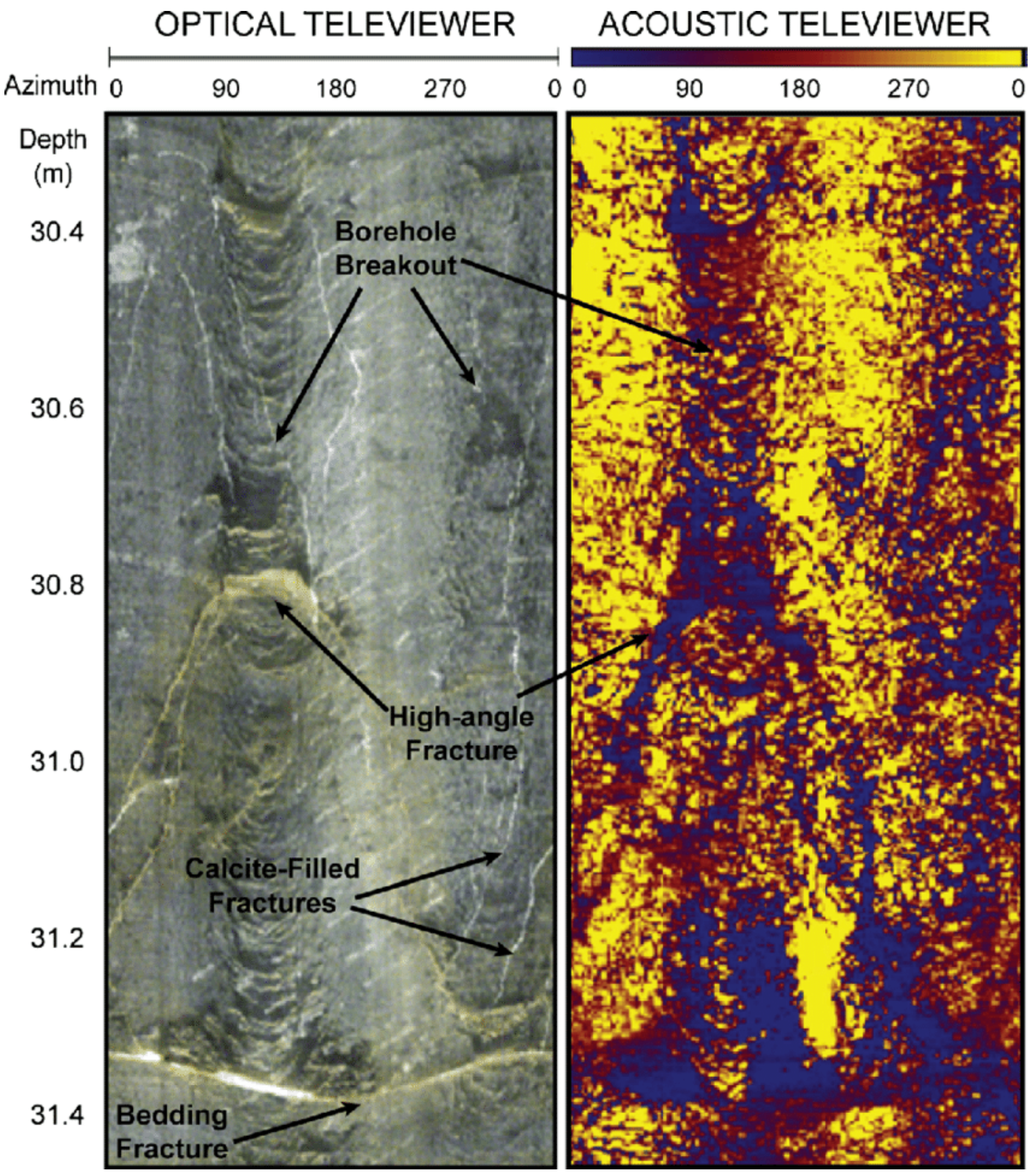
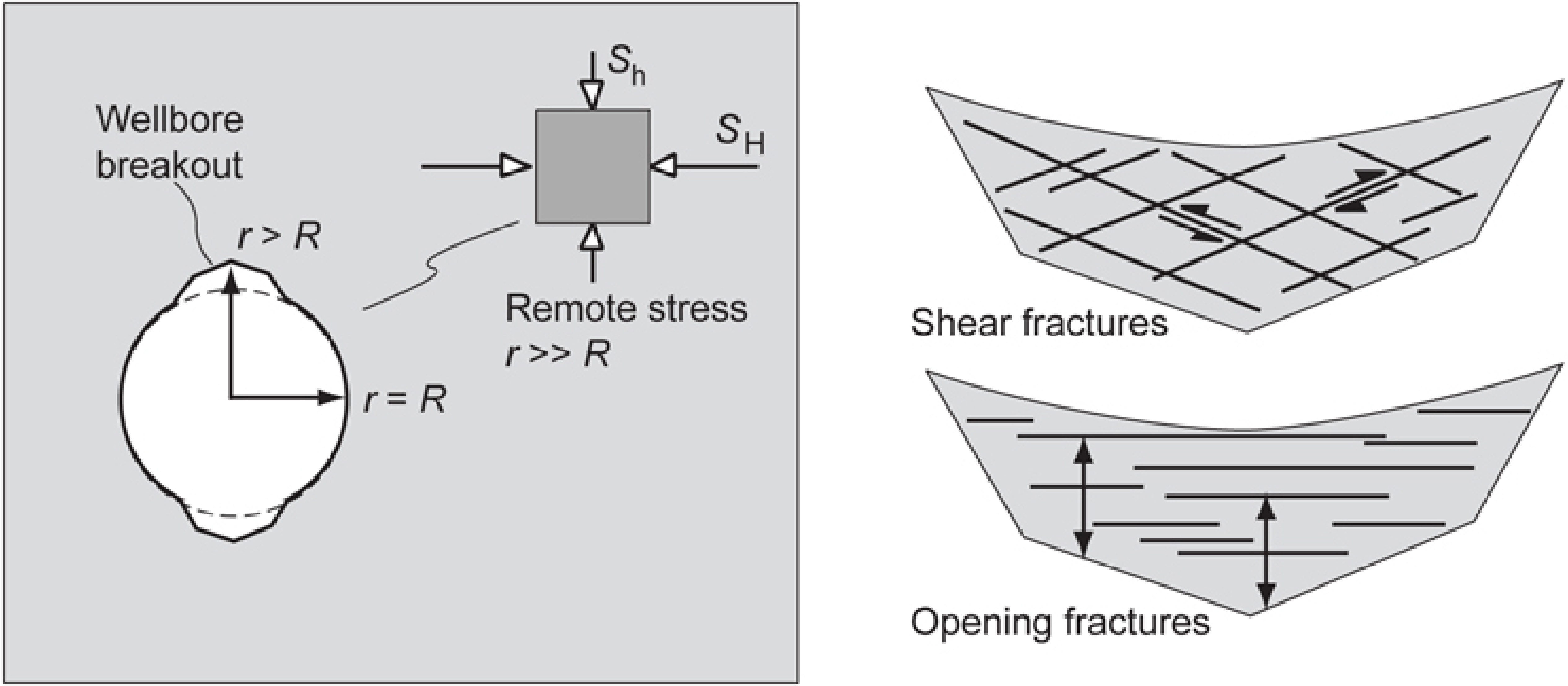


FIG. 1 Stress concentration around a vertical circular hole in an elastic half-space subjected to unequal far-field horizontal stresses, S_{Hmax} and S_{hmin}. As indicated, breakouts and hydraulic fractures form as a result of these stress concentrations.



https://www.researchgate.net/figure/Acoustic-and-optical-televiewer-images-showing-presence-of-vertical-borehole-breakouts_fig8_270756668



Wellbore
breakout
r > R
r = R
S_h
S_H
Remote stress
r >> R
Shear fractures
Opening fractures

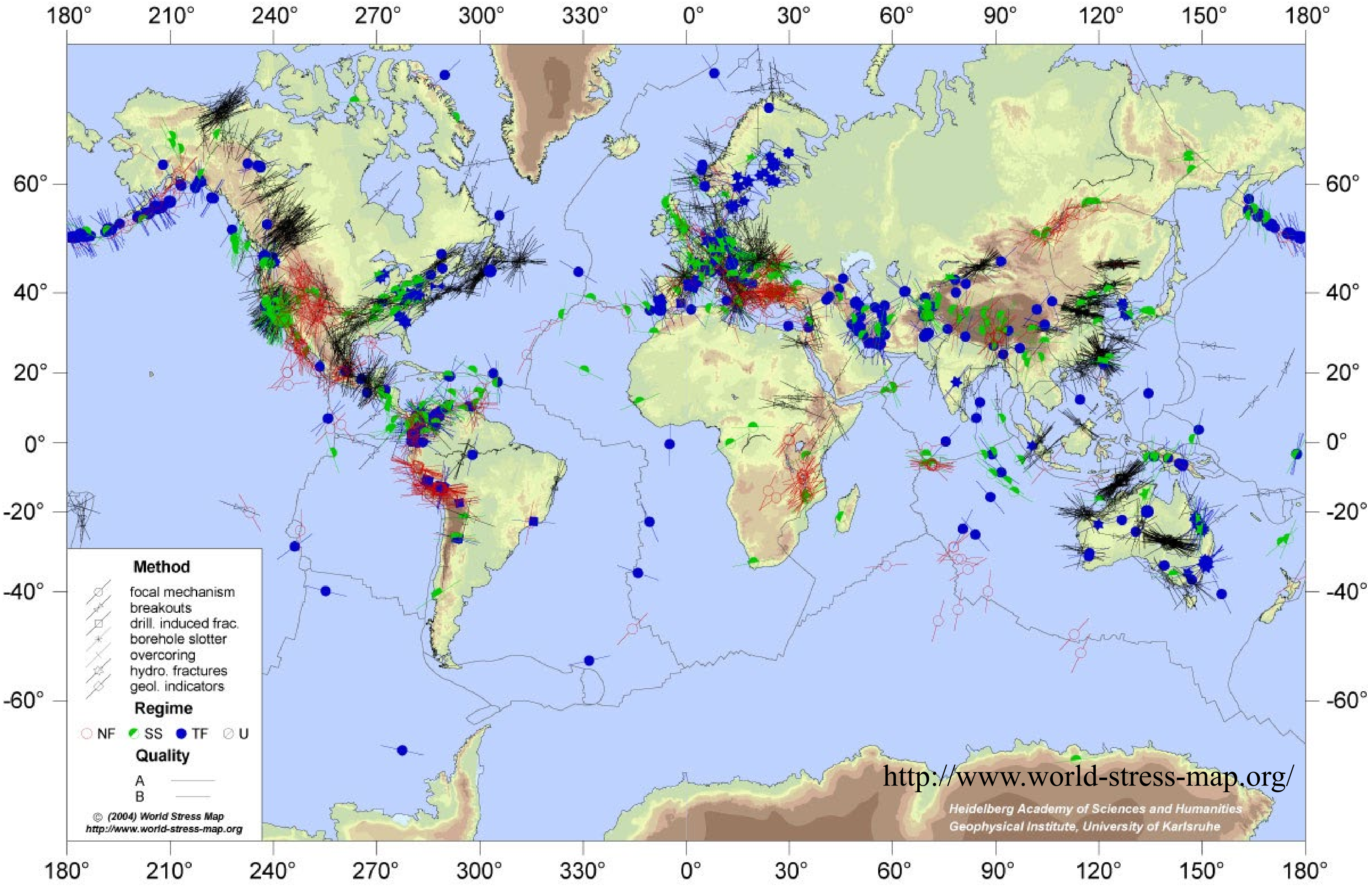
Reprinted from Nature, Vol. 341, No. 6240, pp. 291–298, 28th September, 1989

Global patterns of tectonic stress

Mary Lou Zoback, Mark D. Zoback, J. Adams, M. Assumpção, S. Bell, E. A. Bergman, P. Blümling, N. R. Brereton, D. Denham, J. Ding, K. Fuchs, N. Gay, S. Gregersen, H. K. Gupta, A. Gvishiani, K. Jacob, R. Klein, P. Knoll, M. Magee, J. L. Mercier, B. C. Müller, C. Paquin, K. Rajendran, O. Stephansson, G. Suarez, M. Suter, A. Udias, Z. H. Xu & M. Zhizhin

Regional patterns of present-day tectonic stress can be used to evaluate the forces acting on the lithosphere and to investigate intraplate seismicity. Most intraplate regions are characterized by a compressional stress regime; extension is limited almost entirely to thermally uplifted regions. In several plates the maximum horizontal stress is subparallel to the direction of absolute plate motion, suggesting that the forces driving the plates also dominate the stress distribution in the plate interior.

World Stress Map



http://www.world-stress-map.org/

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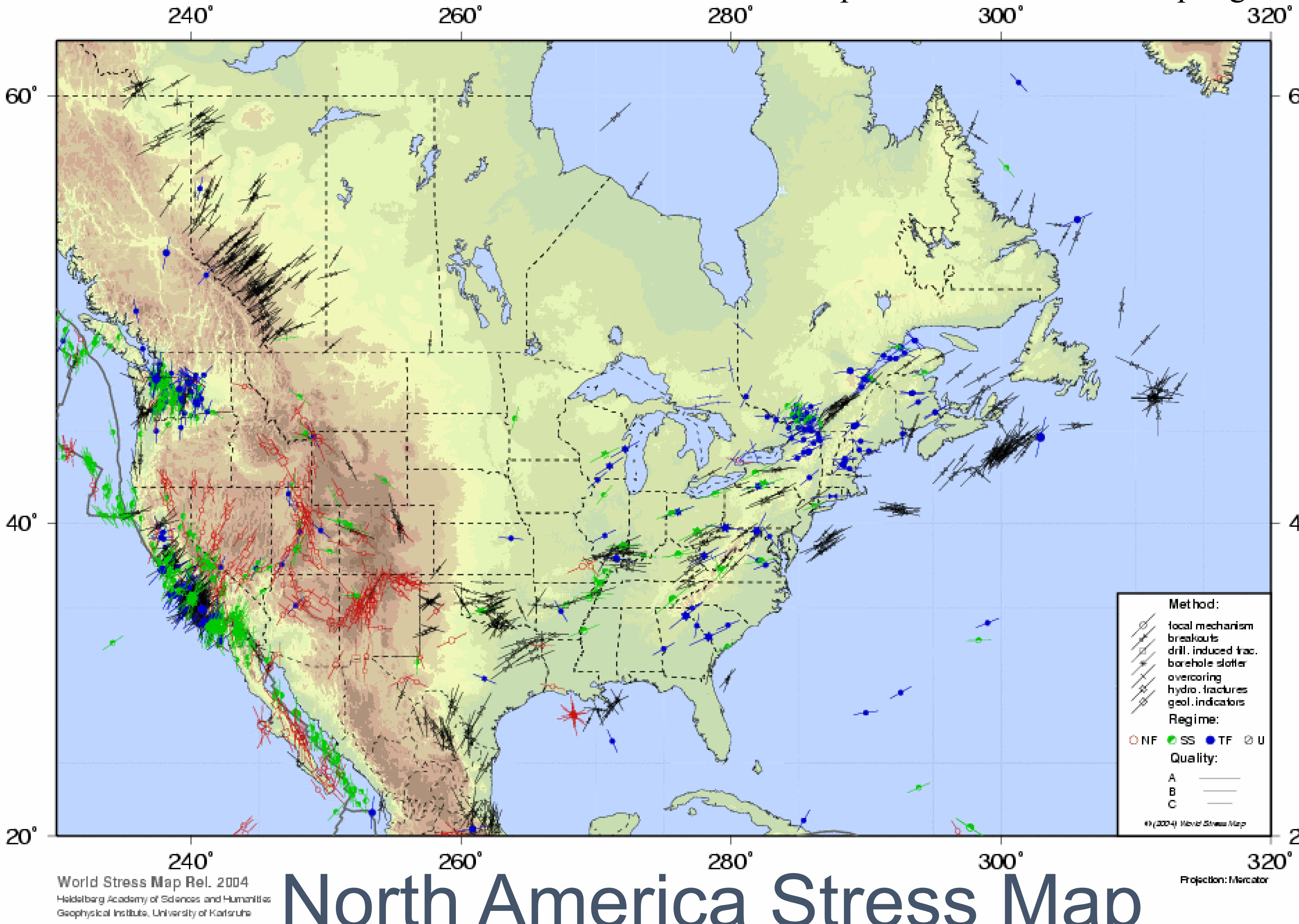
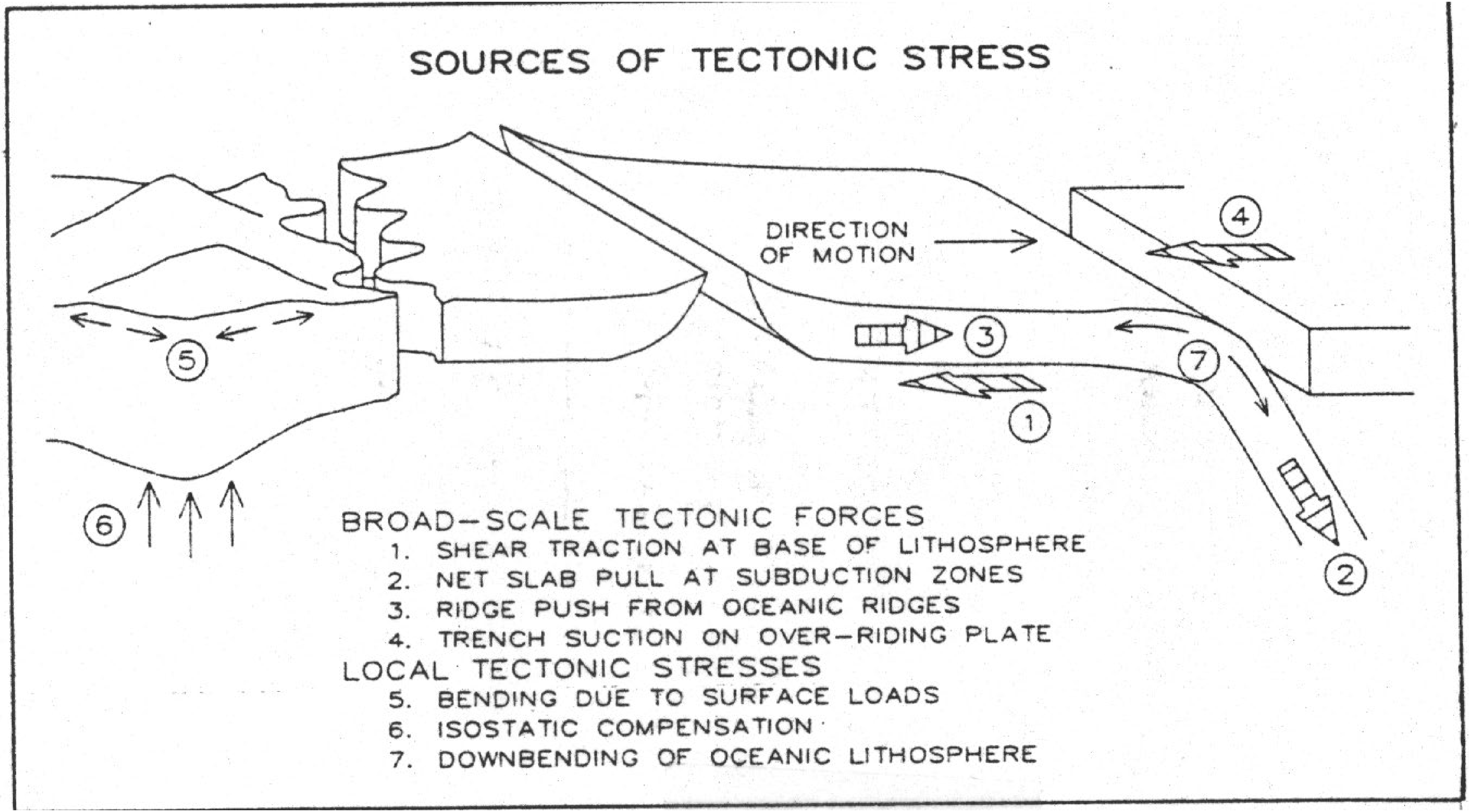


North America Stress Map


SOURCES OF TECTONIC STRESS
DIRECTION OF MOTION
4
3
7
5
1
6
2
BROAD-SCALE TECTONIC FORCES
1. SHEAR TRACTION AT BASE OF LITHOSPHERE
2. NET SLAB PULL AT SUBDUCTION ZONES
3. RIDGE PUSH FROM OCEANIC RIDGES
4. TRENCH SUCTION ON OVER-RIDING PLATE
LOCAL TECTONIC STRESSES
5. BENDING DUE TO SURFACE LOADS
6. ISOSTATIC COMPENSATION
7. DOWNBENDING OF OCEANIC LITHOSPHERE