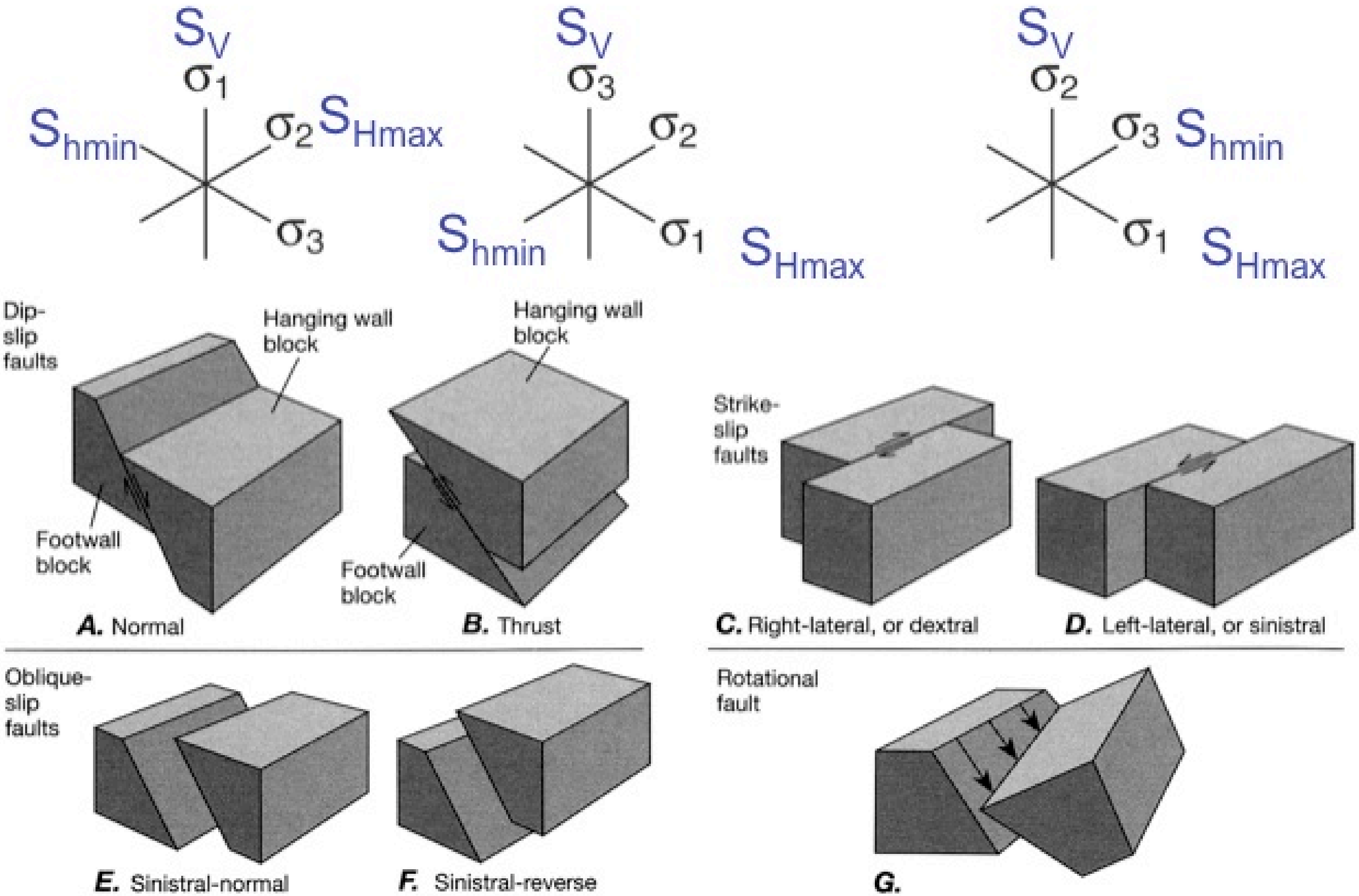
Tektonische Kräfte & Plattenbewegungen

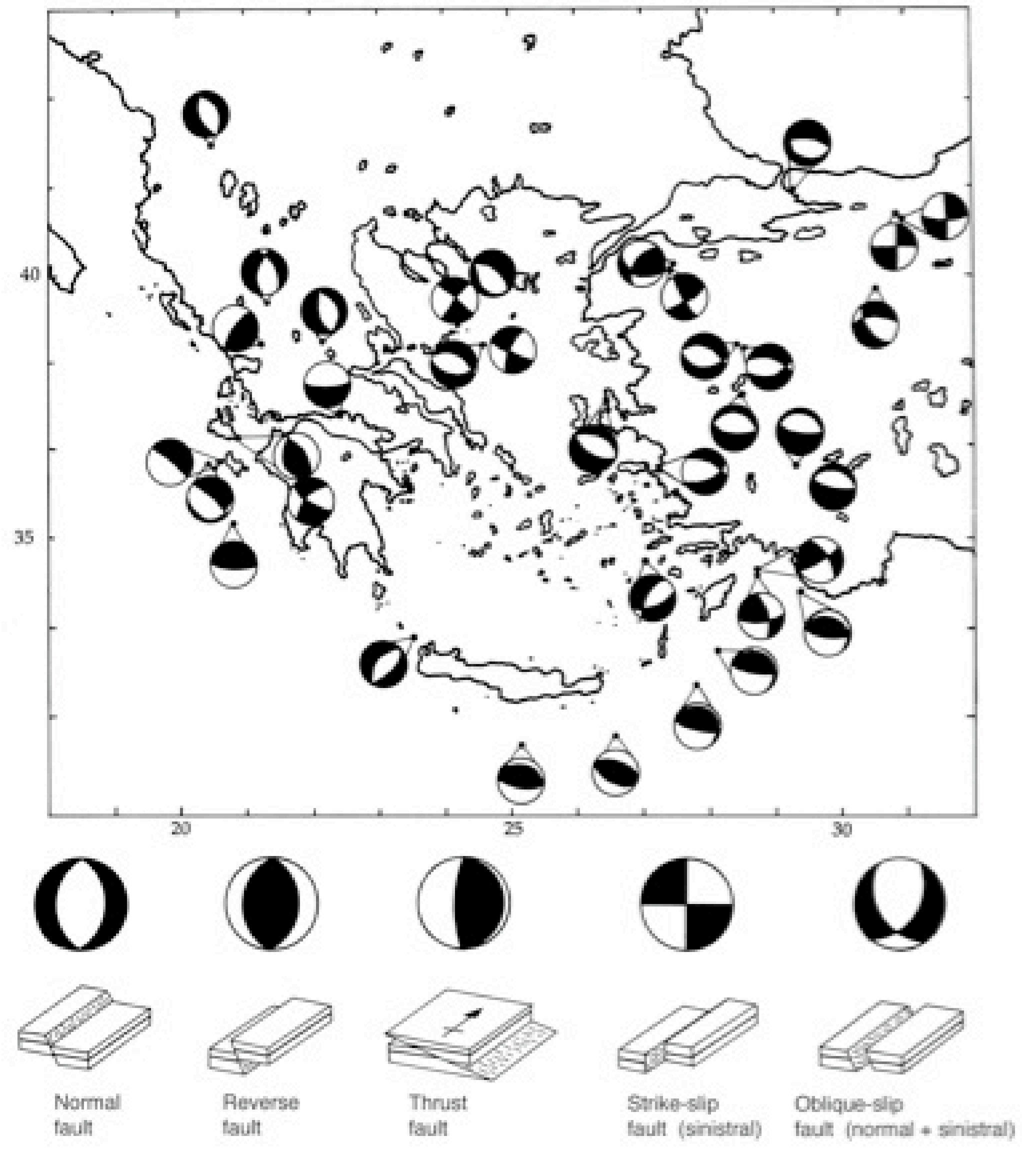
Topics: Jan 15, 2009

(1) Indicators of tectonic stress fields
(2) Tectonic stress-field provinces
(3) Neotectonics in intraplate regions

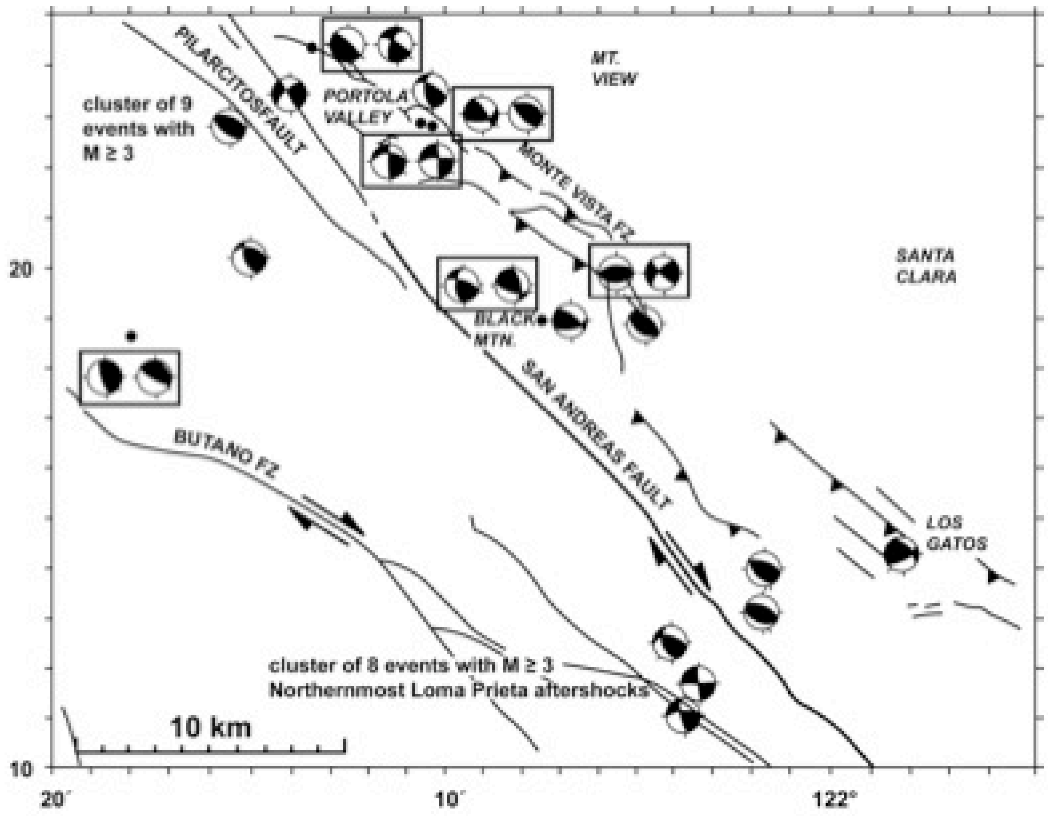
(1) Indicators of tectonic stress fields

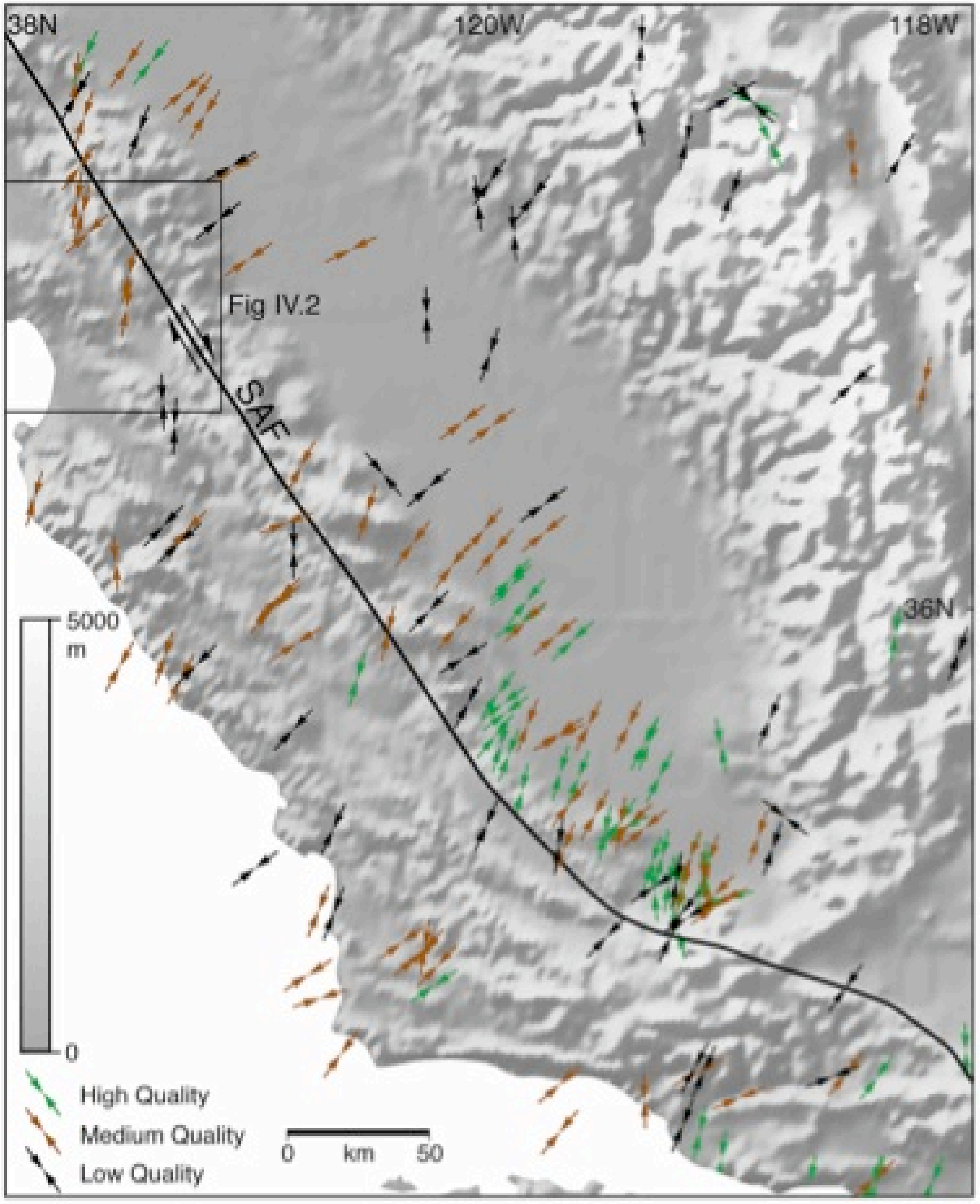


Earthquake focal mechanisms



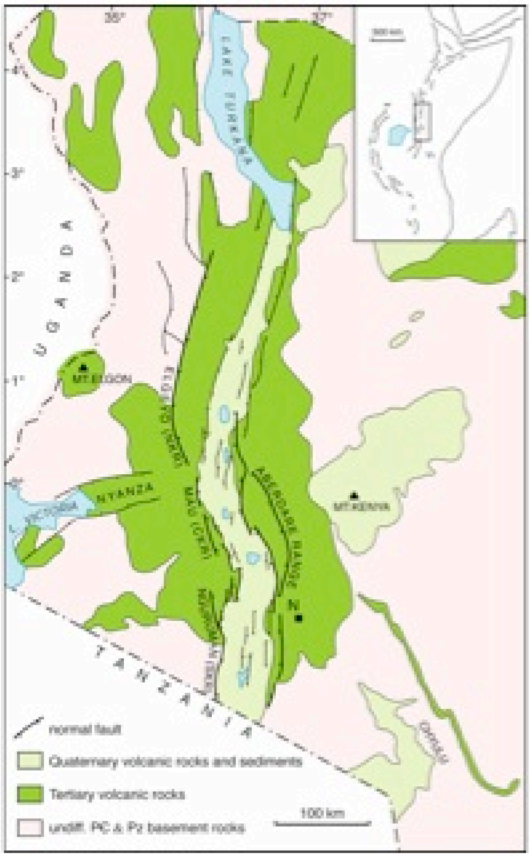
State of stress along the San Andreas Fault

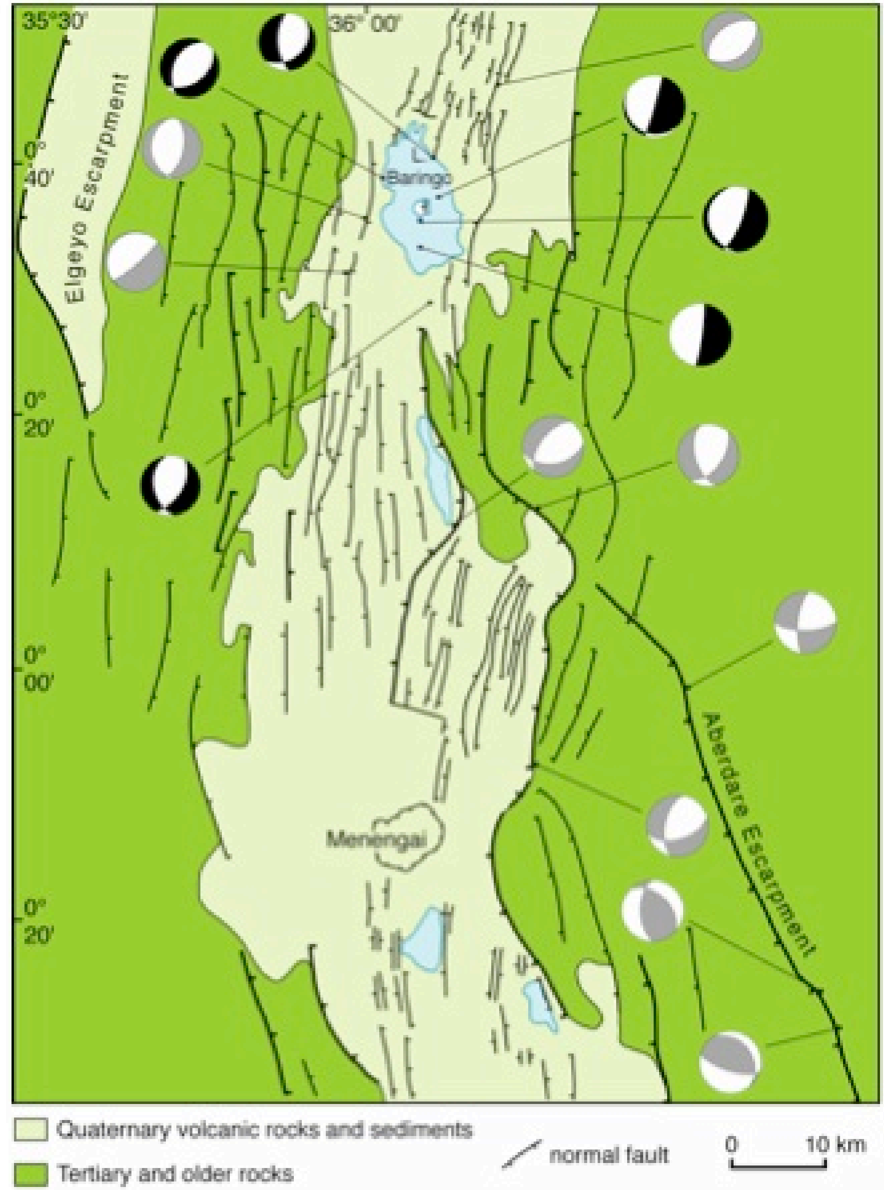




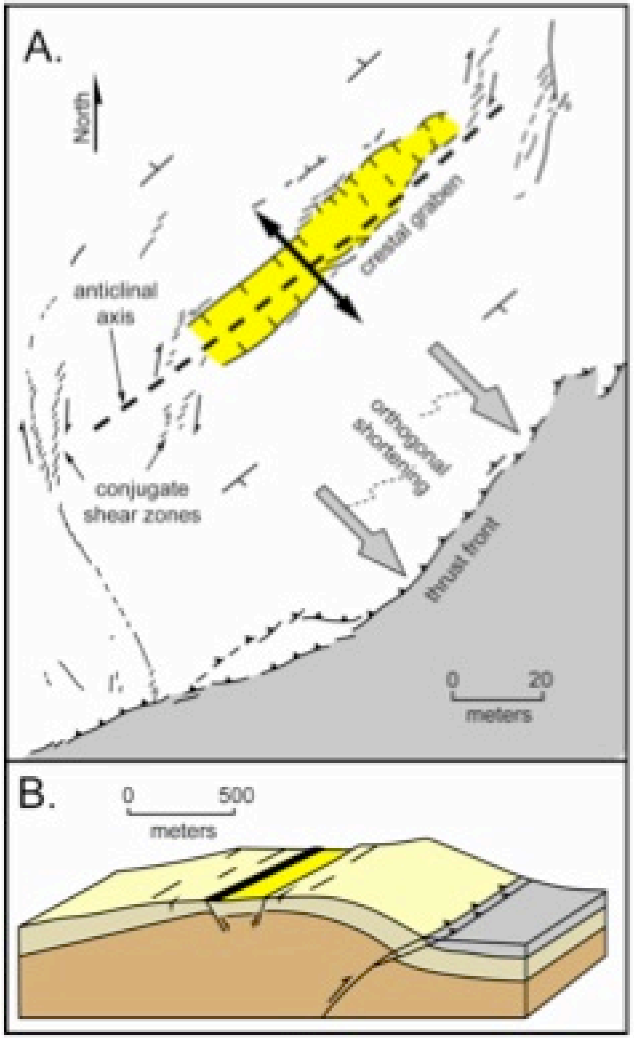
Different types of stress-field indicators in the immediate vicinity of the San Andreas Fault show a fault-normal orientation of S_{Hmax}

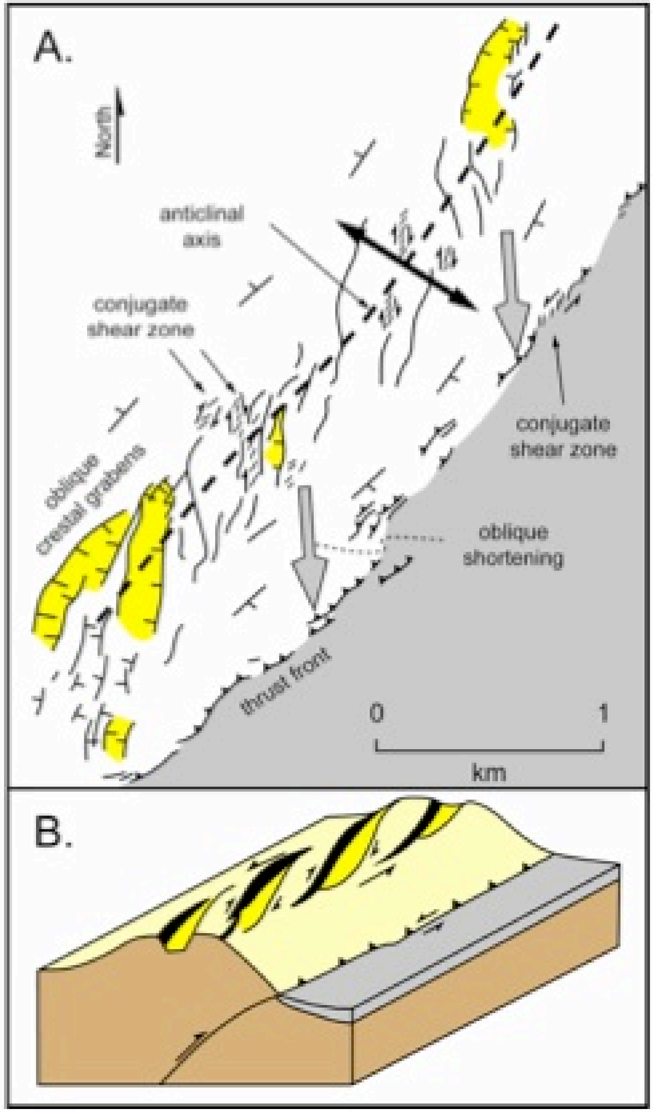
Diverging strikes of different normal fault generations and inferred S_{hmin} orientation obtained from focal mechanisms





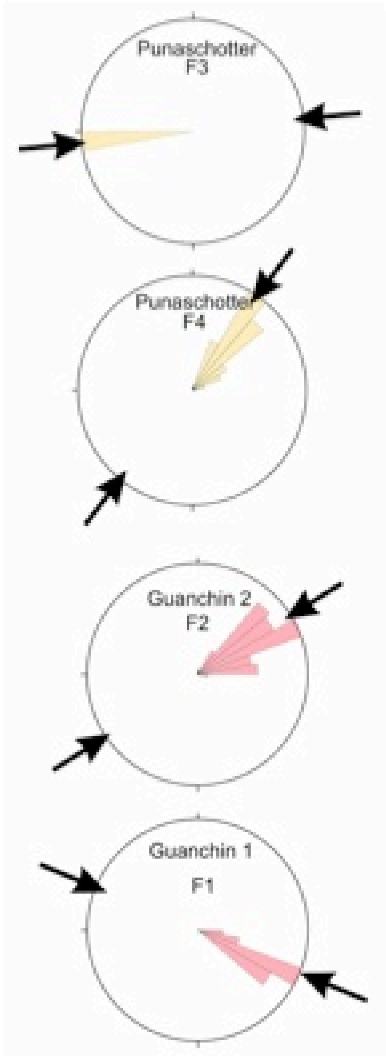
Inferences based on structures: surface ruptures of the 1980 El Asnam earthquake

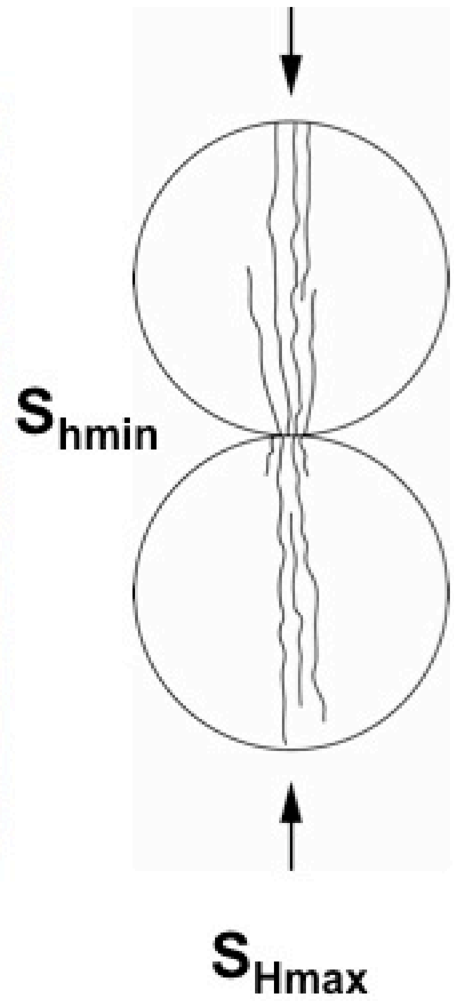




Philip and Meghraoui, 1983

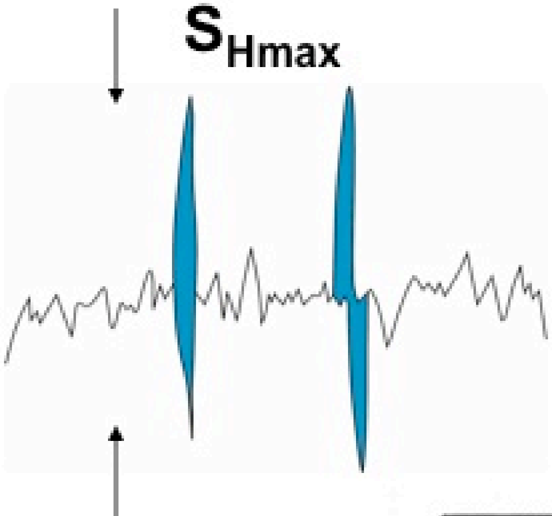
Transgranular rock fractures - inferring S_{Hmax}

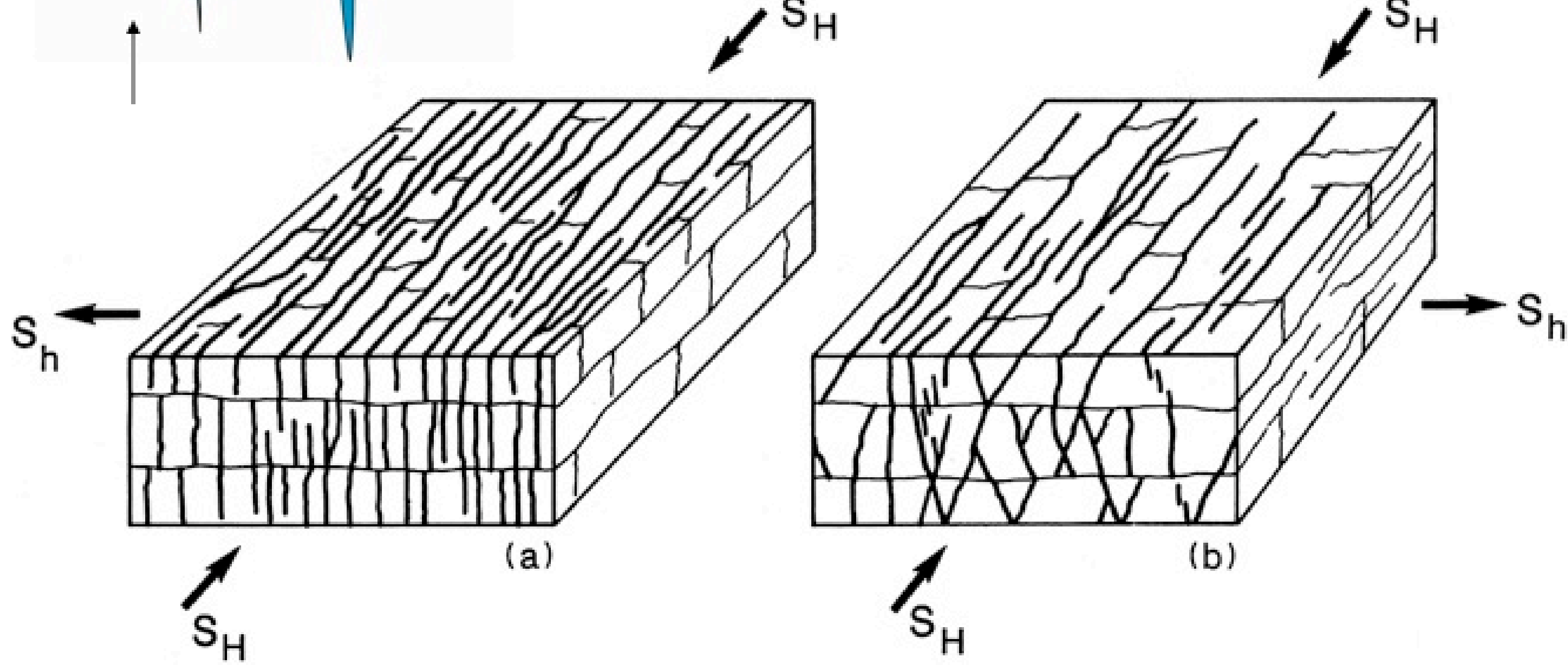




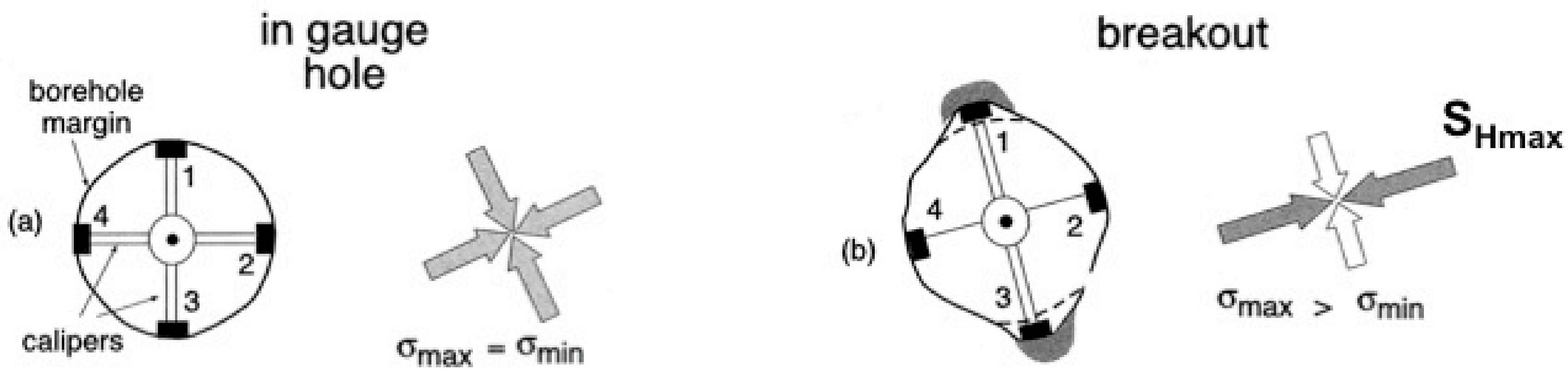
Stylolites

Neotectonic joints





Borehole breakouts



Burbank and Anderson, 2005

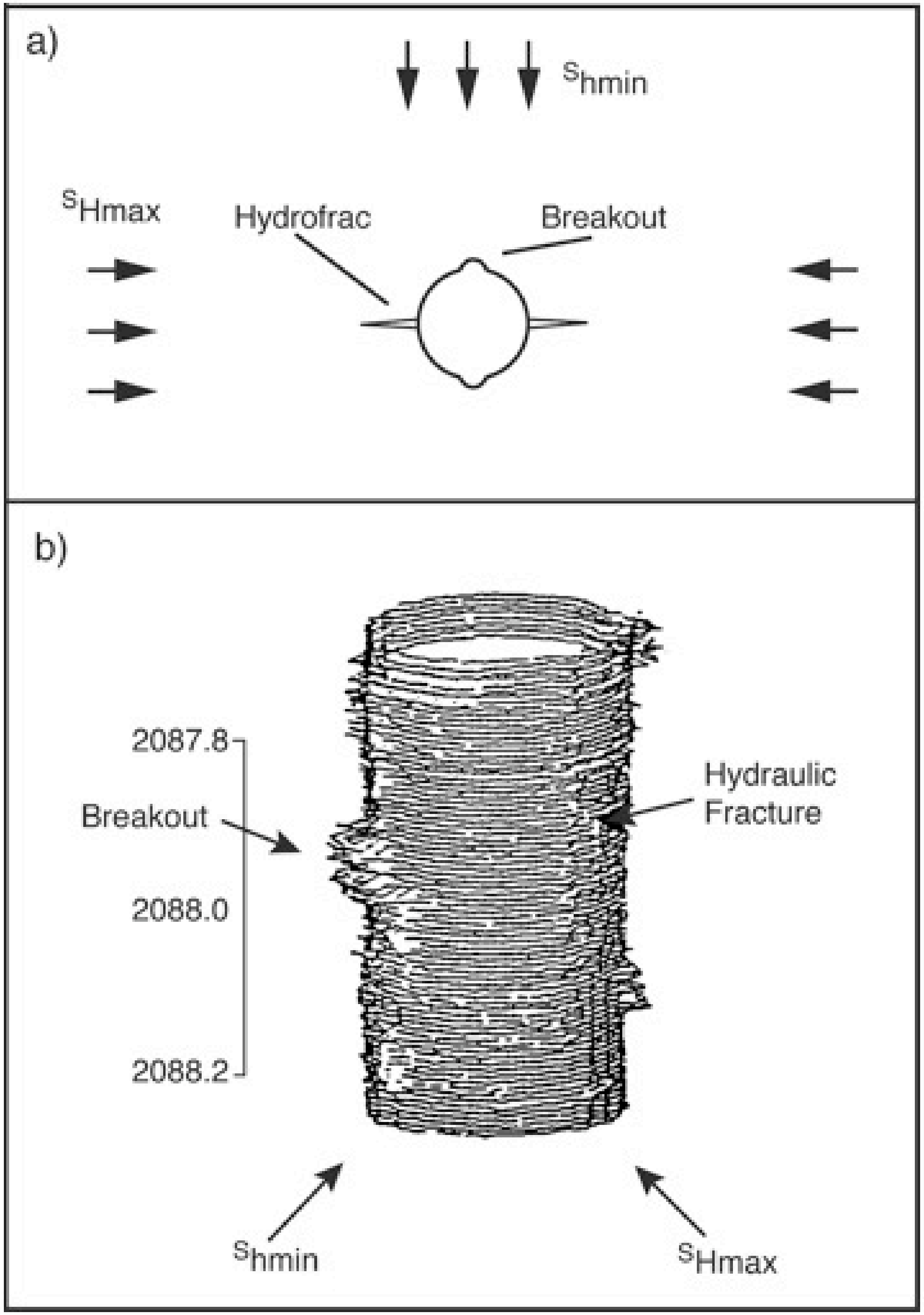
Borehole breakouts and hydrofracs

Hydrofracs = S_{hmax}

Fracture perpendicular to S_{hmin}

Breakouts = S_{hmin}

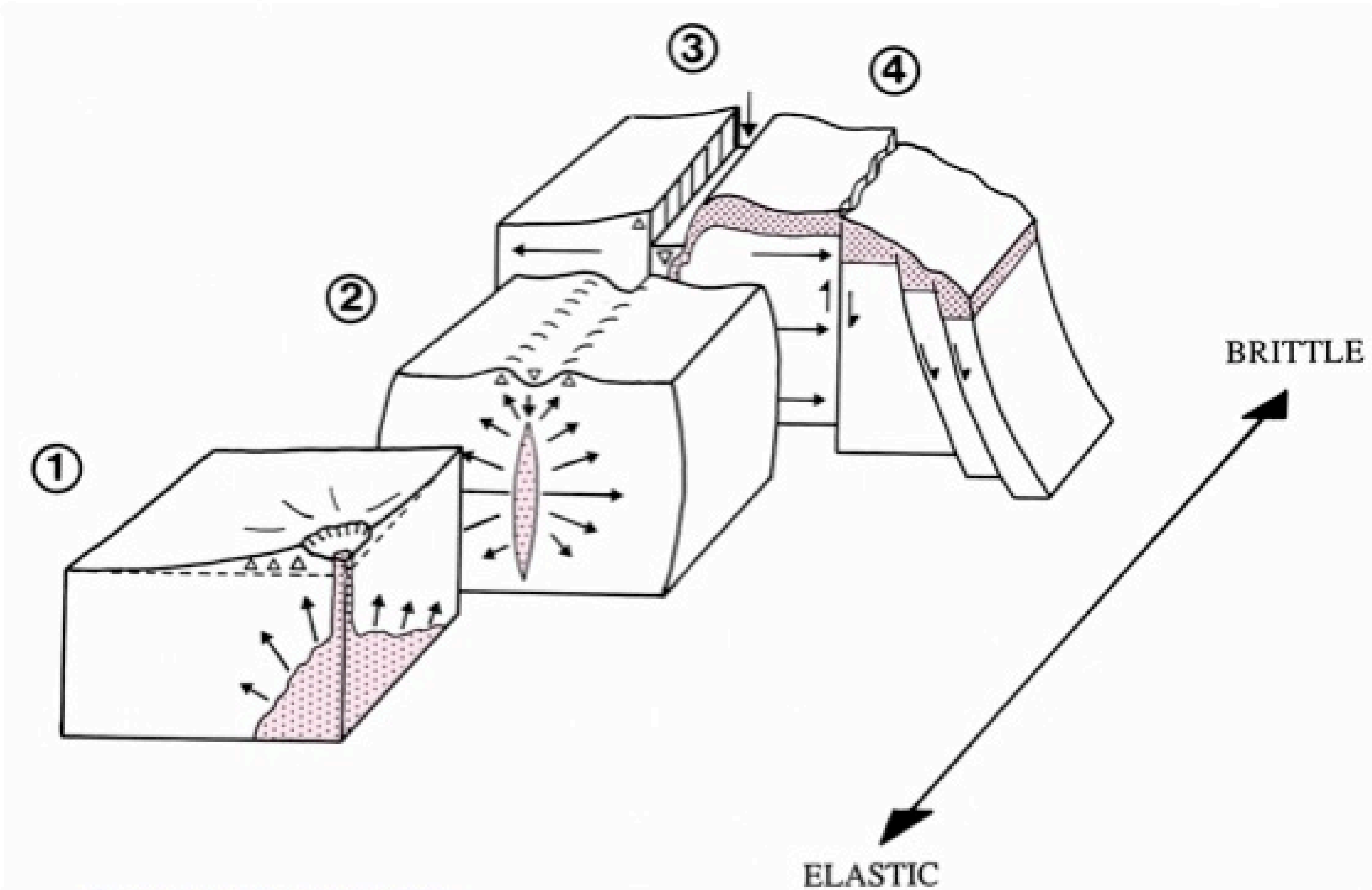
Shear fractures oblique to S_{hmax}



Neptunic dykes

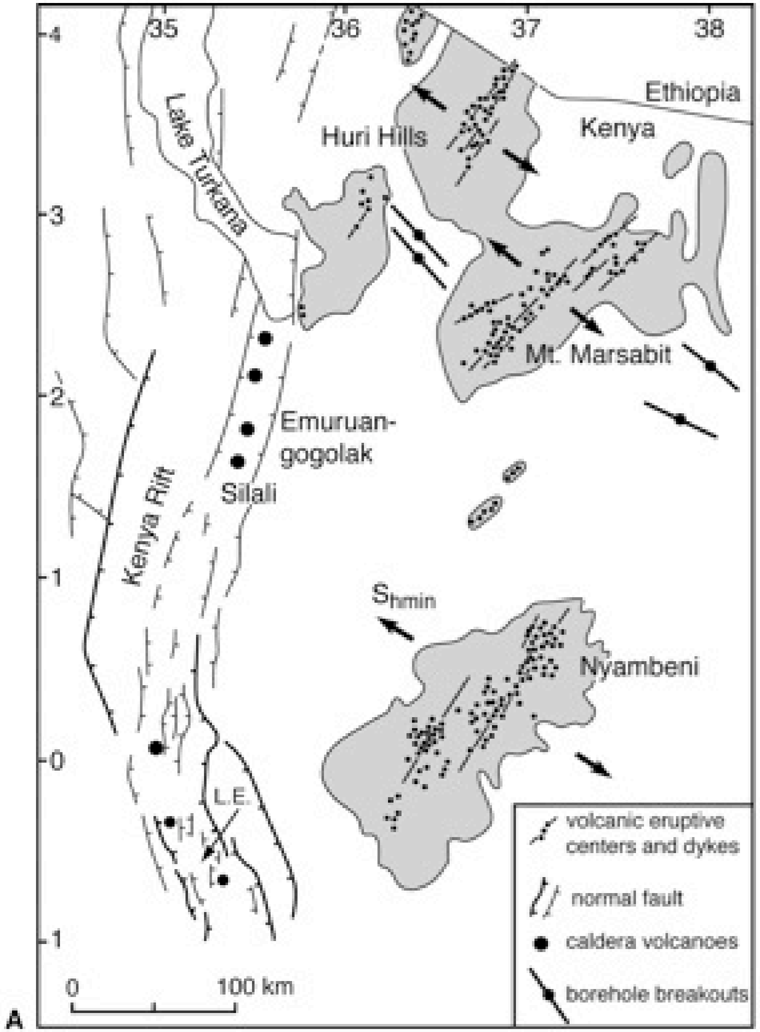
$$P_f = r_f \cdot g \cdot D \; > \; S_v = r_{sed} \cdot g \cdot D$$

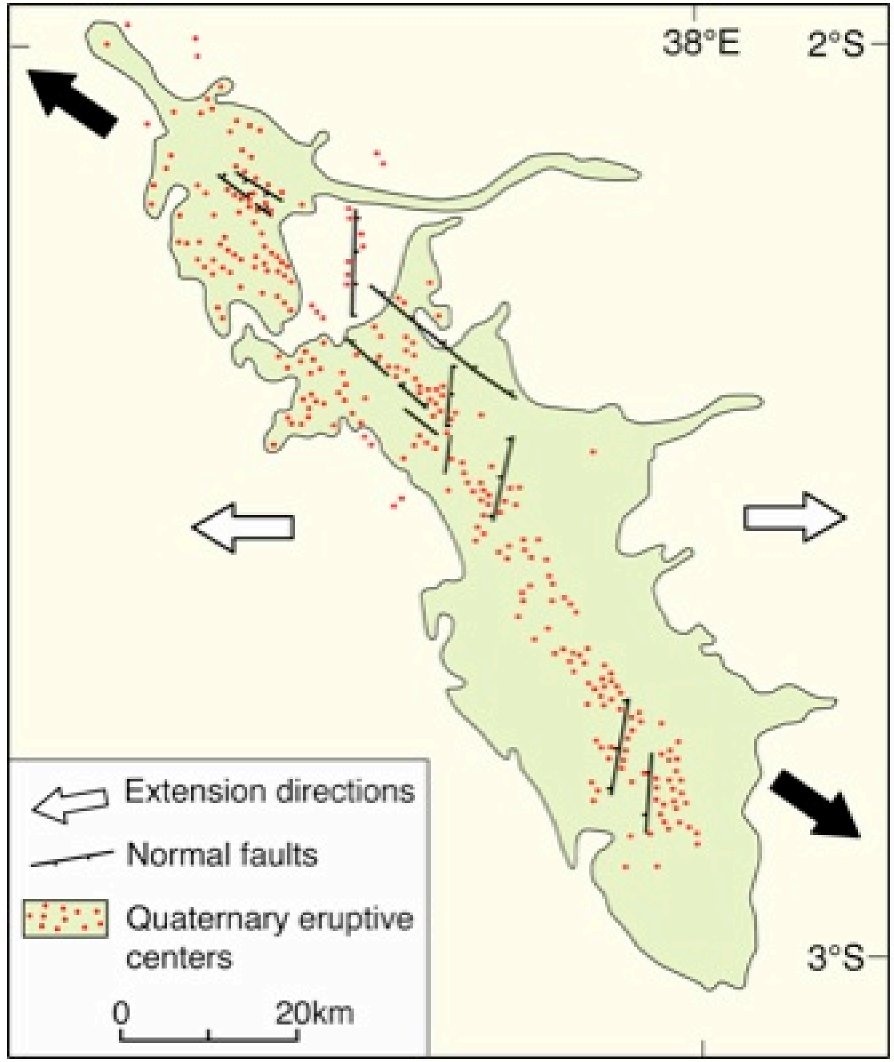
Dyke swarms, volcanic alignments & caldera elongation



Stewart and Hancock, 1994

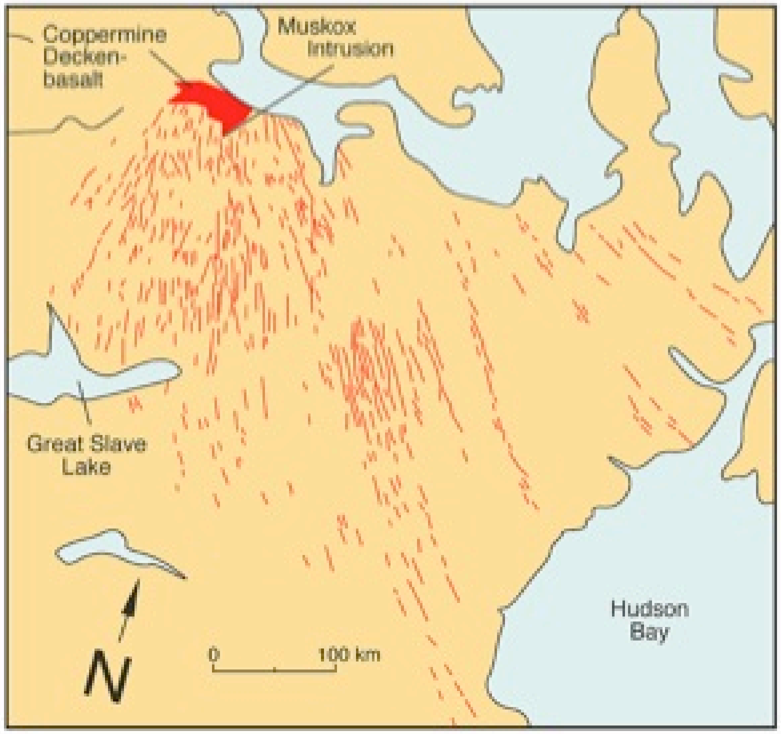
Volcanic chains





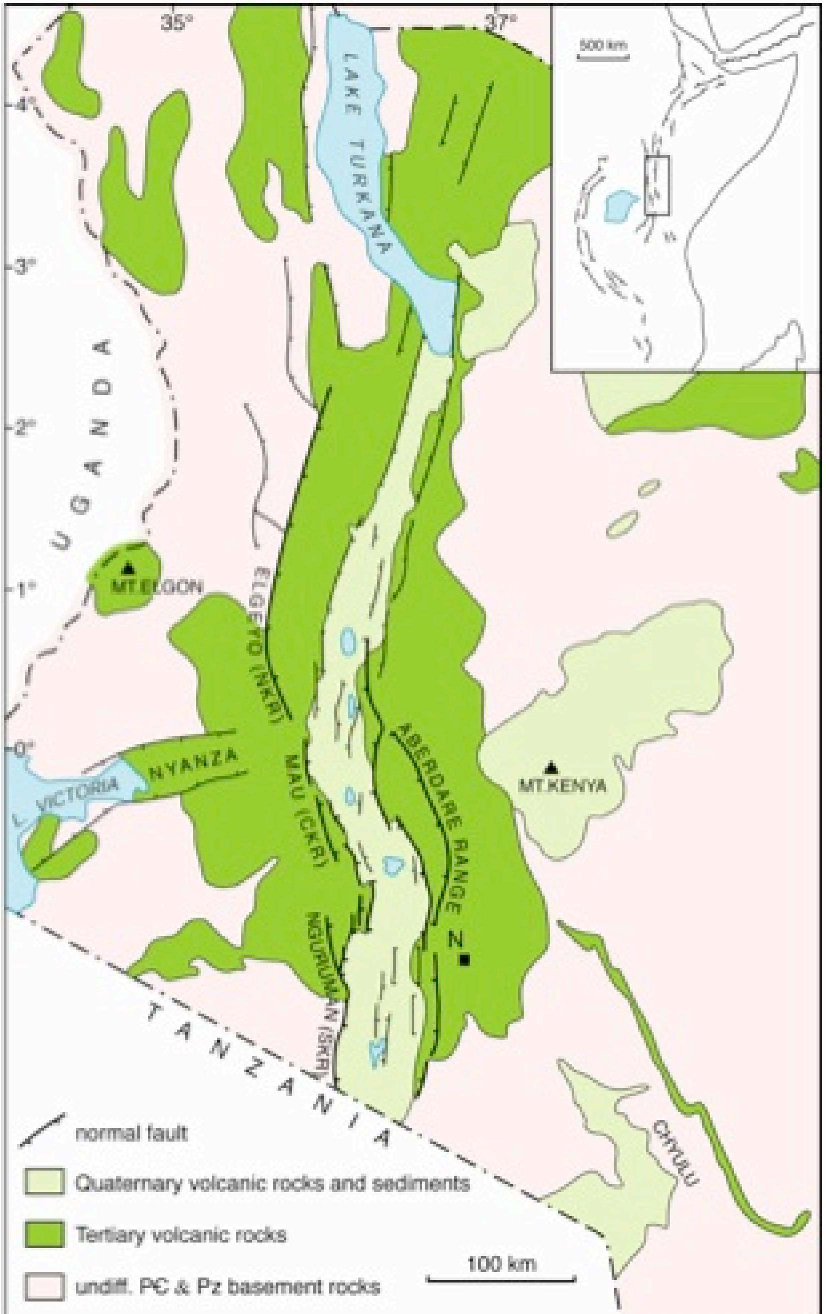
Haug and Strecker, 1994; Bosworth and Strecker, 1998;

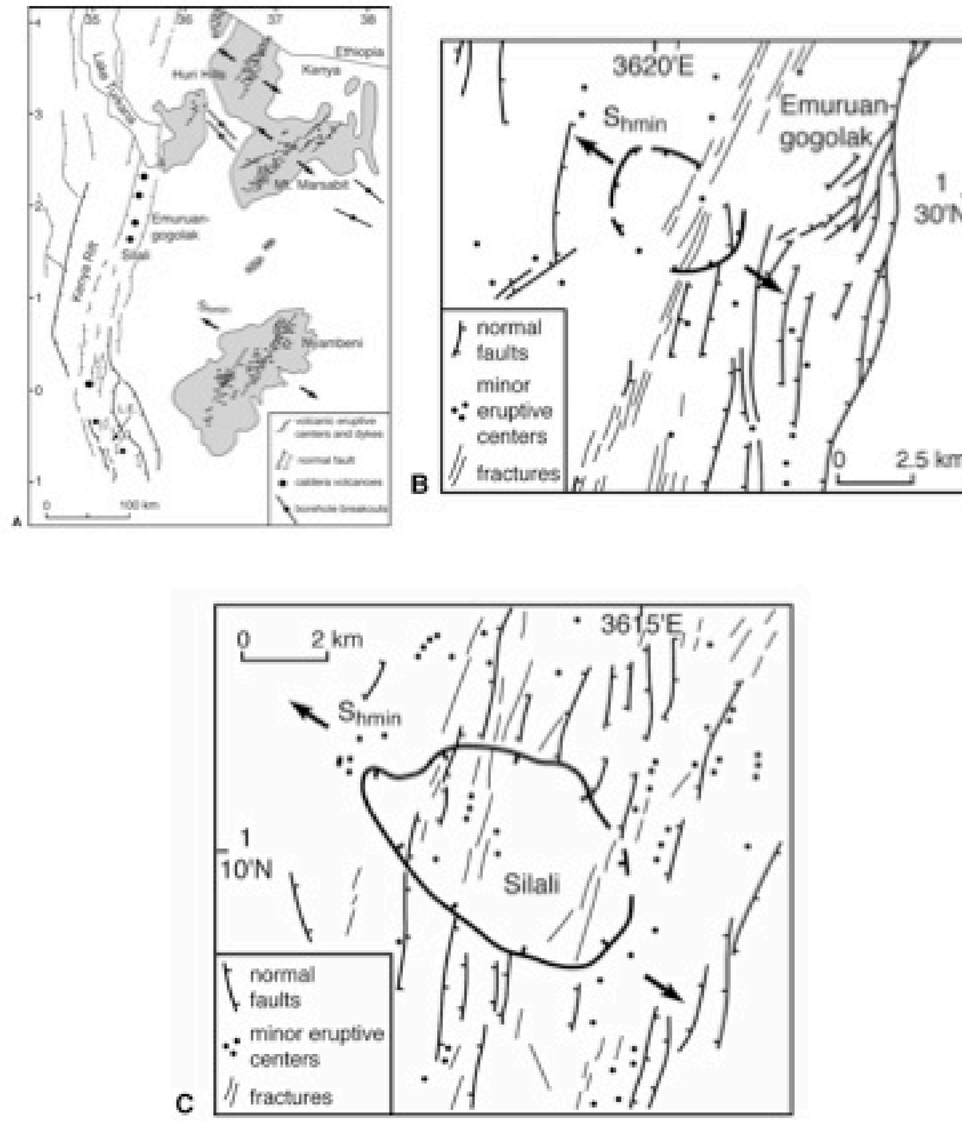
Dyke swarms

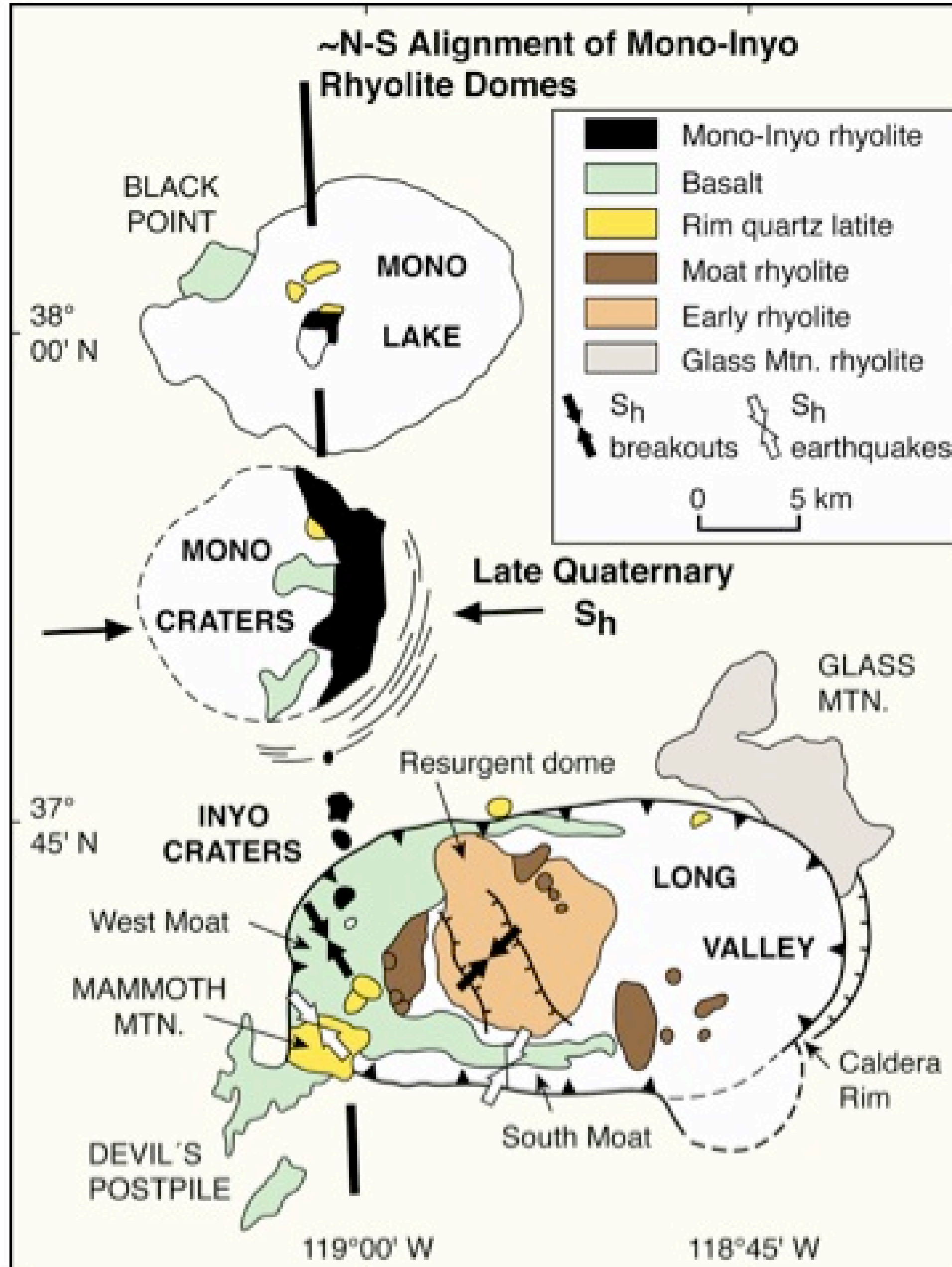


Halls and Fahrig, 1987

Caldera elongation

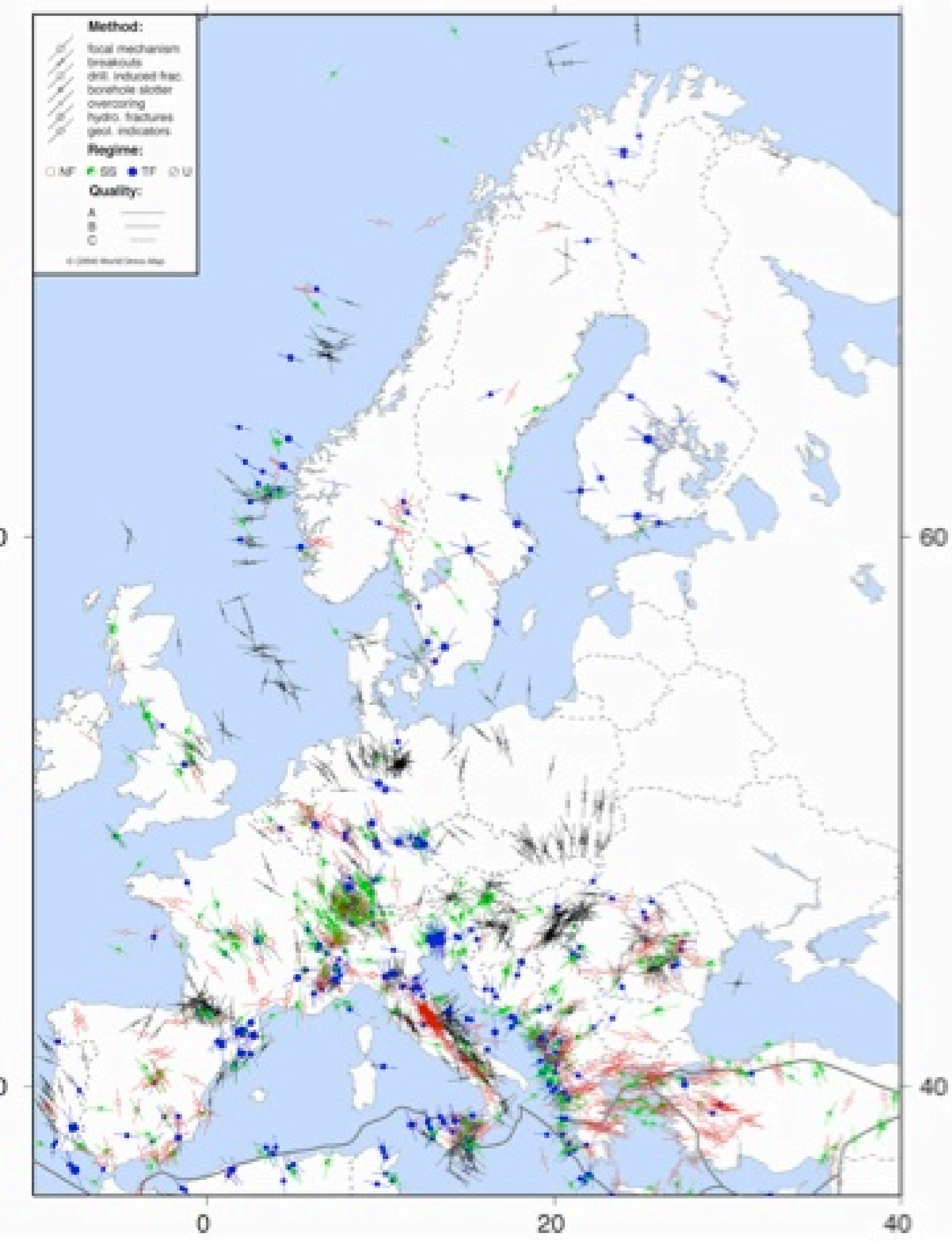




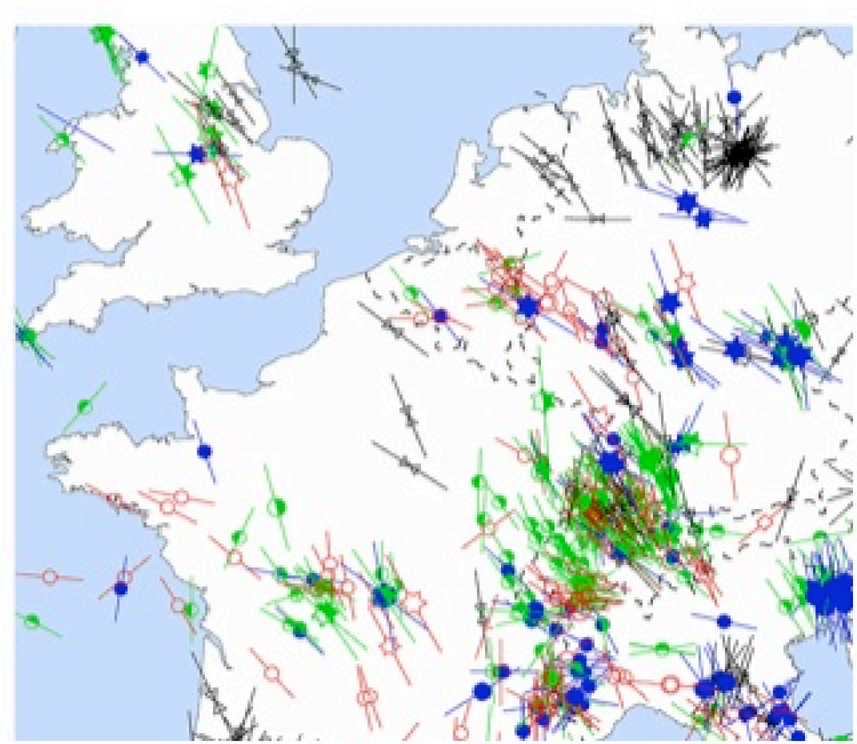


Bosworth et al., 2003

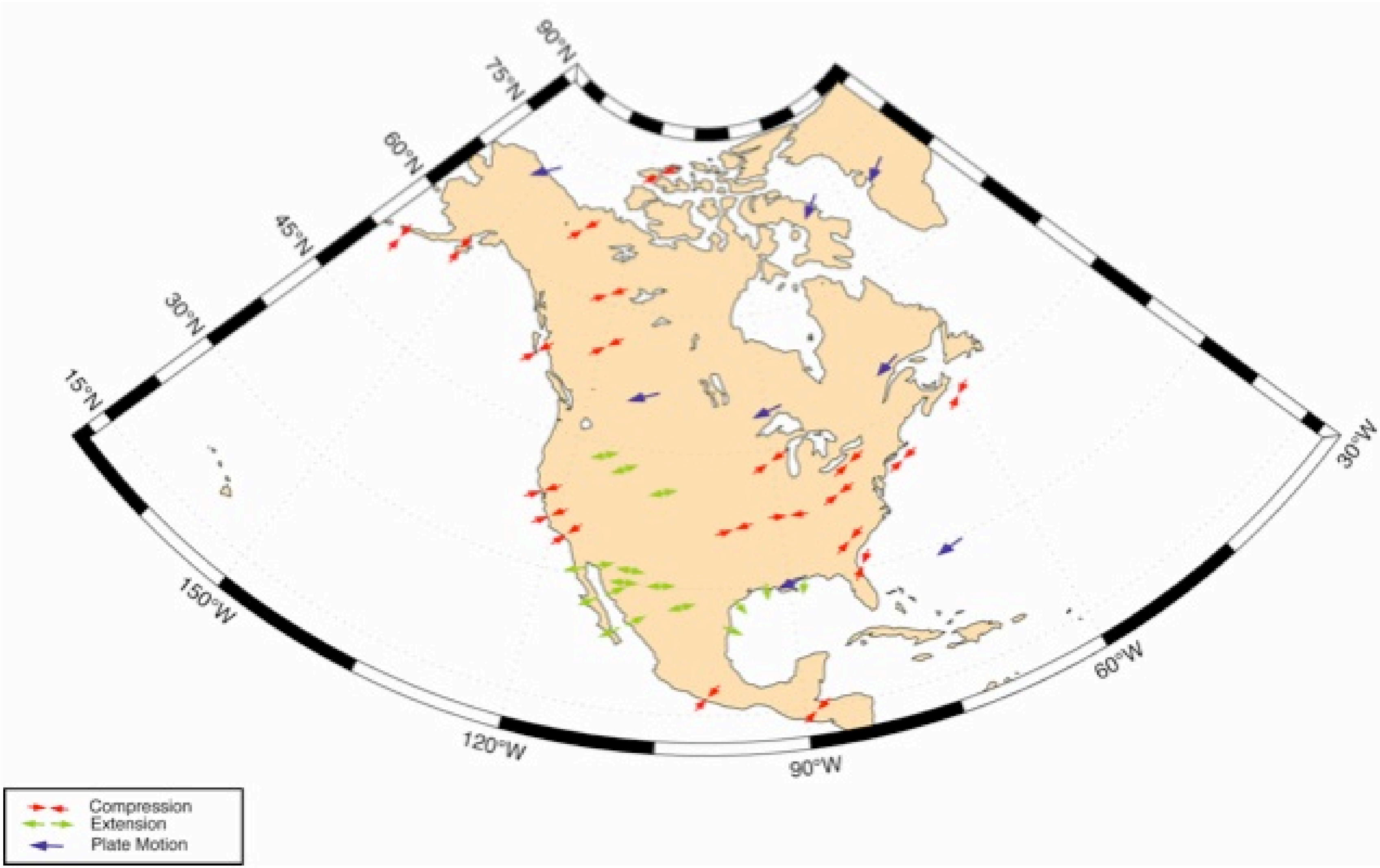
(2) Tectonic stress - field provinces

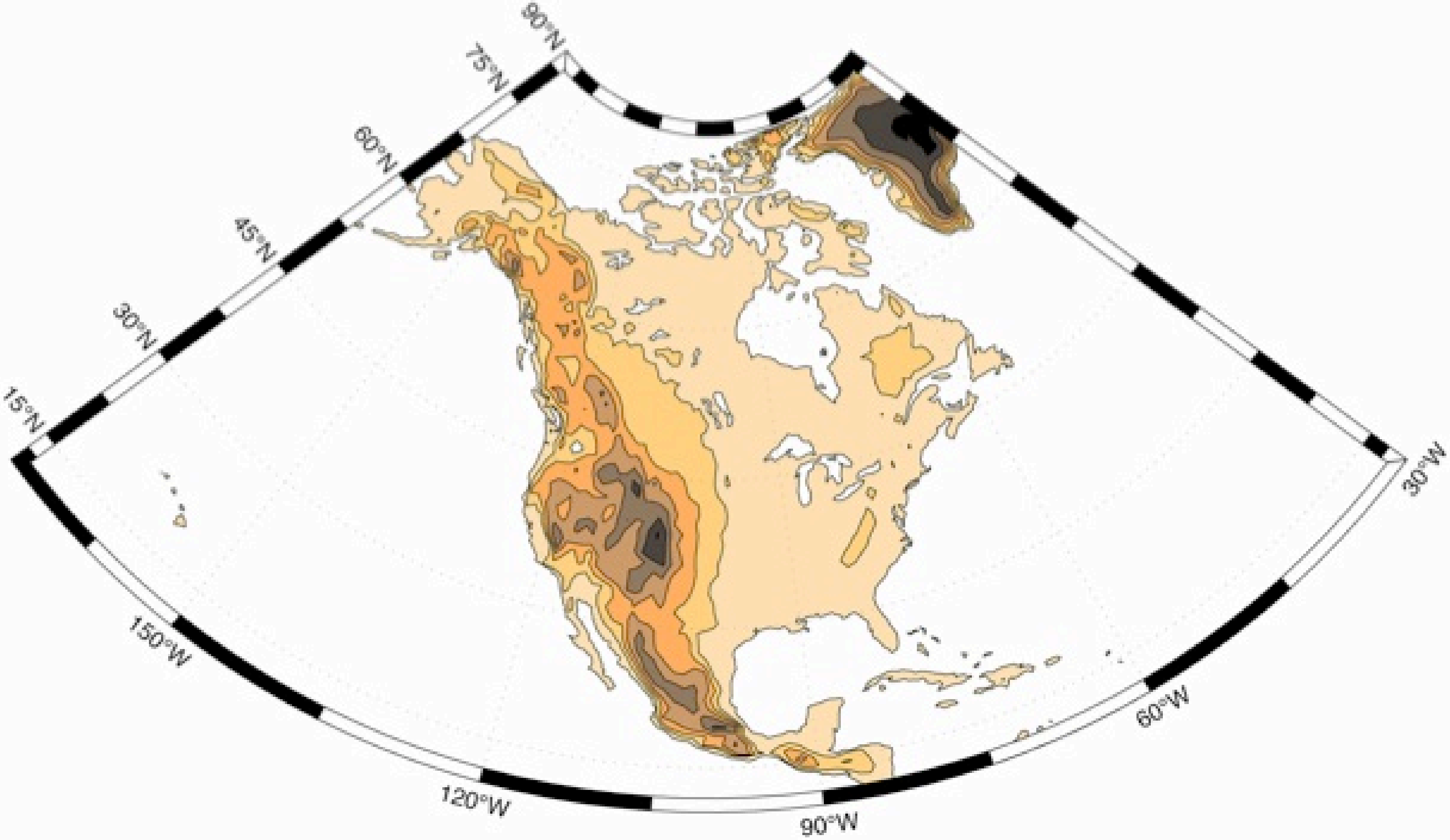


Europe

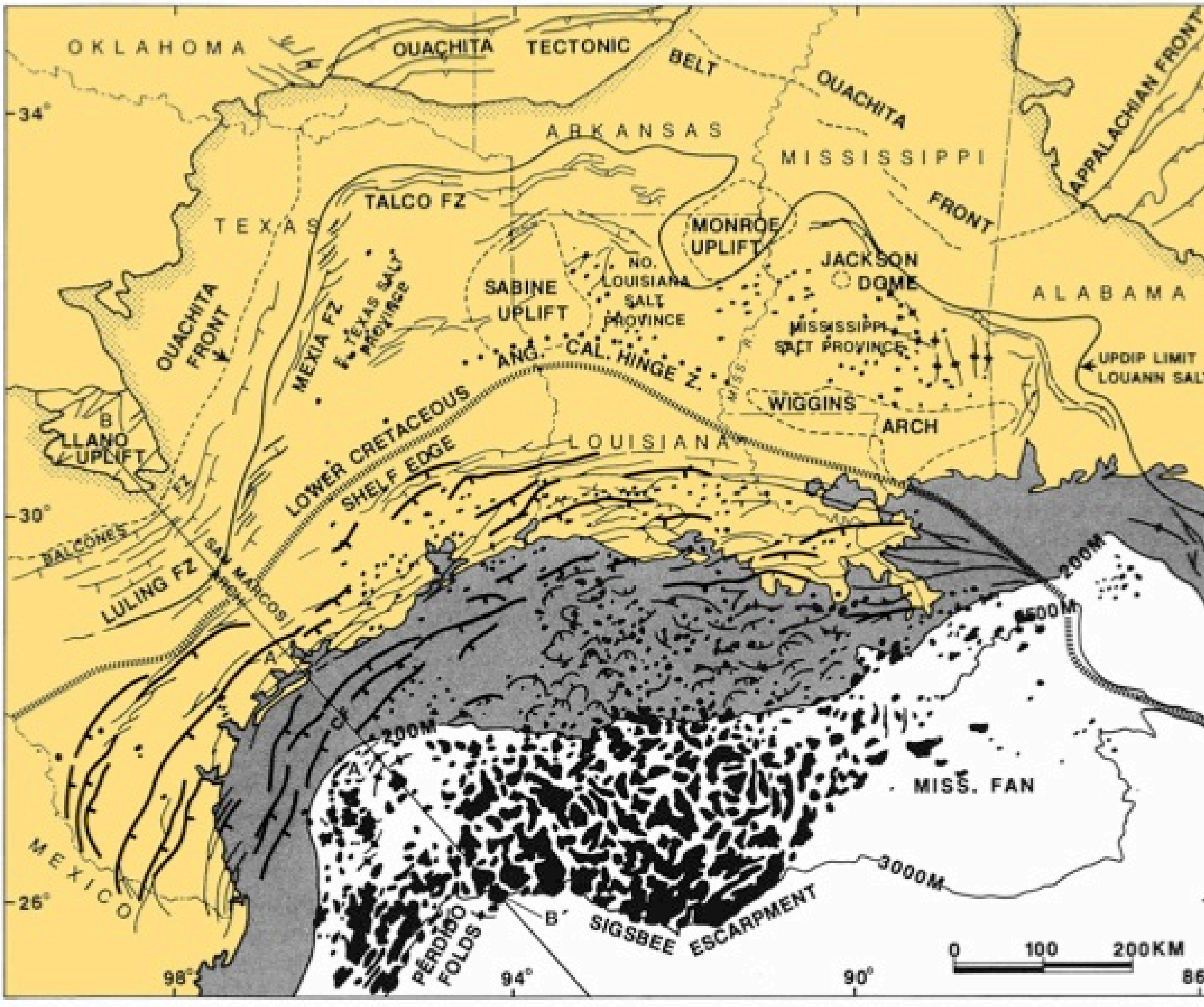


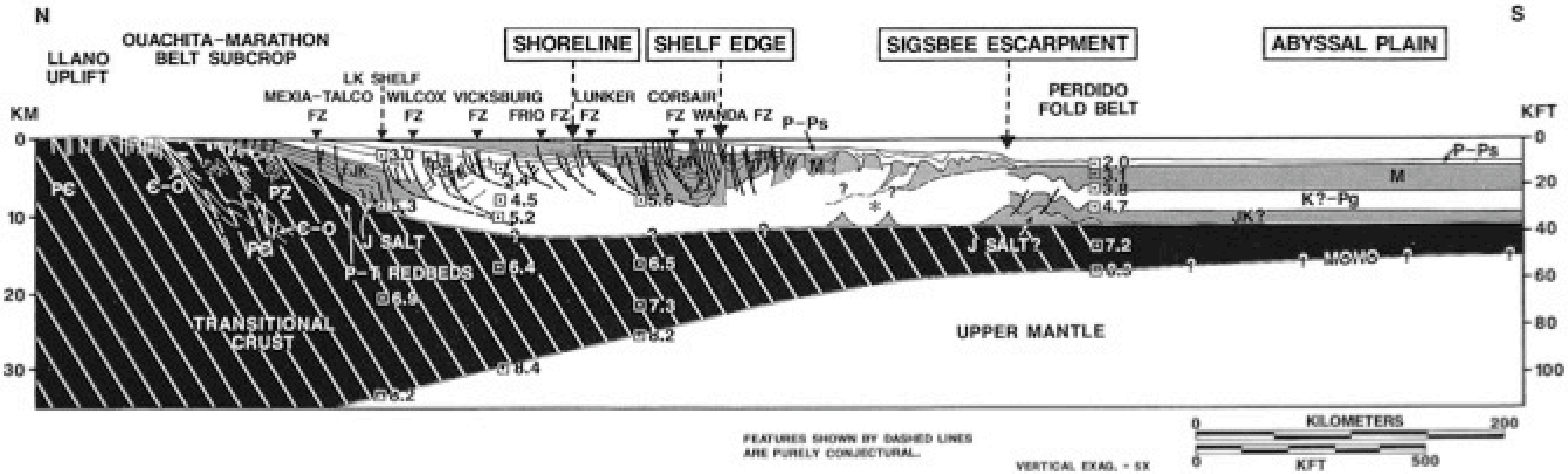
North America



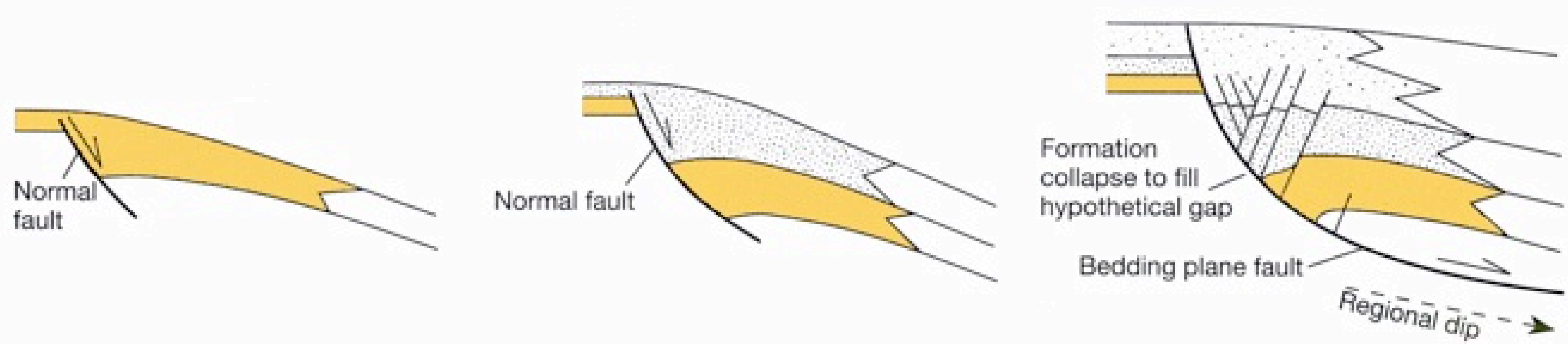


90°N
75°N
60°N
45°N
30°N
15°N
30°W
60°W
90°W
120°W
150°W

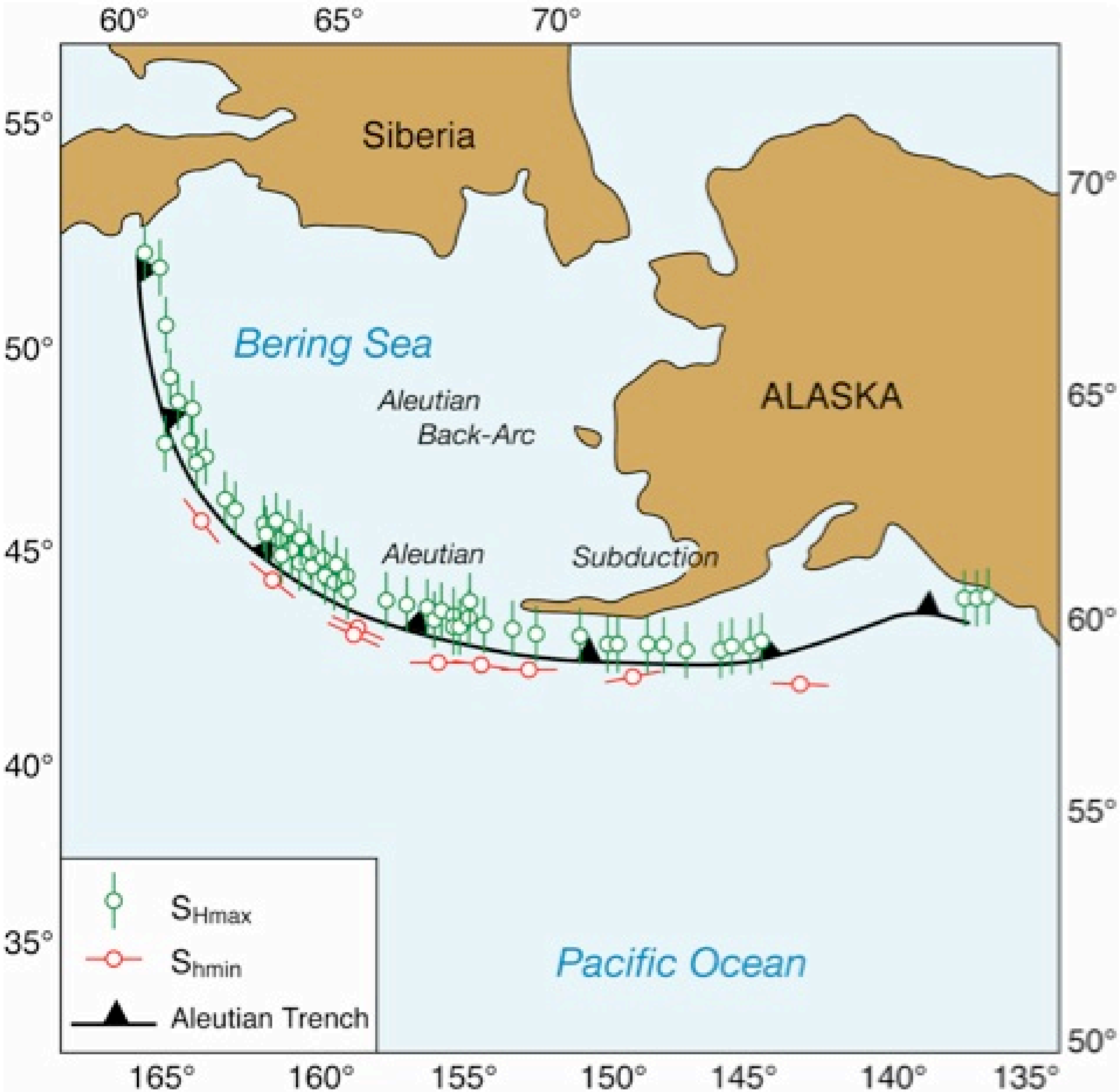

OKLAHOMA
OUACHITA TECTONIC BELT
OUACHITA FRONT
APPALACHIAN FRONT
ARKANSAS
MISSISSIPPI
TALCO FZ
TEXAS
MONROE UPLIFT
NO. LOUISIANA SALT PROVINCE
JACKSON DOME
SABINE UPLIFT
ALABAMA
OUACHITA FRONT
MEXIA FZ
E. TEXAS SALT PROVINCE
MISSISSIPPI SALT PROVINCE
ANG. CAL. HINGE Z.
UPDIP LIMIT LOUANN SALT
WIGGINS ARCH
LOWER CRETACEOUS SHELF EDGE
LOUISIANA
LLANO UPLIFT
BALCONES FZ
LULING FZ
SAN MARCOS ARCH
MISS. R.
200M
500M
200M
MISS. FAN
3000M
MEXICO
PERDIDO FOLDS
SIGSBEE ESCARPMENT
0 100 200KM
34°
30°
26°
98°
94°
90°
86°
A
A'
B
B'



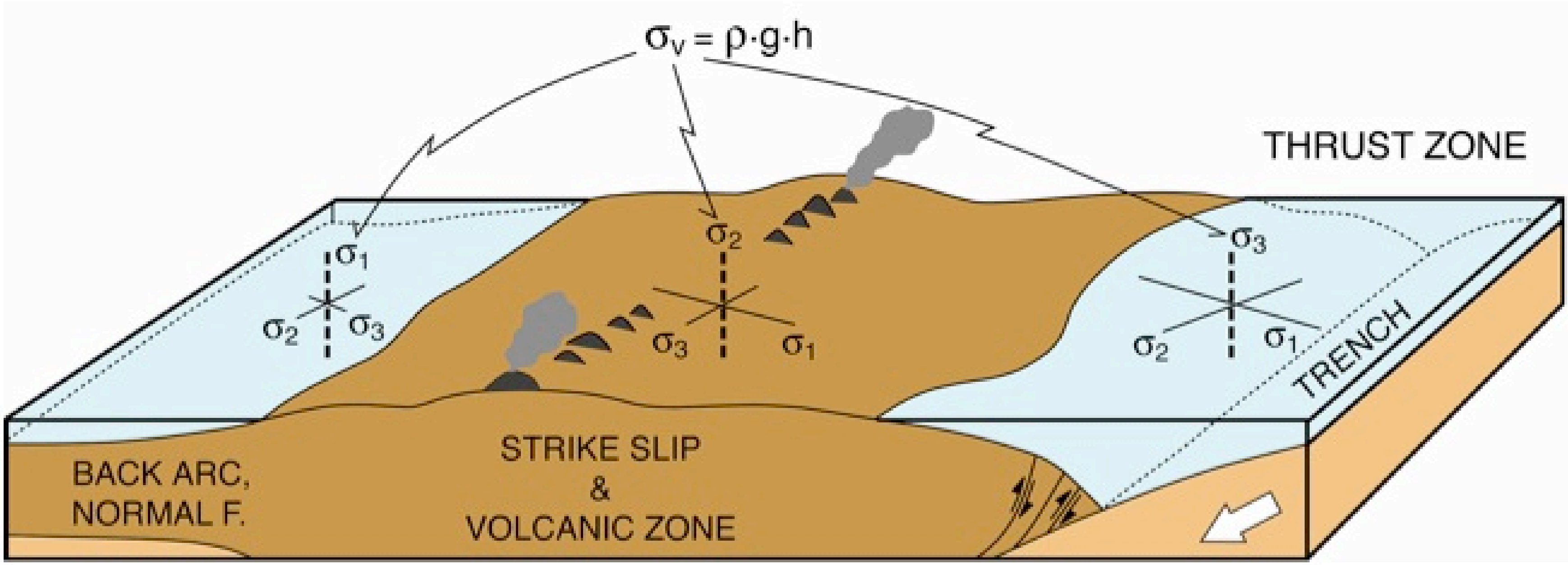
N
S
LLANO UPLIFT
OUACHITA-MARATHON BELT SUBCROP
SHORELINE
SHELF EDGE
SIGSBEE ESCARPMENT
ABYSSAL PLAIN
LK SHELF
MEXIA-TALCO FZ
WILCOX FZ
VICKSBURG FZ
FRIO FZ
LUNKER FZ
CORSAIR FZ
WANDA FZ
P-Ps
PERDIDO FOLD BELT
KM
KFT
J SALT
P-T REDBEDS
TRANSITIONAL CRUST
J SALT?
MOHO
UPPER MANTLE
K?-Pg
M
JK?
FEATURES SHOWN BY DASHED LINES ARE PURELY CONJECTURAL.
VERTICAL EXAG. - 5X
KILOMETERS
KFT



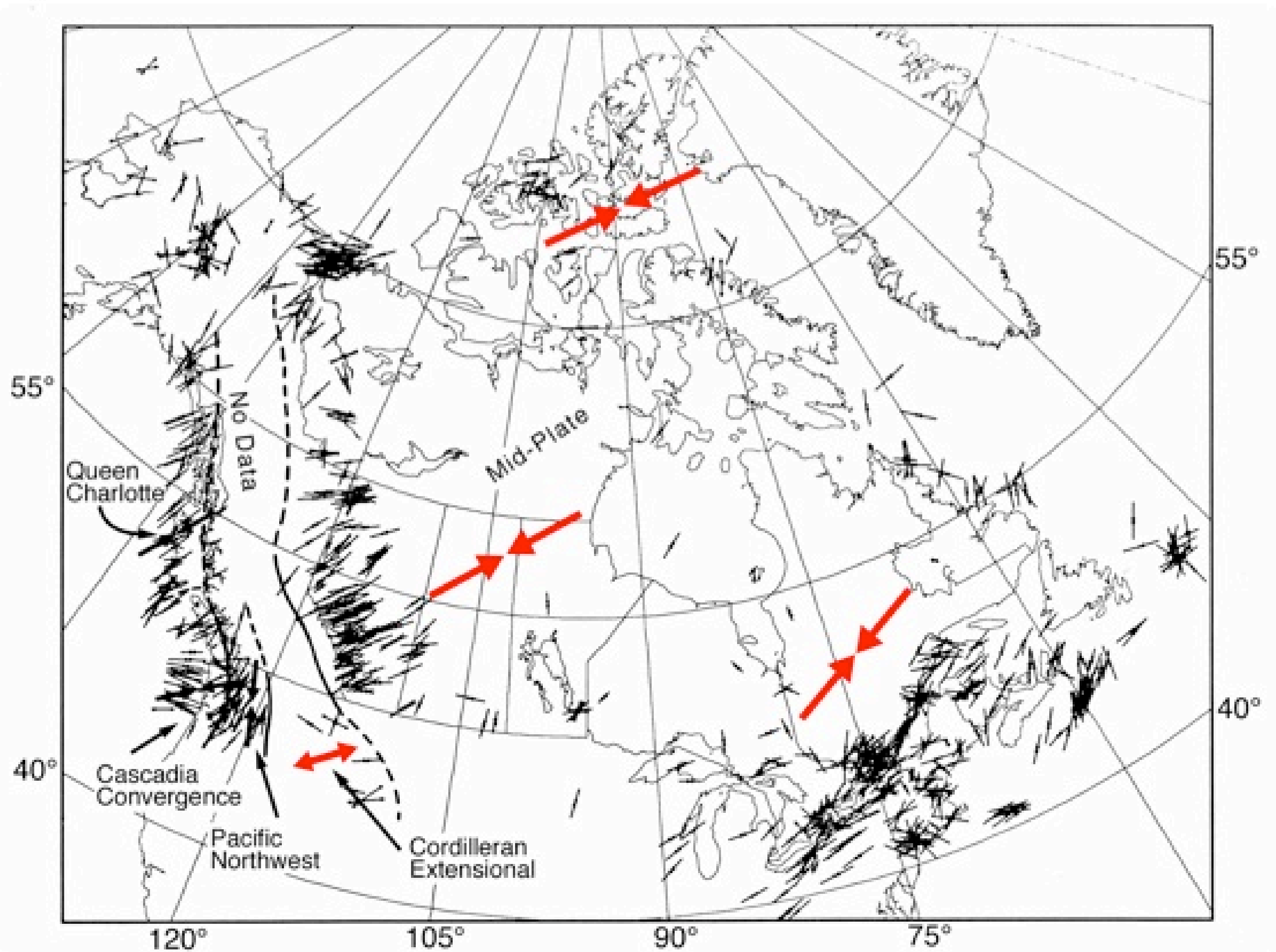
Normal fault
Normal fault
Formation collapse to fill hypothetical gap
Bedding plane fault
Regional dip



60°
65°
70°
55°
50°
45°
40°
35°
70°
65°
60°
55°
50°
165°
160°
155°
150°
145°
140°
135°
Siberia
ALASKA
Bering Sea
Aleutian
Back-Arc
Aleutian
Subduction
Pacific Ocean
S_{Hmax}
S_{hmin}
Aleutian Trench

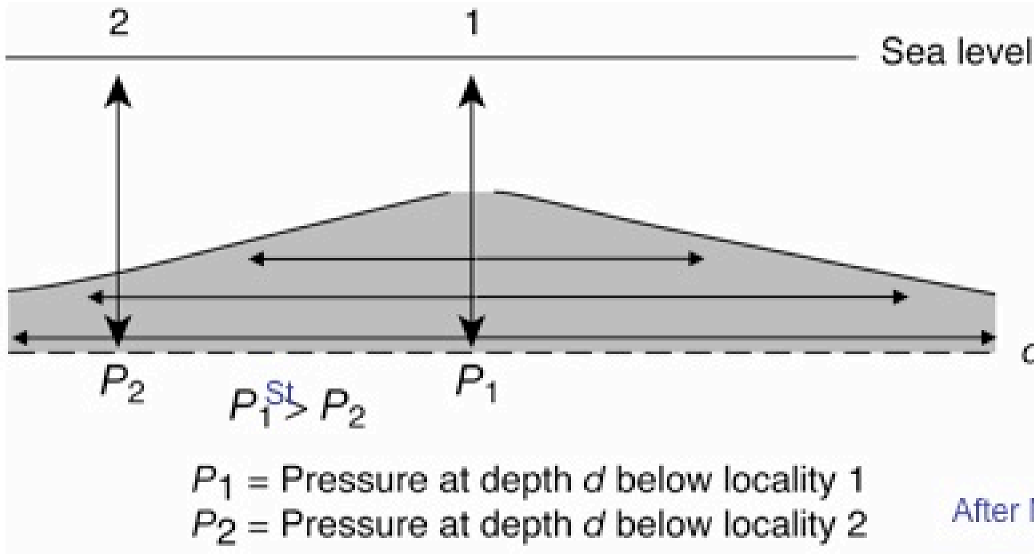


Nakamura and Uyeda, 1980



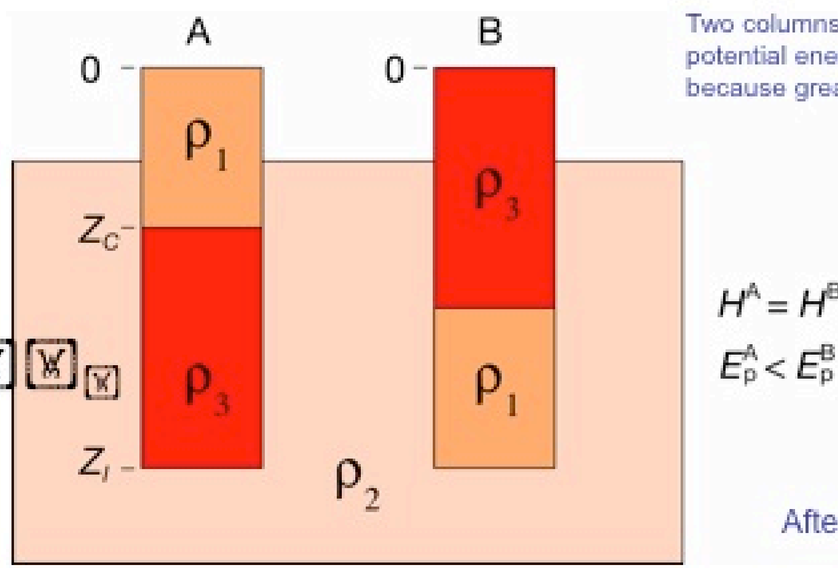
55°
55°
40°
40°
No Data
Mid-Plate
Queen
Charlotte
Cascadia
Convergence
Pacific
Northwest
Cordilleran
Extensional
120°
105°
90°
75°

Ridge push



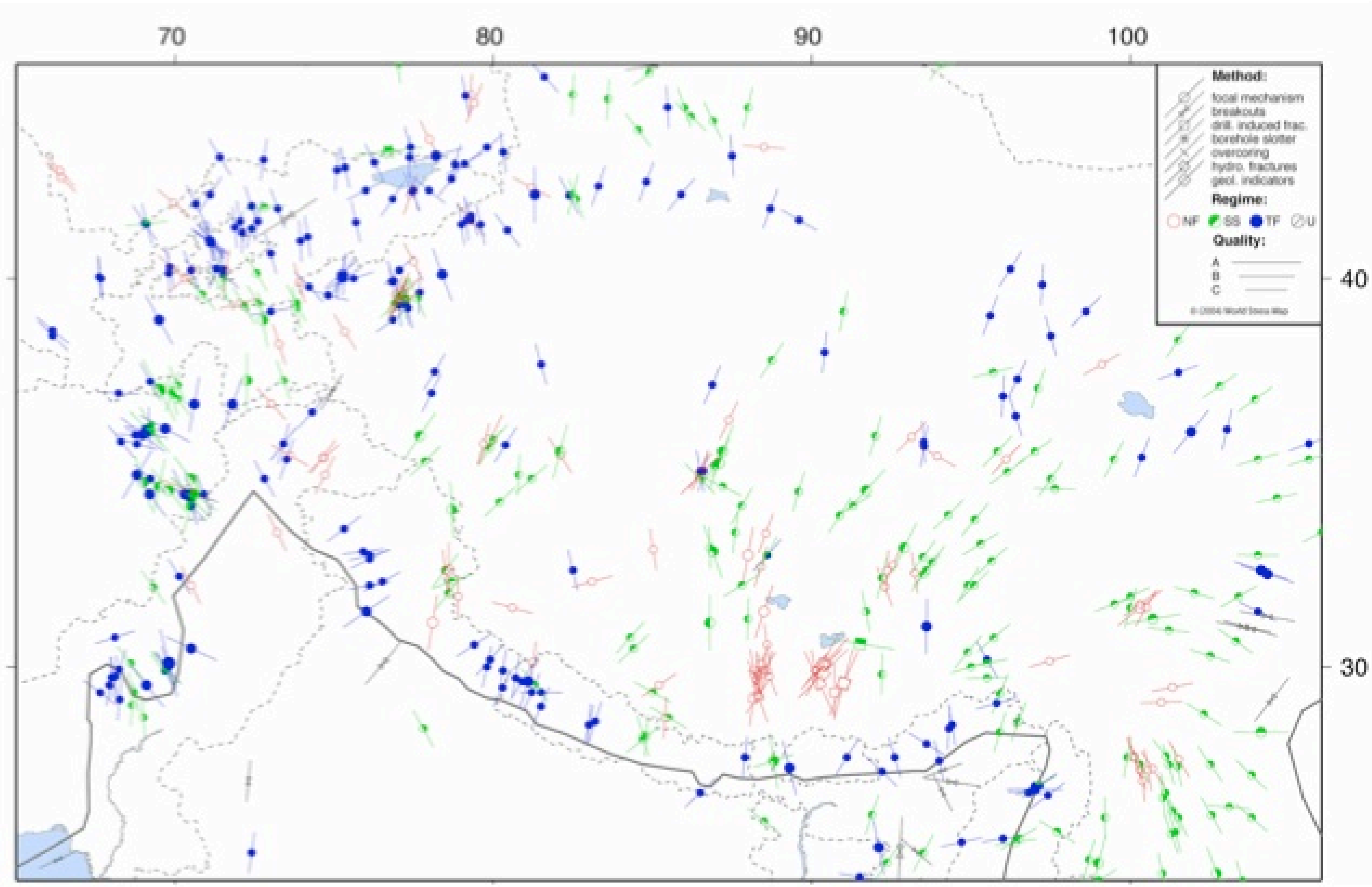
After Moores and Twiss, 1997

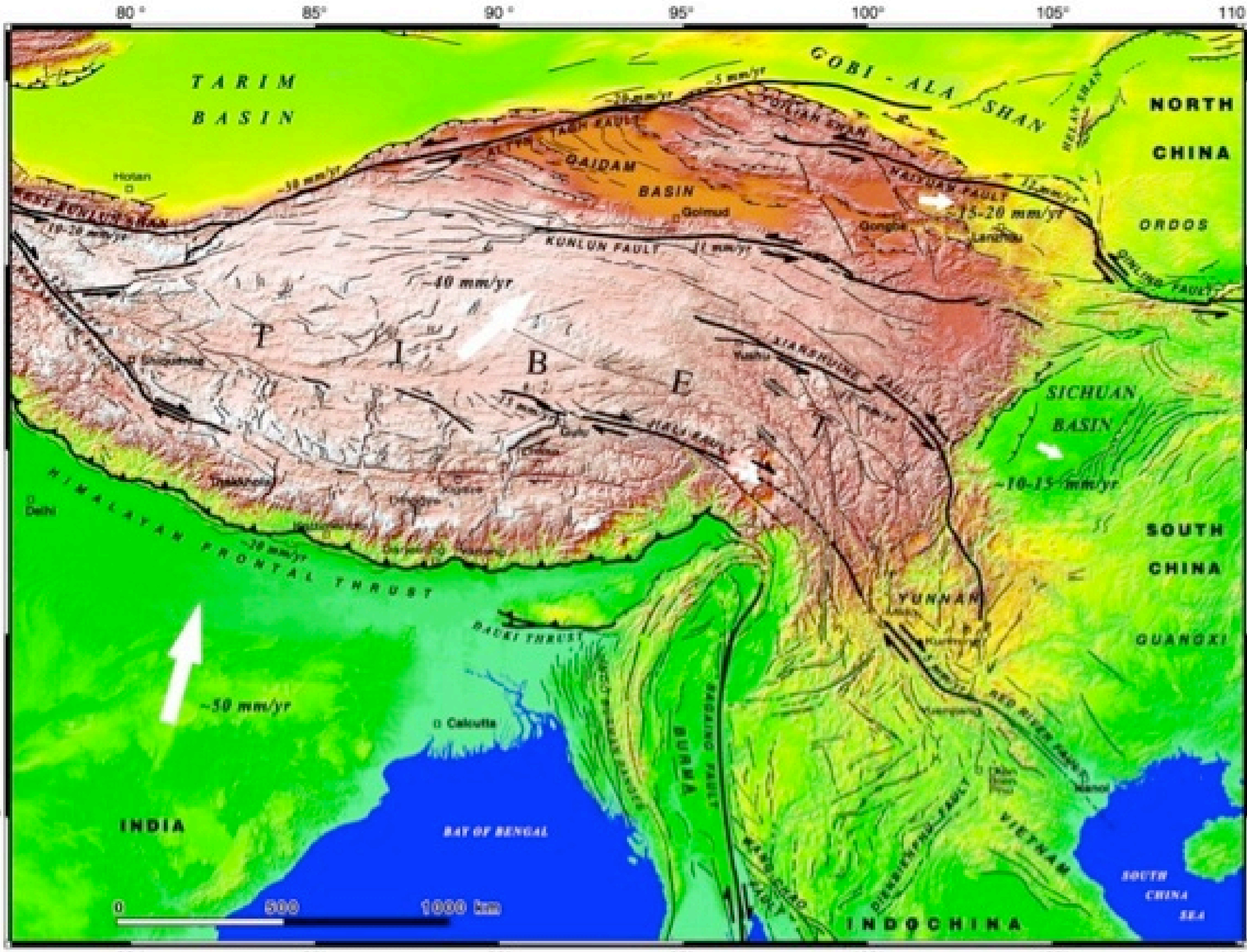
Two columns of equal height and density; potential energy (E) on right is higher, because greater density segment is higher



After Stüwe, 2000

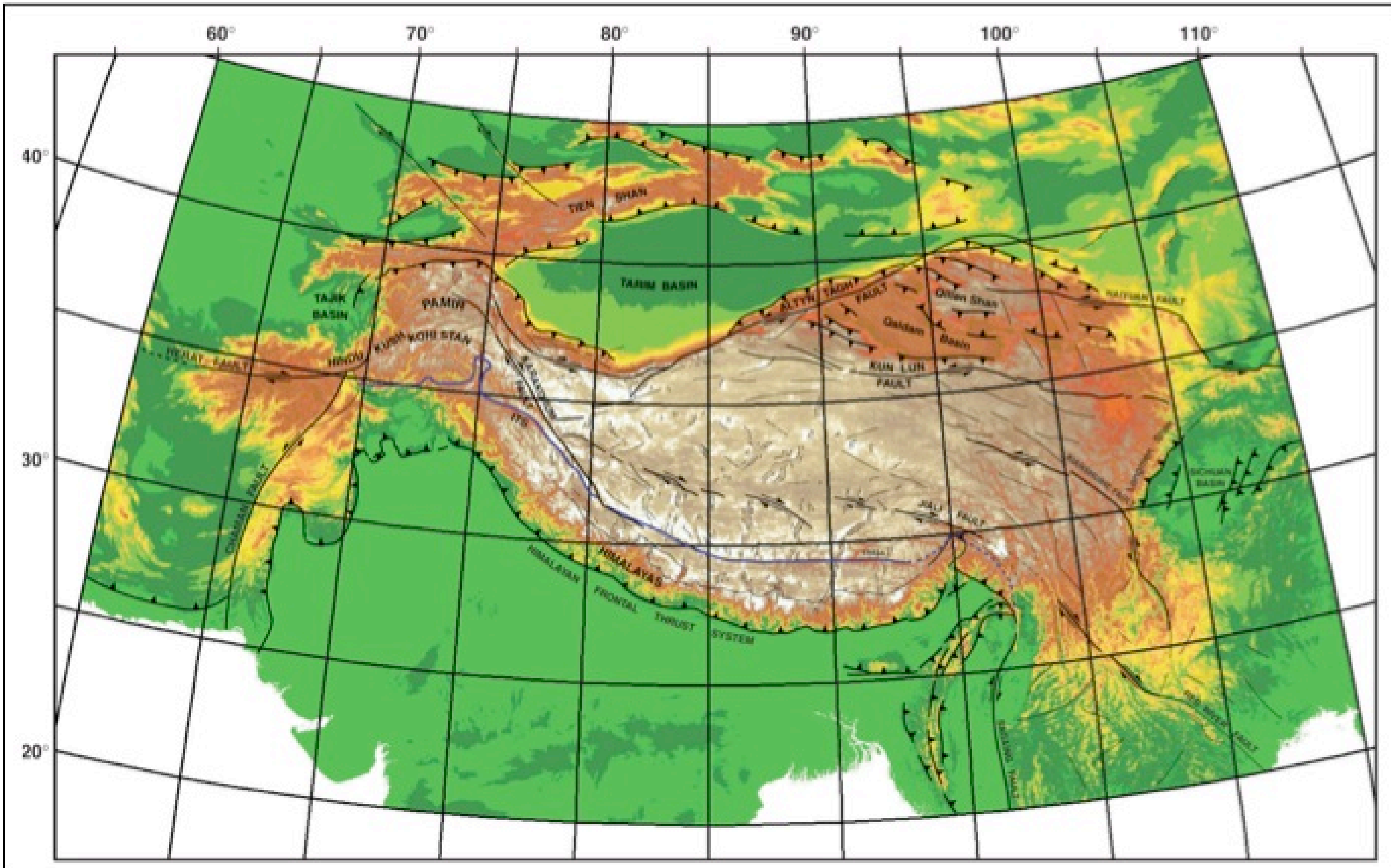
The World Stress Map

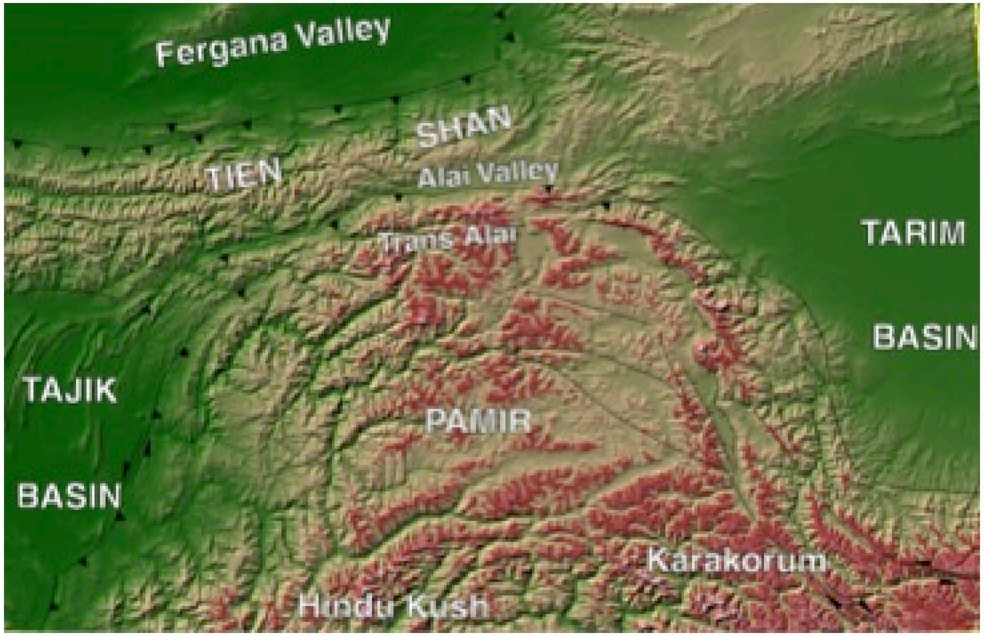


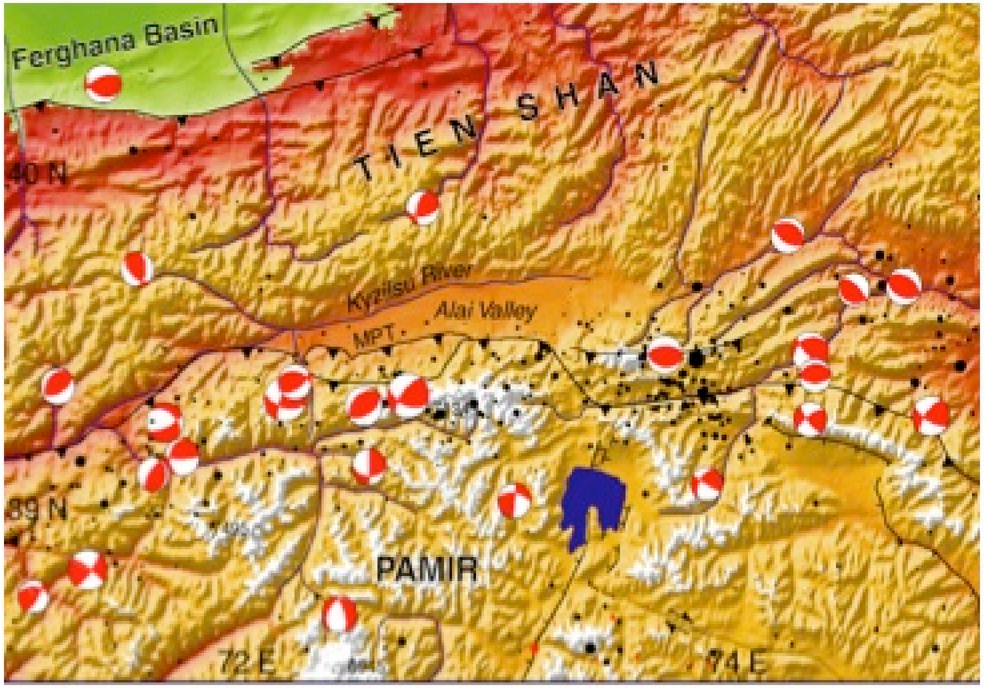


TARIM BASIN
GOBI - ALA SHAN
NORTH CHINA
QAIDAM BASIN
ALTYN TAGH FAULT
HAIYUAN FAULT
KUNLUN FAULT
~40 mm/yr
~15-20 mm/yr
ORDOS
QINLING FAULT
T I B E T
XIANSHUIHE FAULT
SICHUAN BASIN
~10-15 mm/yr
SOUTH CHINA
JIALI FAULT
HIMALAYAN FRONTAL THRUST
YUNNAN
DAUKI THRUST
GUANGXI
~50 mm/yr
INDIA
BAY OF BENGAL
BURMA
SAGAING FAULT
RED RIVER FAULT
VIETNAM
SOUTH CHINA SEA
INDOCHINA
Delhi
Calcutta
Golmud
Lanzhou
Hanoi
0
500
1000 km
80°
85°
90°
95°
100°
105°
110°
40°
35°
30°
25°
20°

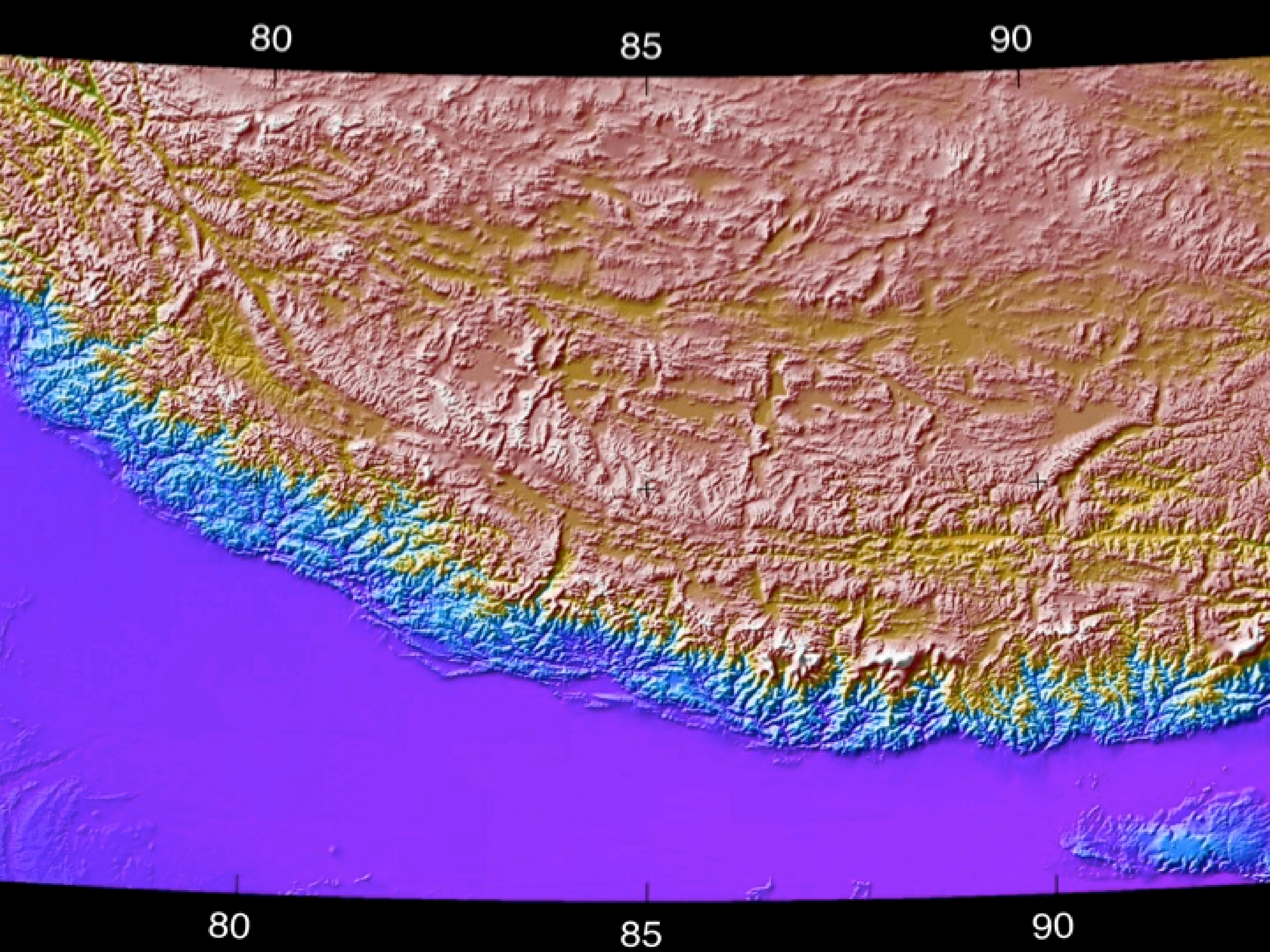
Central Asia

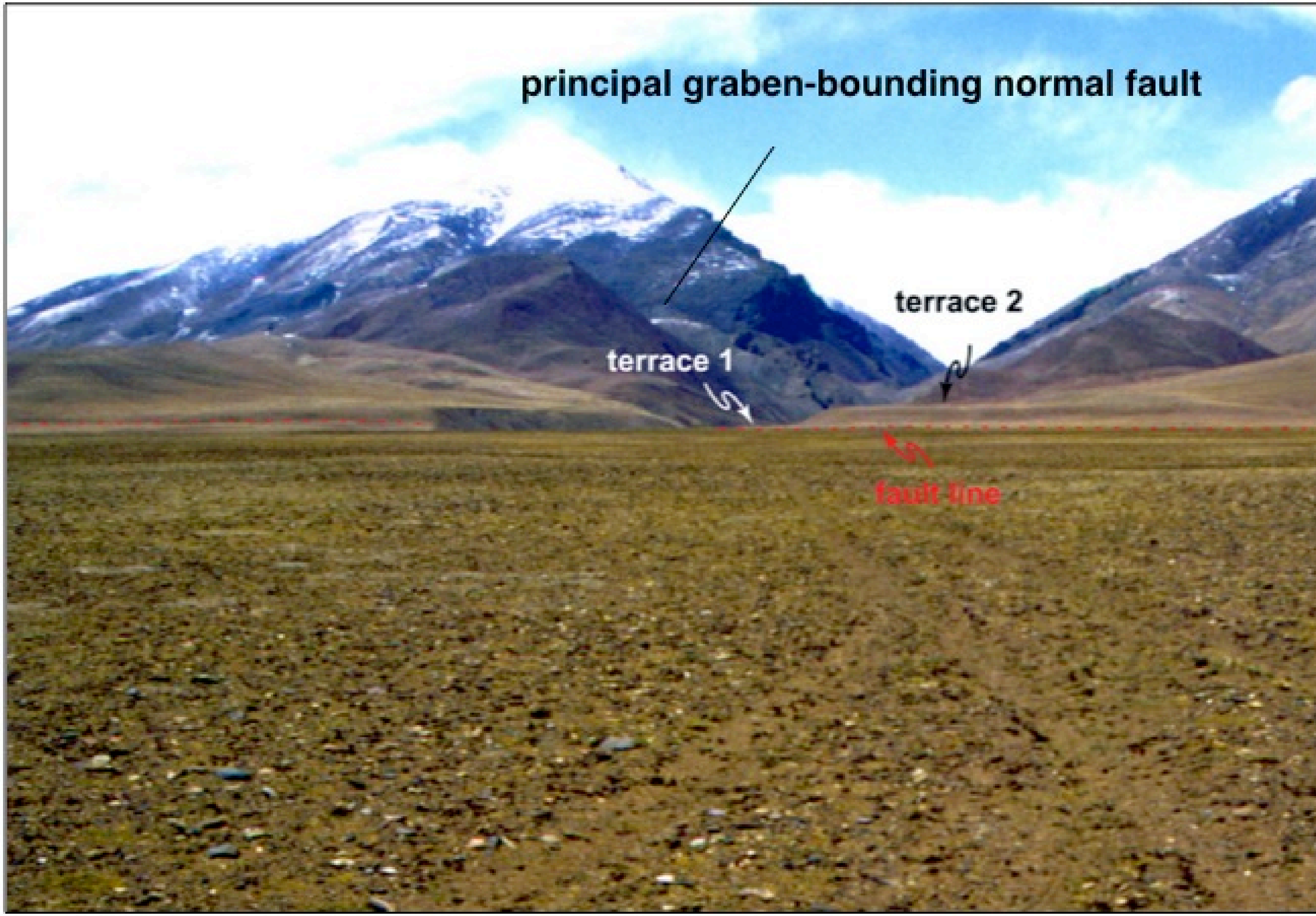






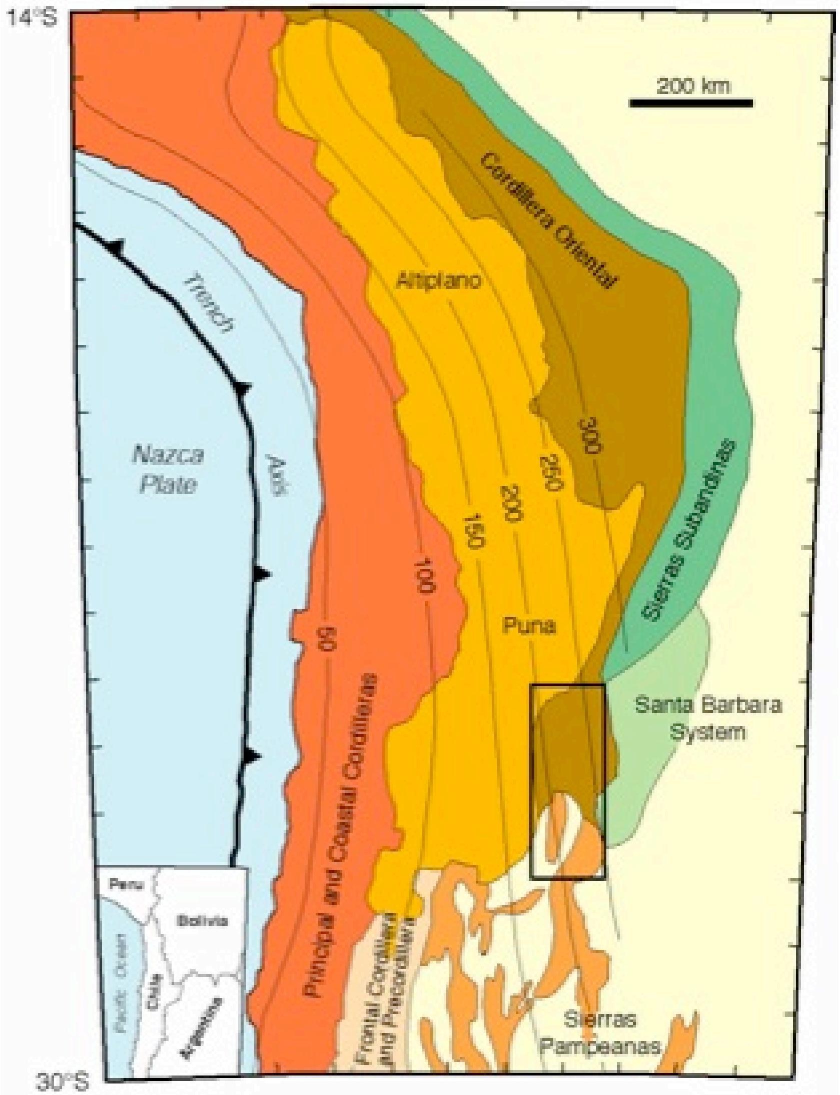
Arrowsmith and Strecker, 1999


80
85
90
80
85
90

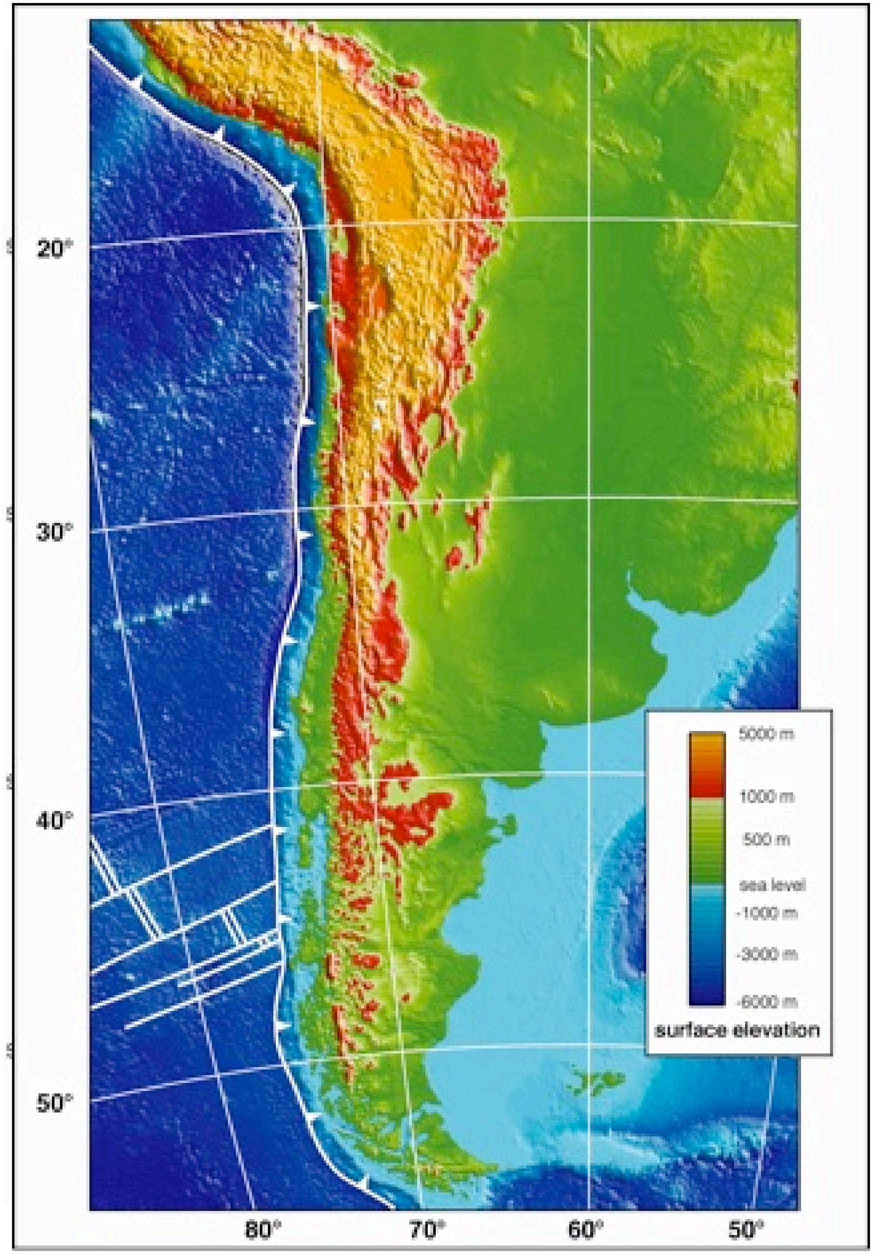


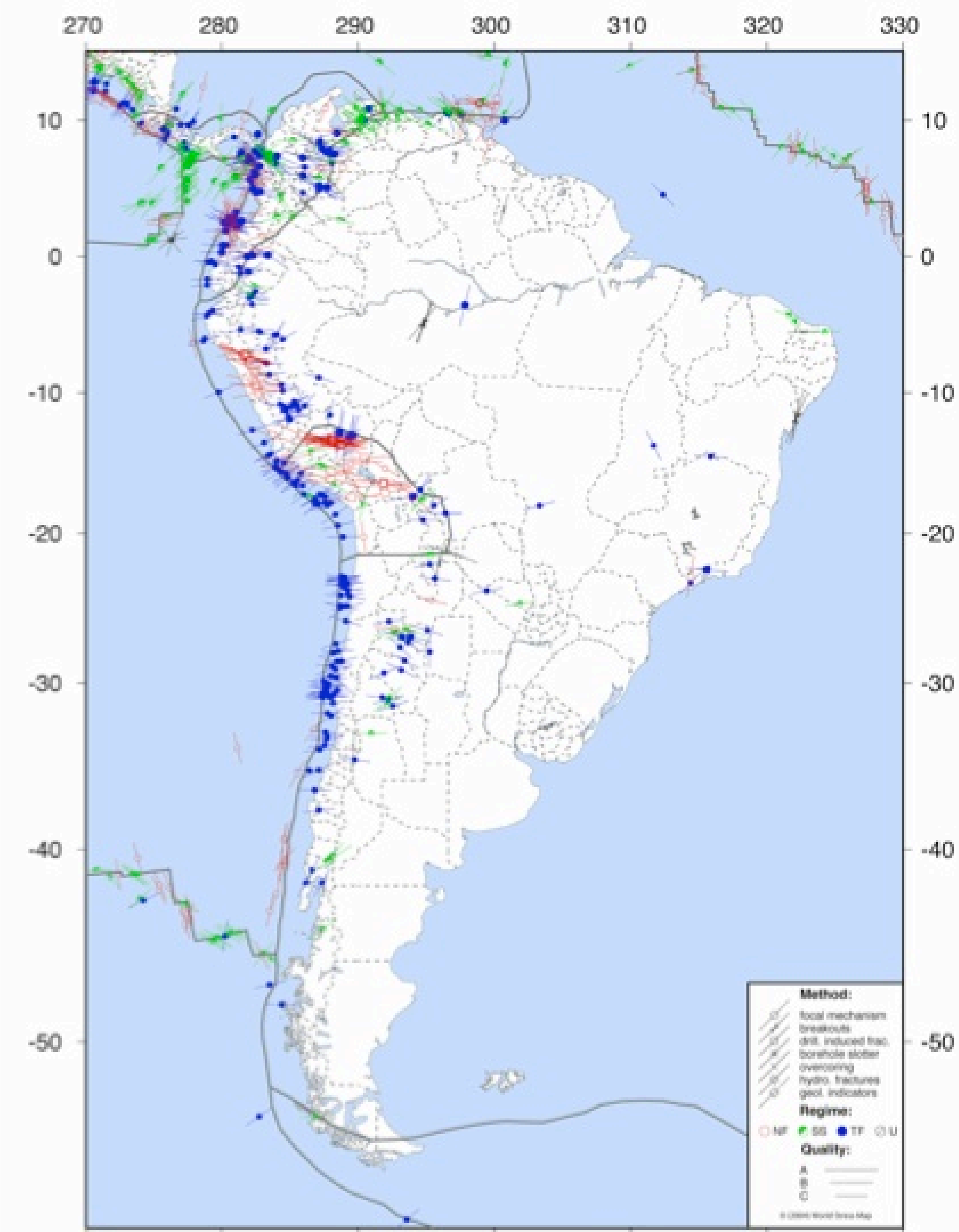
Shuang Hu graben: view of the SW graben margin, looking W

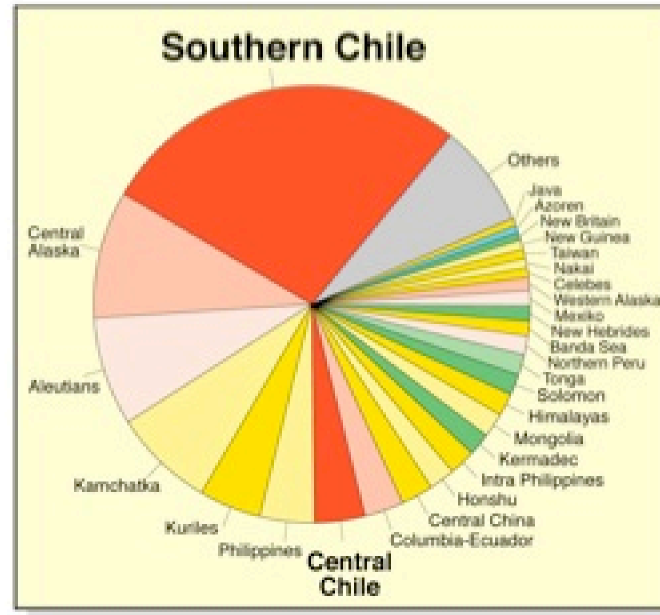
South America



modified after Isacks, 1988 and Cahill et al., 1992

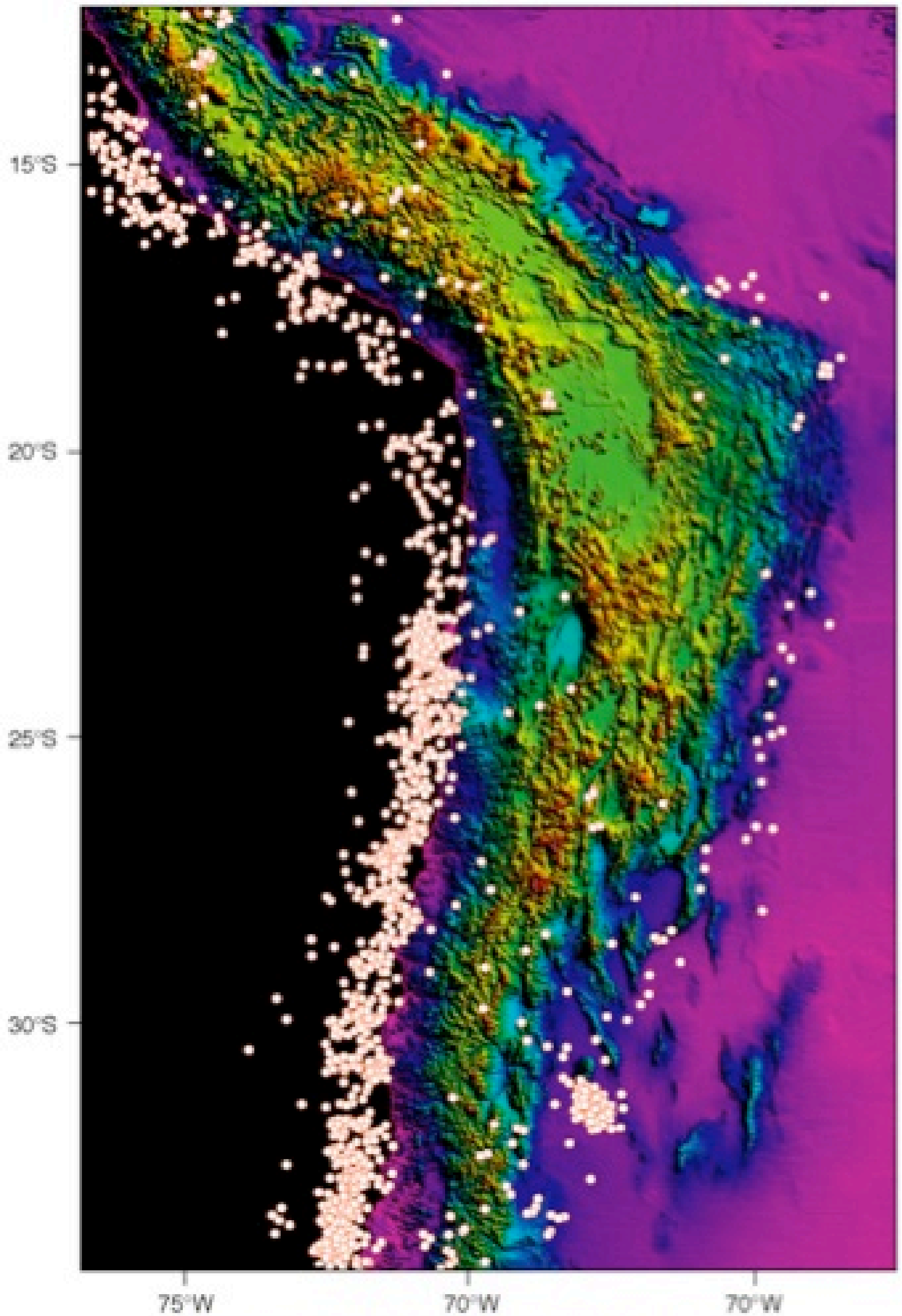




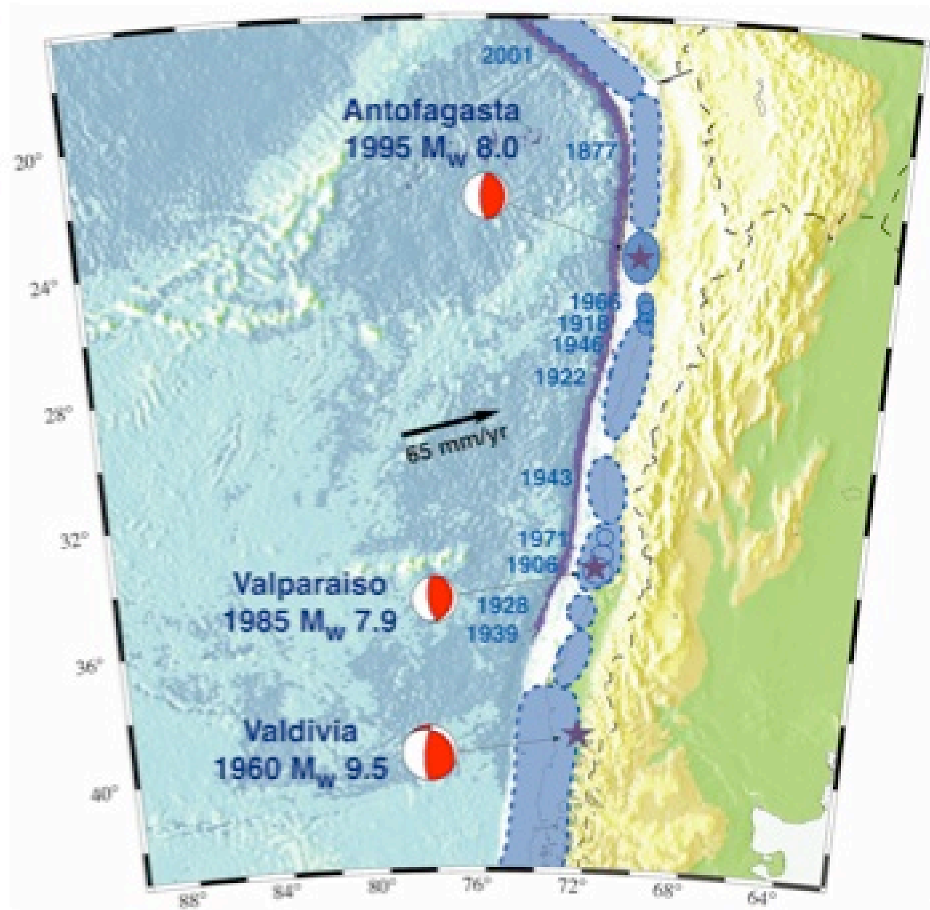


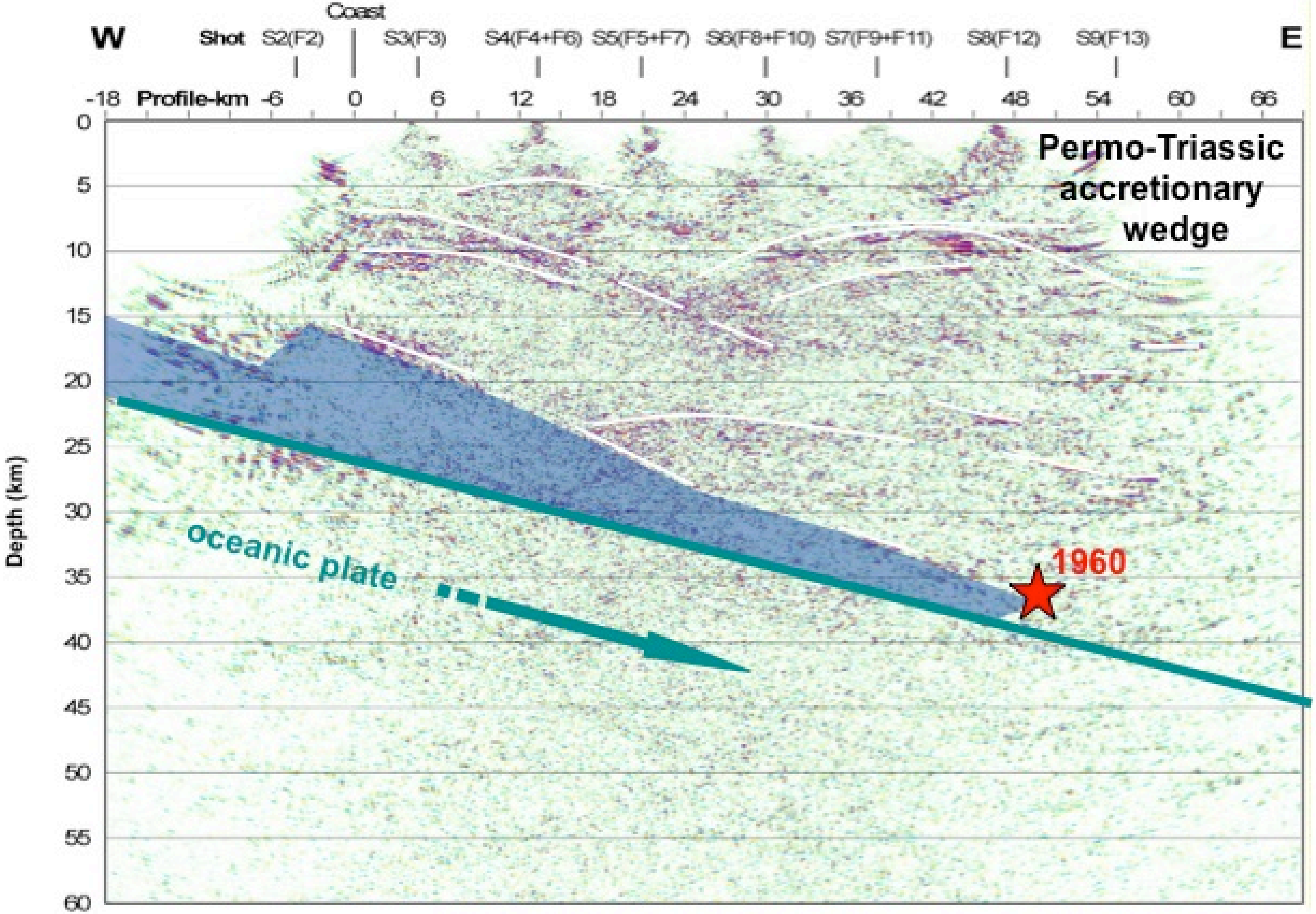
Seismic energy release in the 20th century

Crustal seismicity (D<60 km, M>4.5)



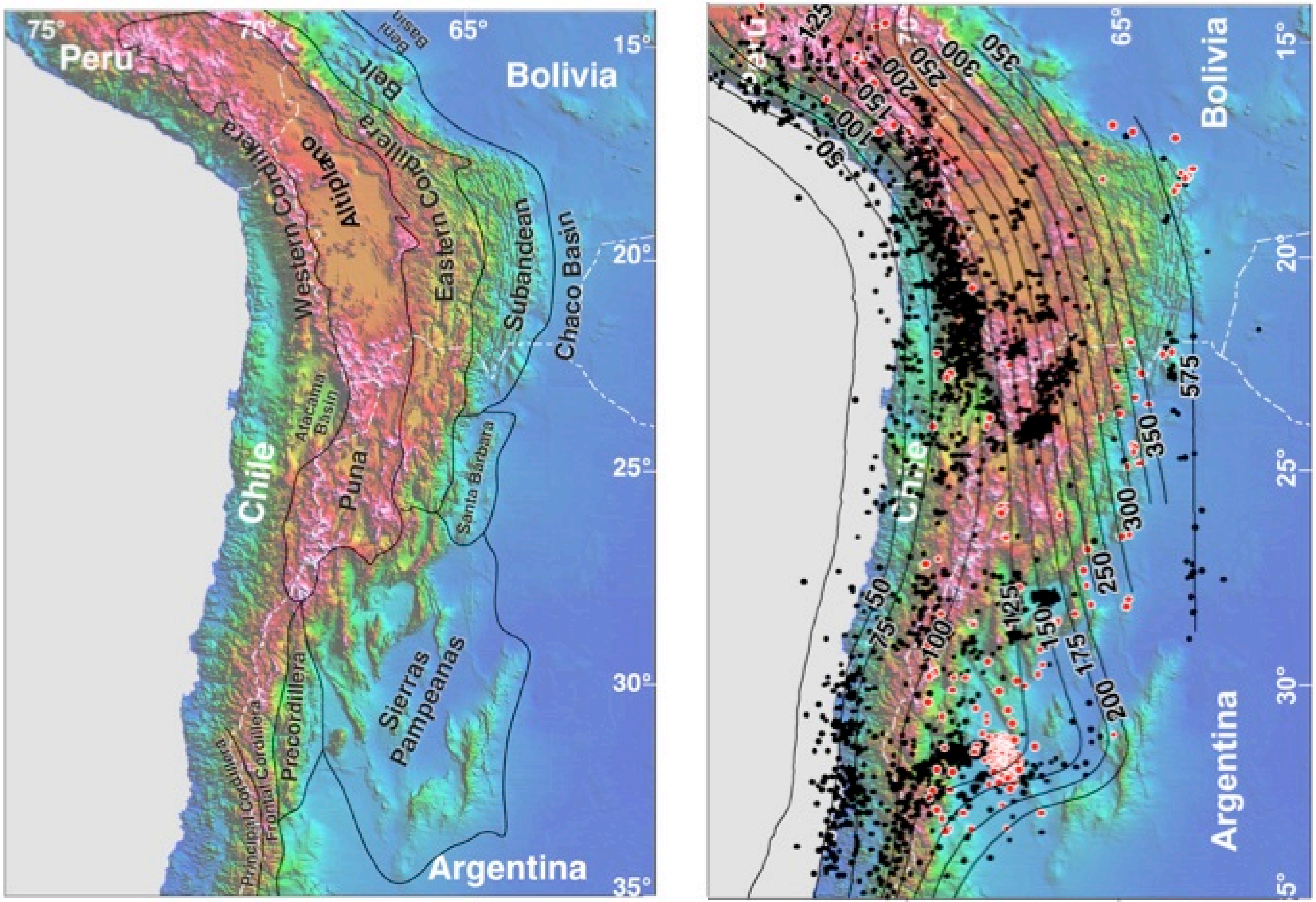
Seismicity data from Engdahl et al., 1998





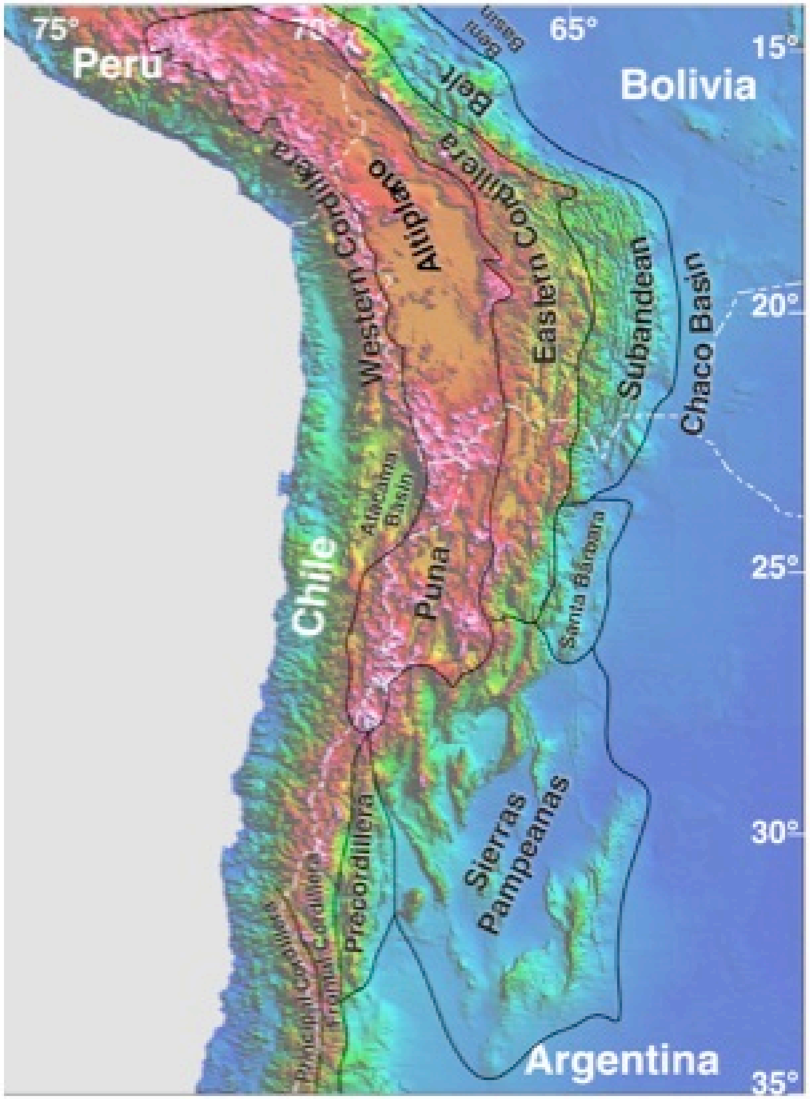
(modified after Krawczyk & The SPOC Team 2003; regional seismicity: Bohm et al. 2002

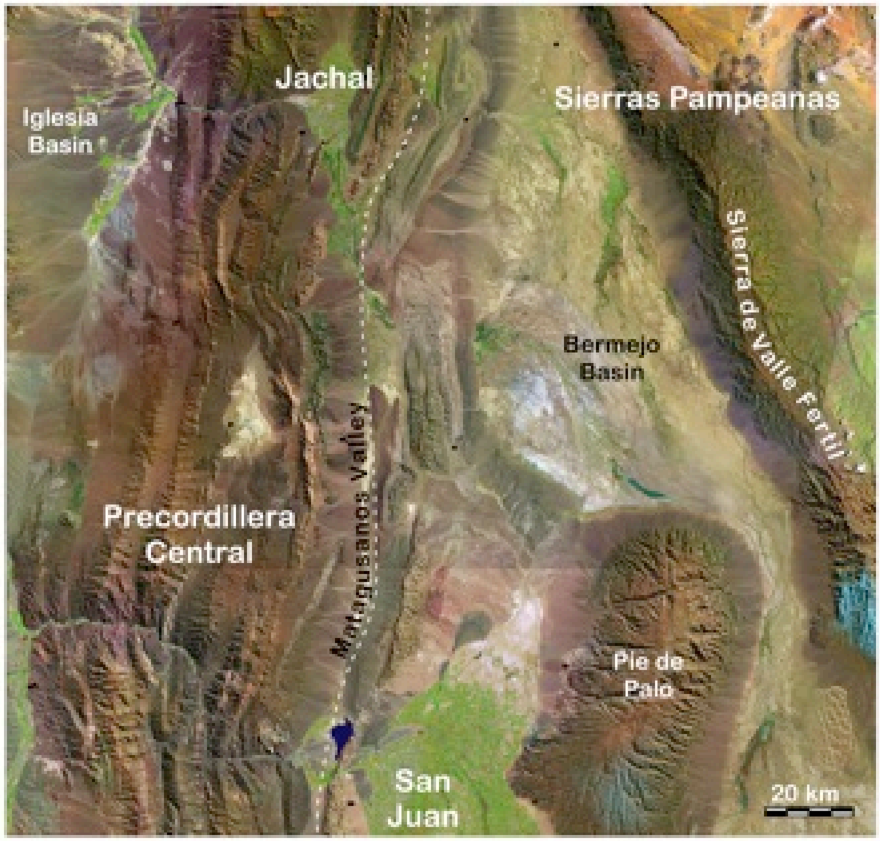
The Central Andes



Modified after Jordan et al., 1983 and Cahill et al., 1988

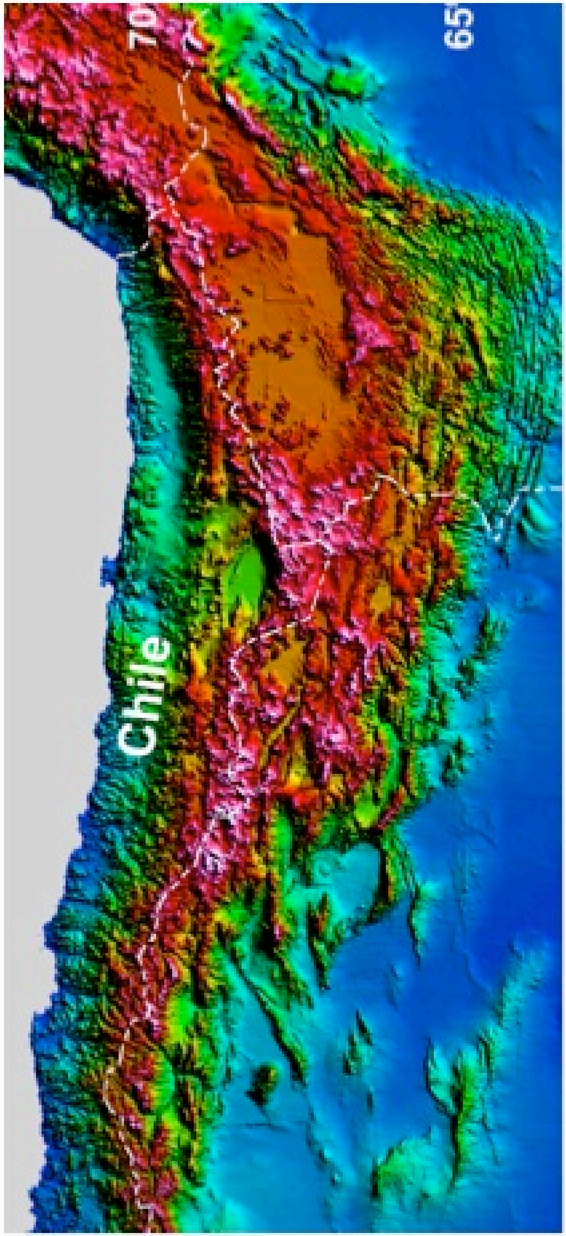
The Flat-Slab Region: Precordillera & Sierras Pampeanas Provinces

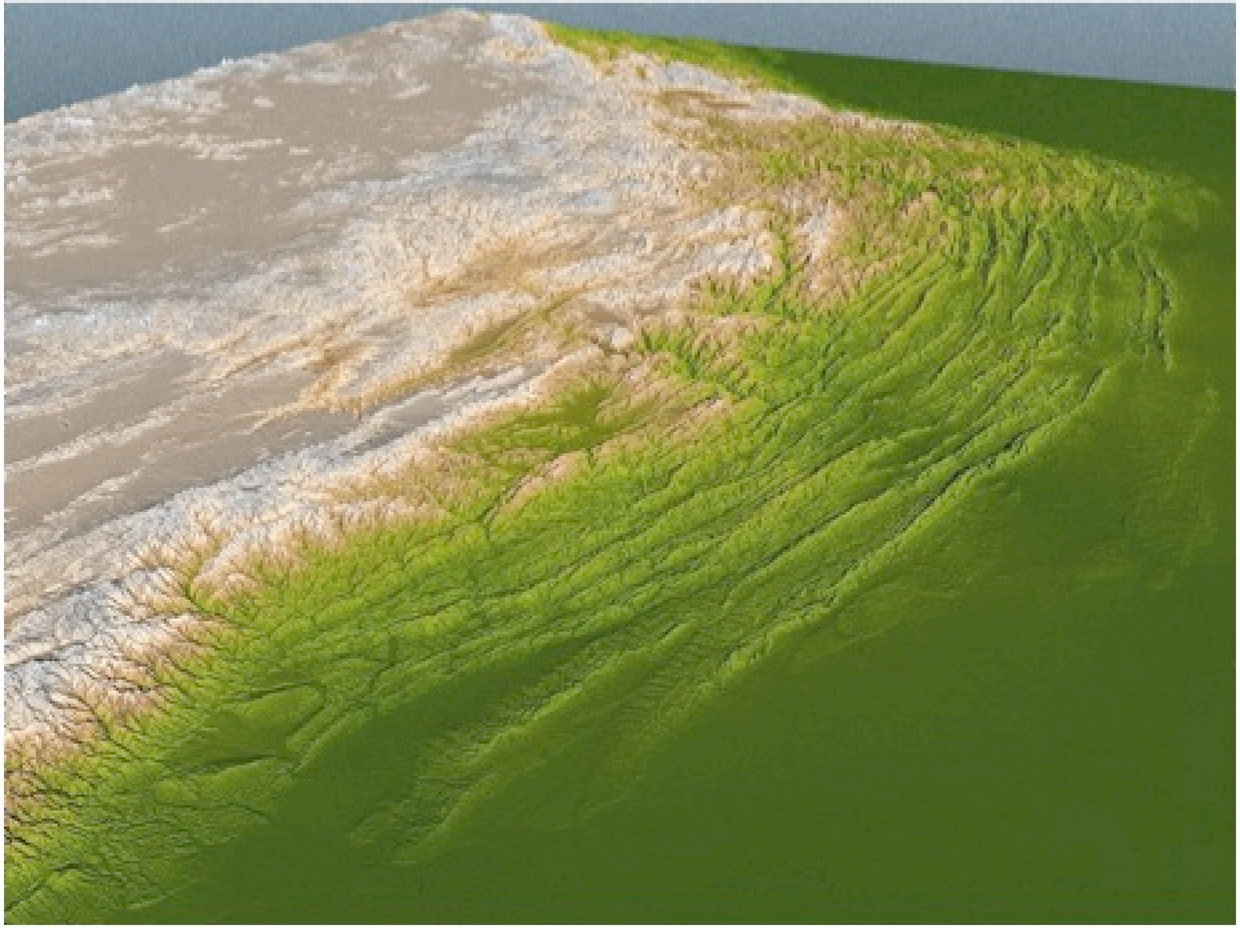




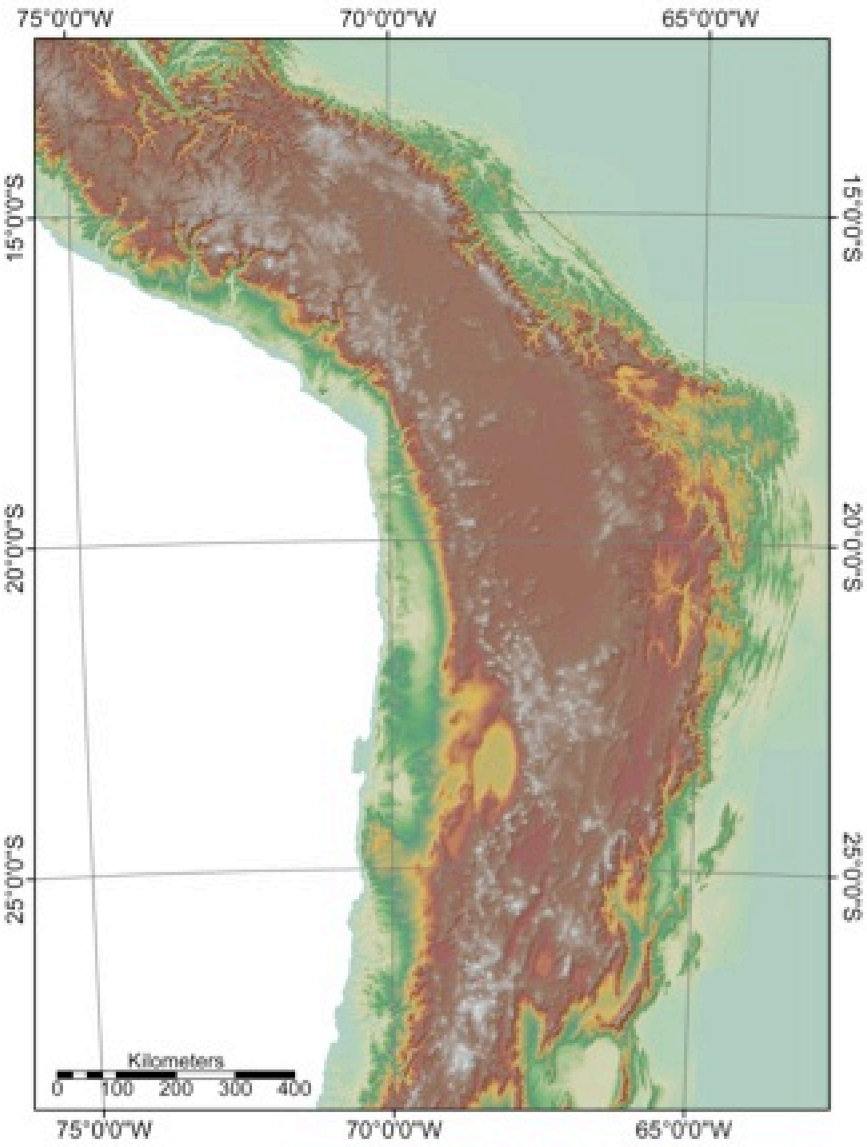
Modified after Jordan et al., 1983 and Cahill et al., 1988

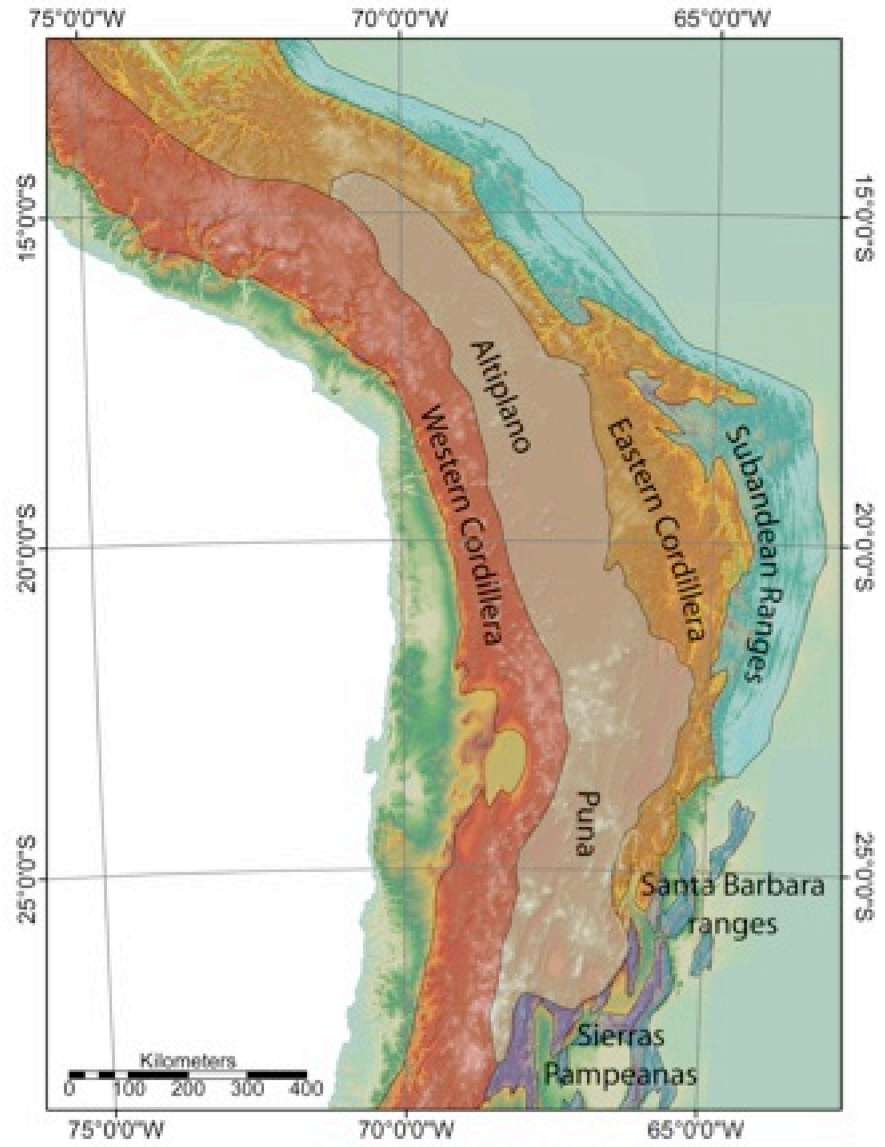
Subandes & Eastern Cordillera

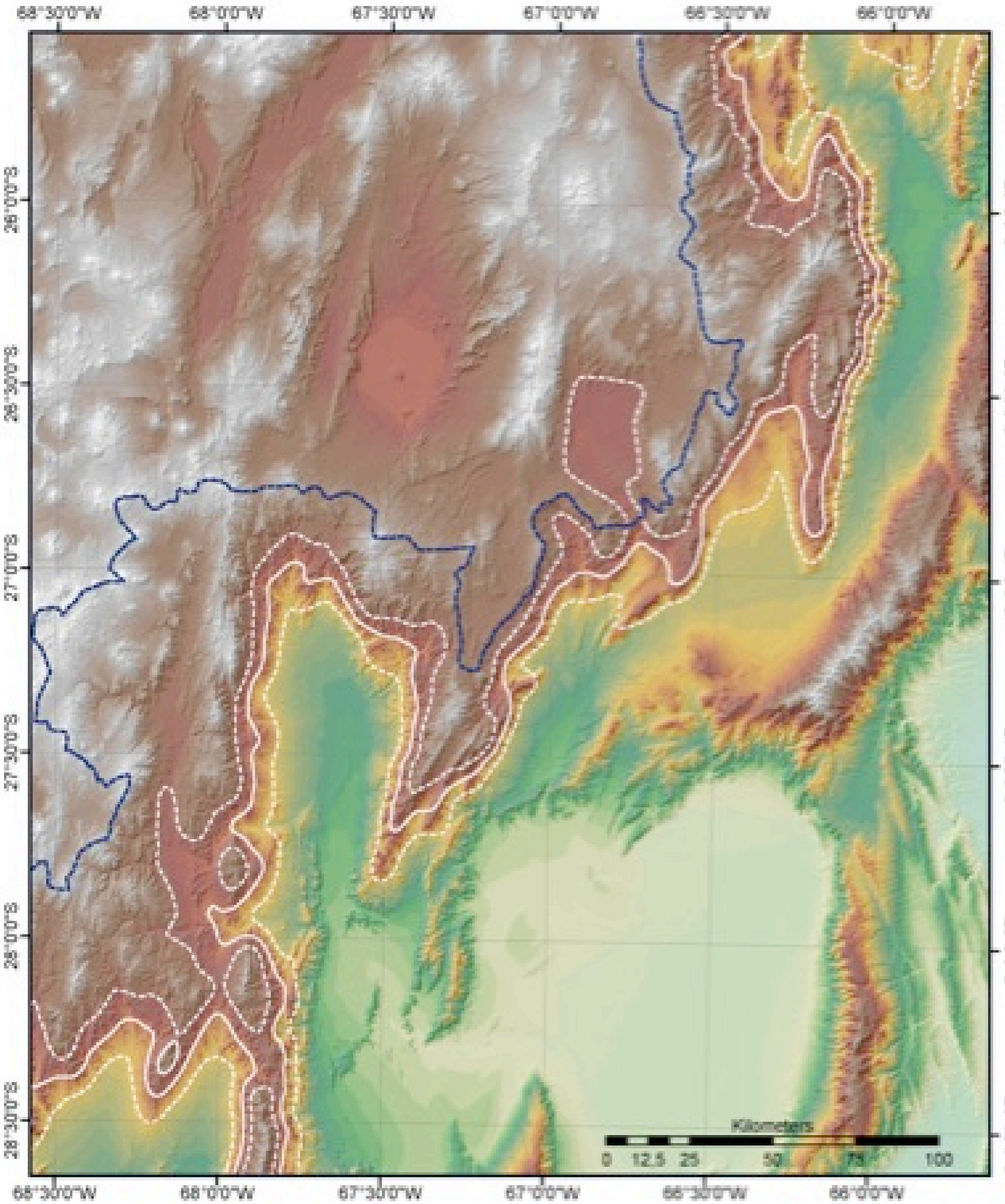




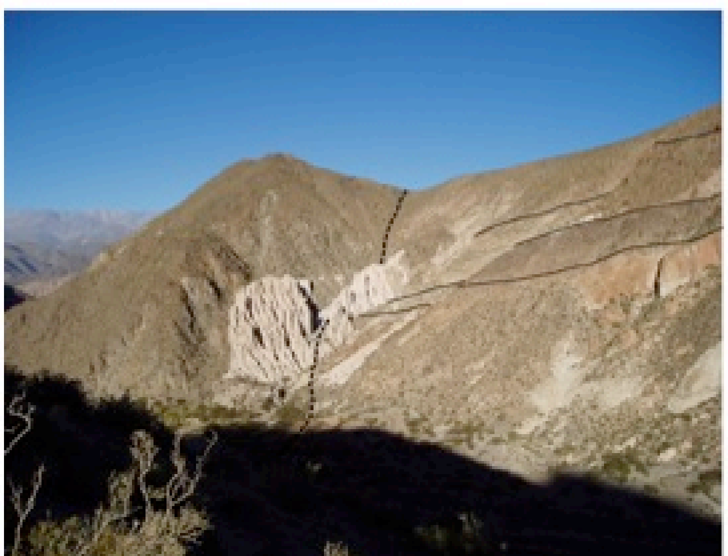
Altiplano-Puna Plateau

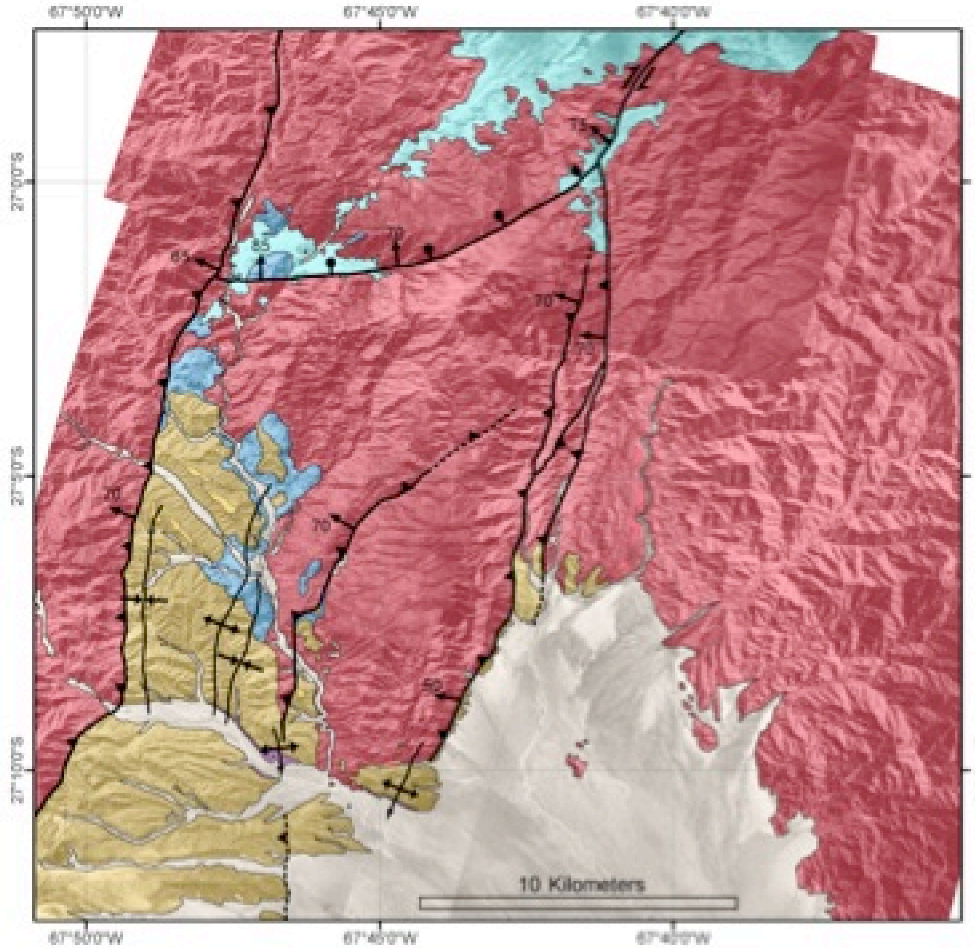




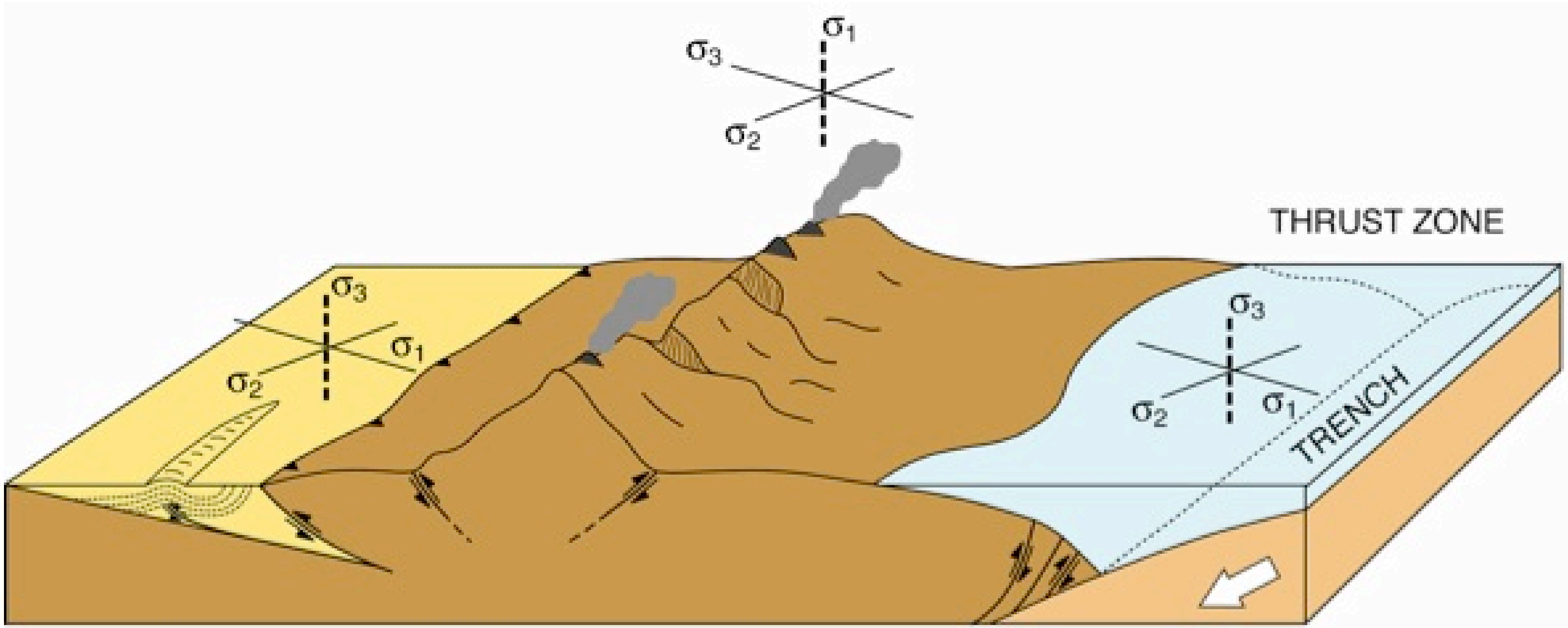


- Southern Puna Plateau
  - Region of internal drainage
  - 3000 +/- 500 m contour



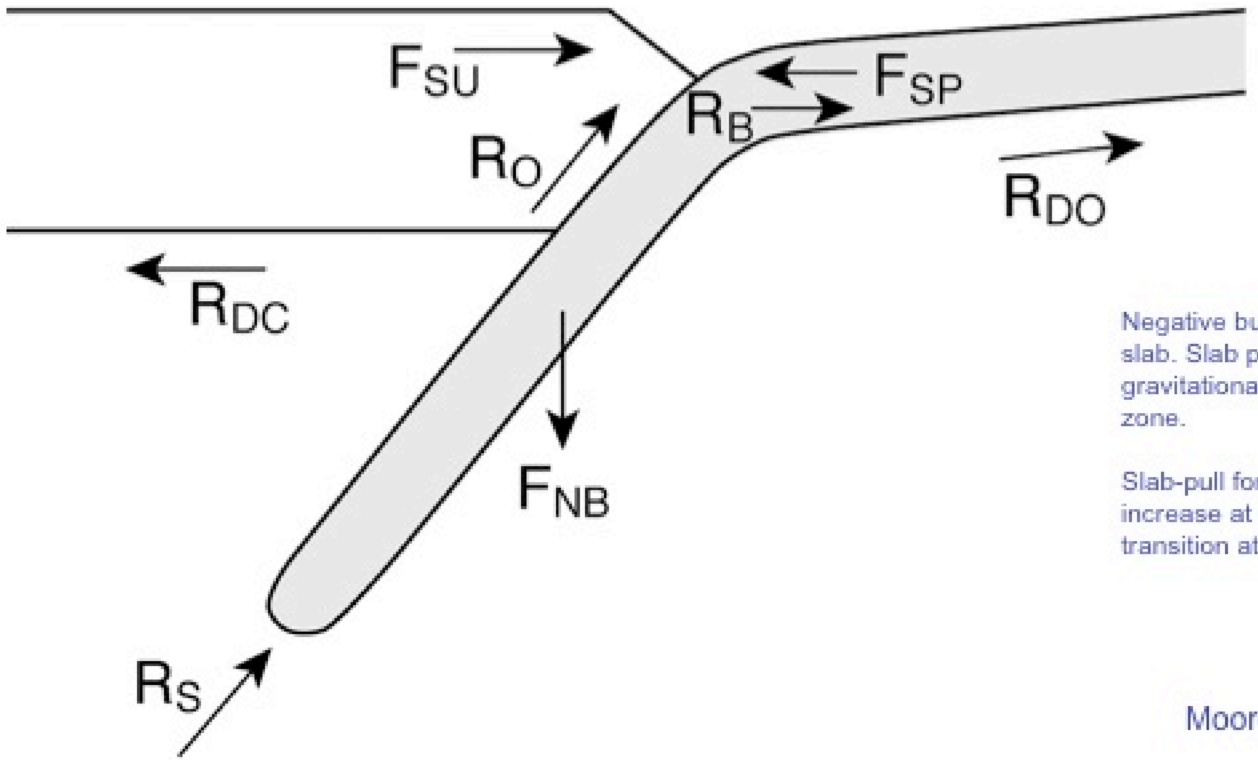


Schoenbohm and Strecker, in prep.



Nakamura and Uyeda, 1980

Slab-pull force

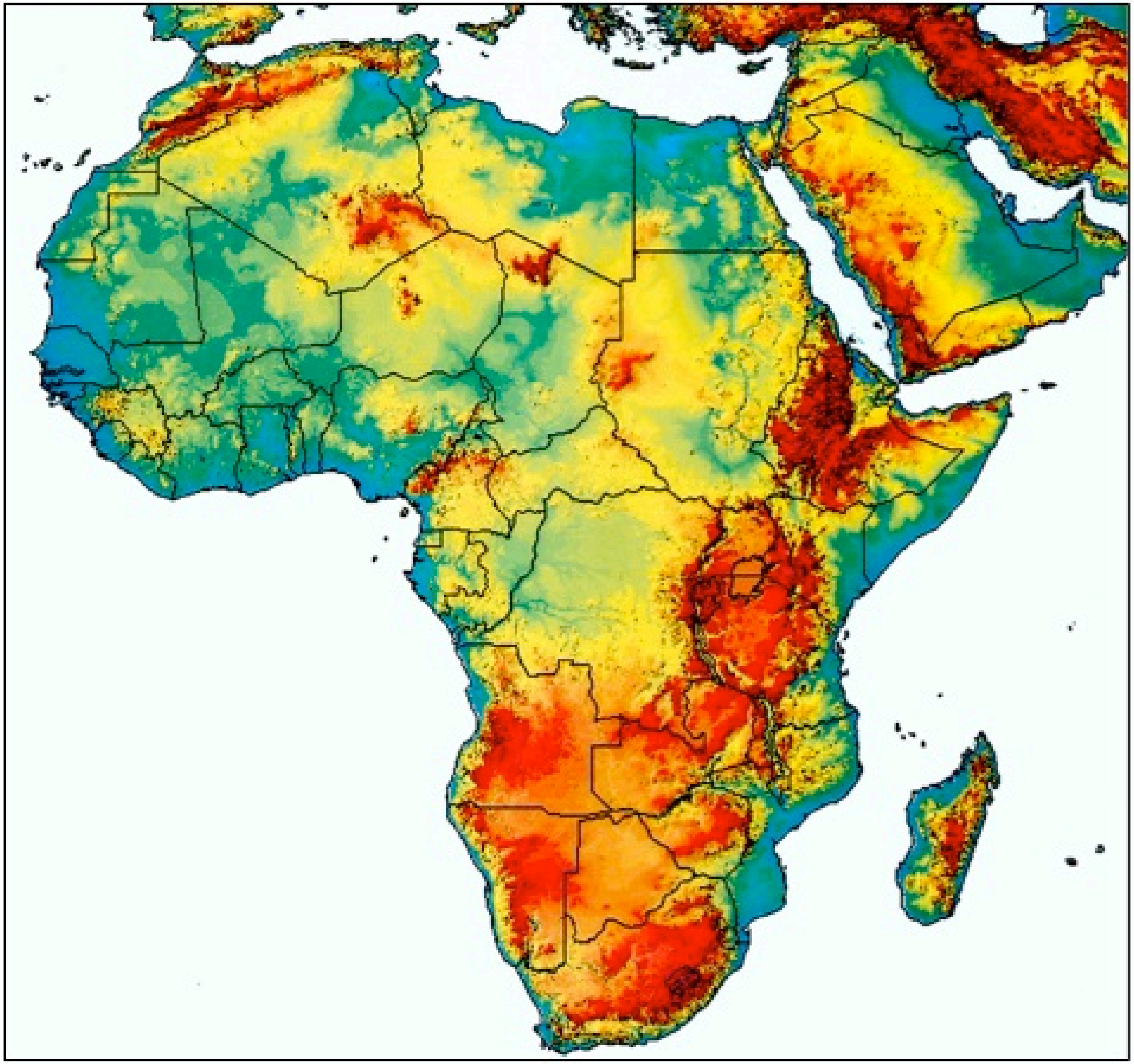


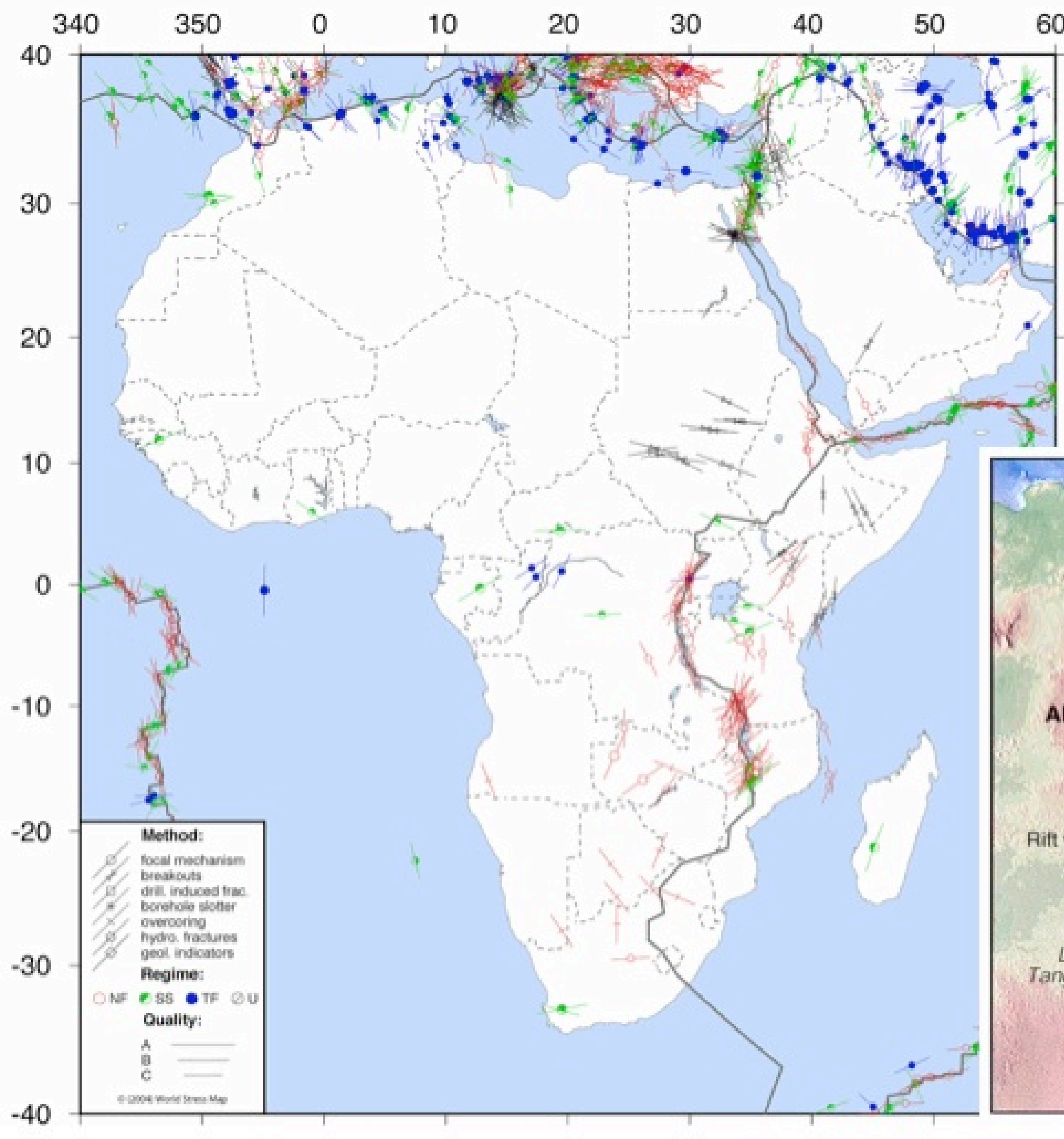
Negative buoyancy pulls dense oceanic slab. Slab pull thus results from a gravitational force in the subduction zone.

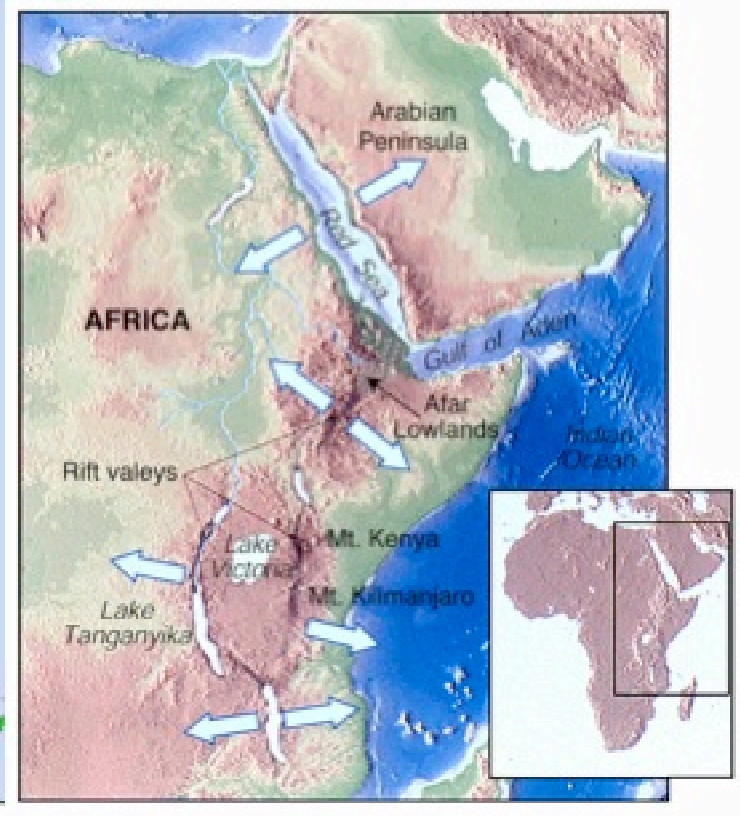
Slab-pull force is increased by density increase at depth due to olivine-spinel transition at 400 km

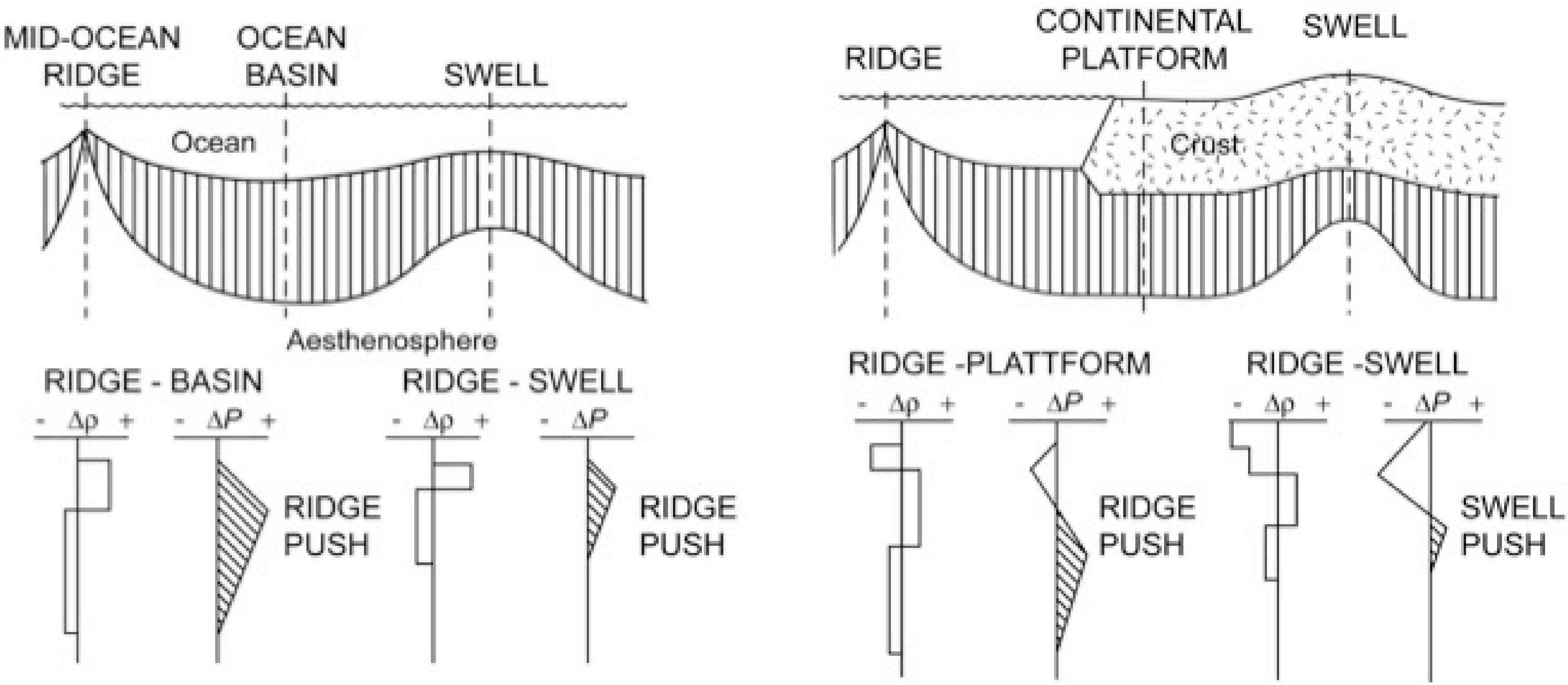
Moores and Twiss, 1997

Africa



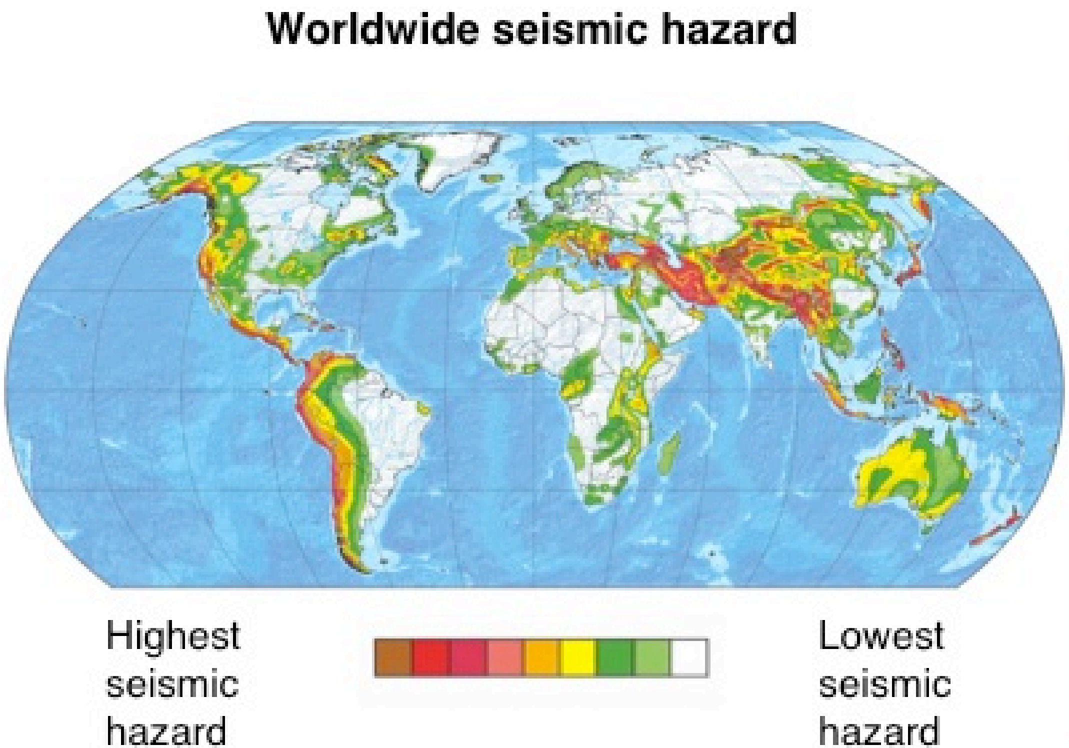

340
350
0
10
20
30
40
50
60
40
30
20
10
0
-10
-20
-30
-40
Method:
focal mechanism
breakouts
drill. induced frac.
borehole slotter
overcoring
hydro. fractures
geol. indicators
Regime:
NF
SS
TF
U
Quality:
A
B
C
© (2004) World Stress Map

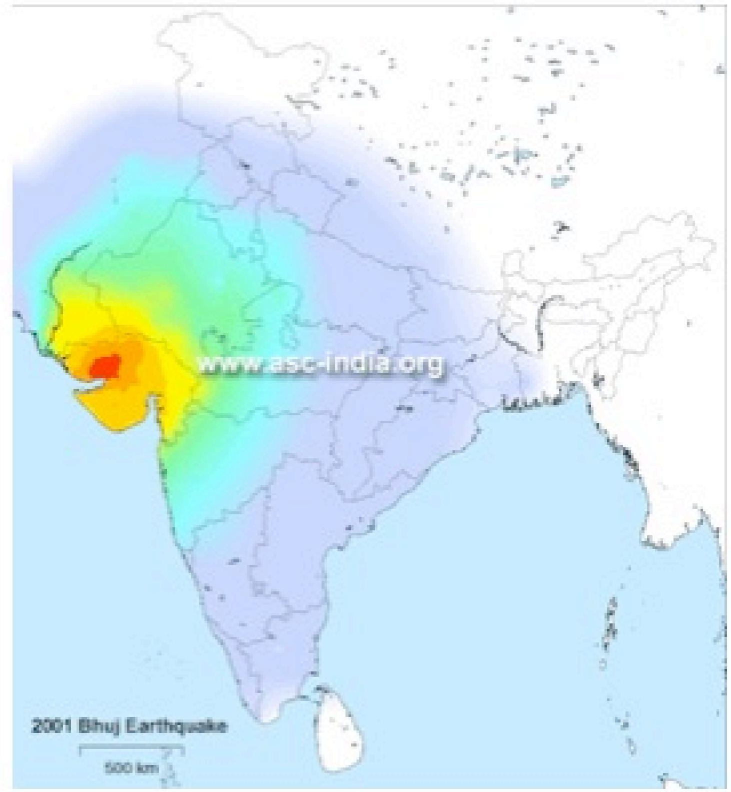

Arabian
Peninsula
Red Sea
AFRICA
Gulf of Aden
Afar
Lowlands
Indian
Ocean
Rift valleys
Mt. Kenya
Lake
Victoria
Mt. Kilimanjaro
Lake
Tanganyika



Allen and Allen, 1990

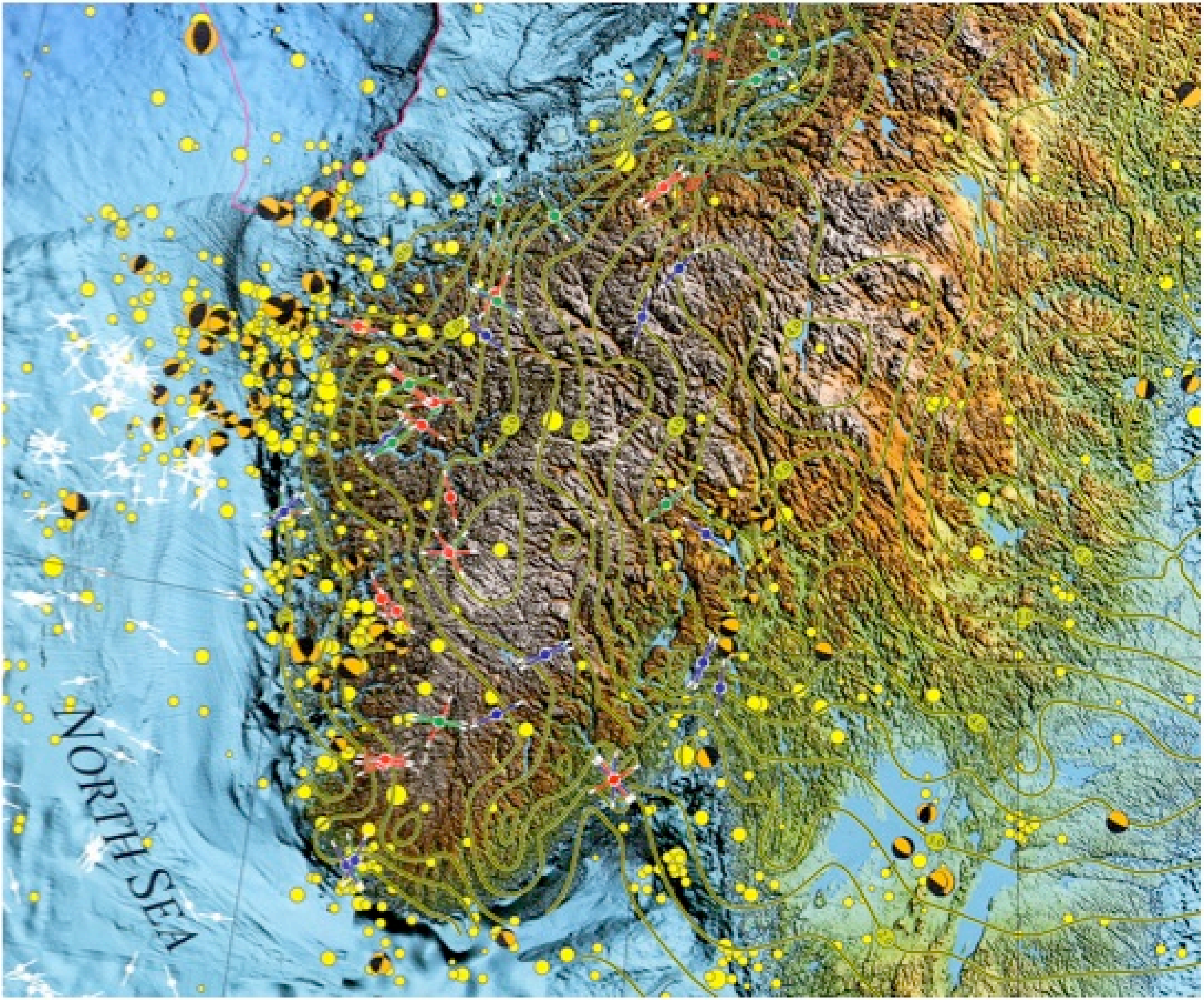
(3) Neotectonics in intraplate regions





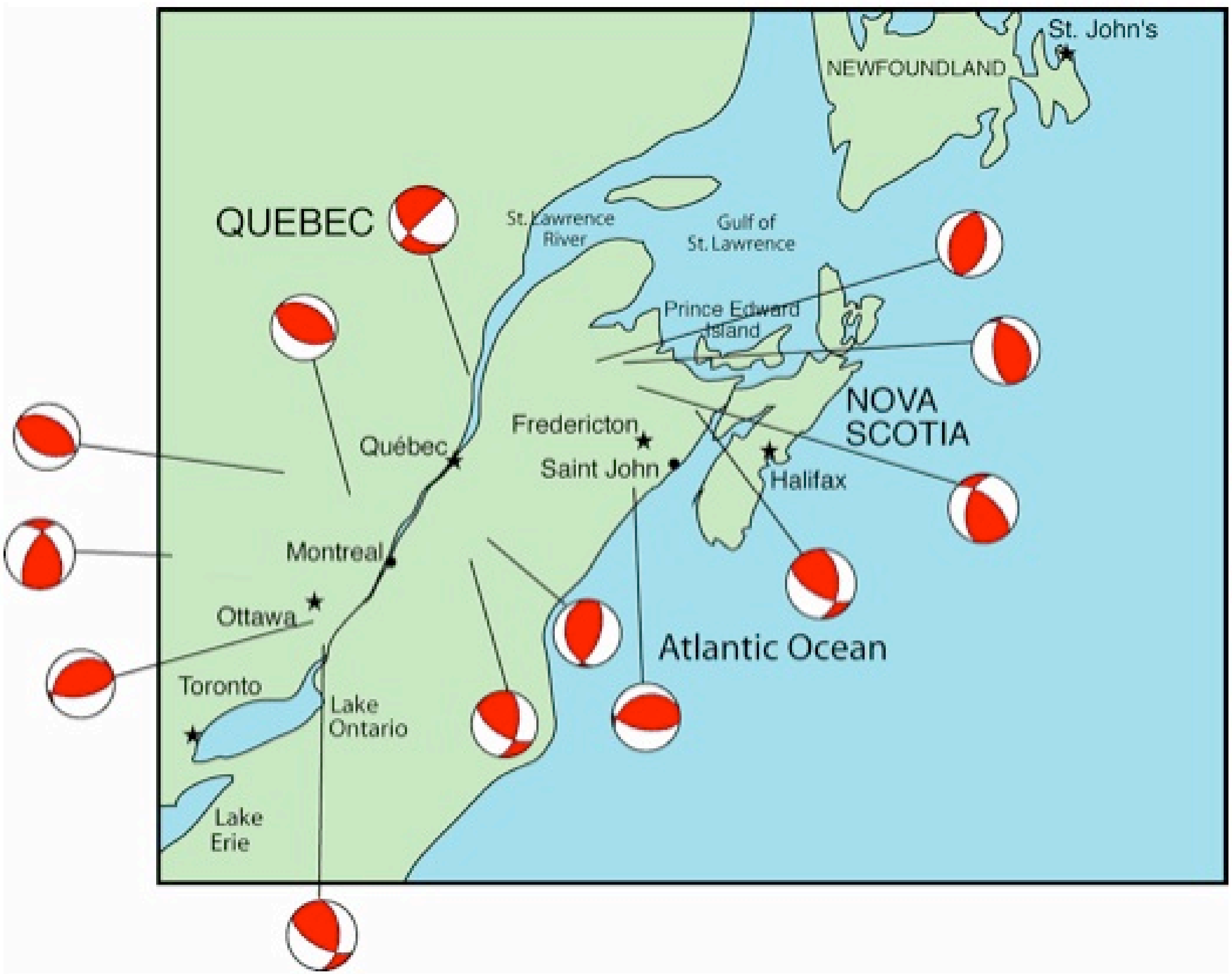
Guajarat Bhuj earthquake, 2001

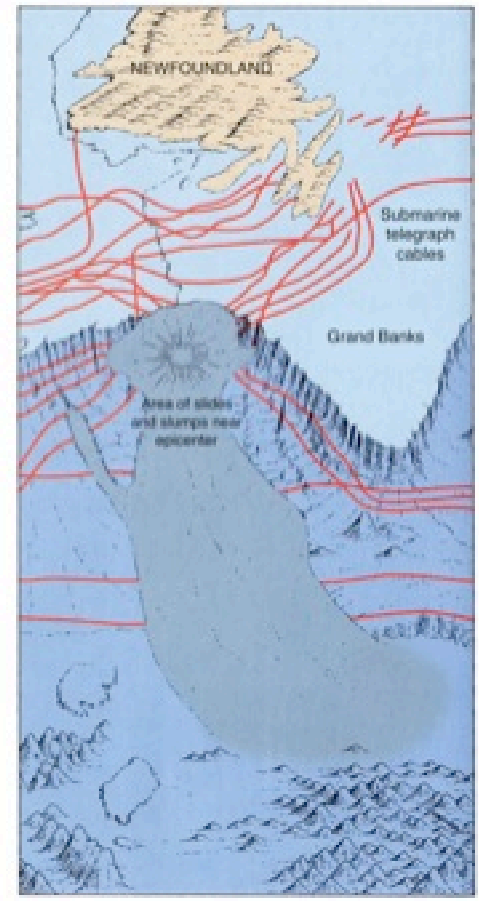
Seismicity in Scandinavia



Neotectonic map, Norwegian Geological Survey

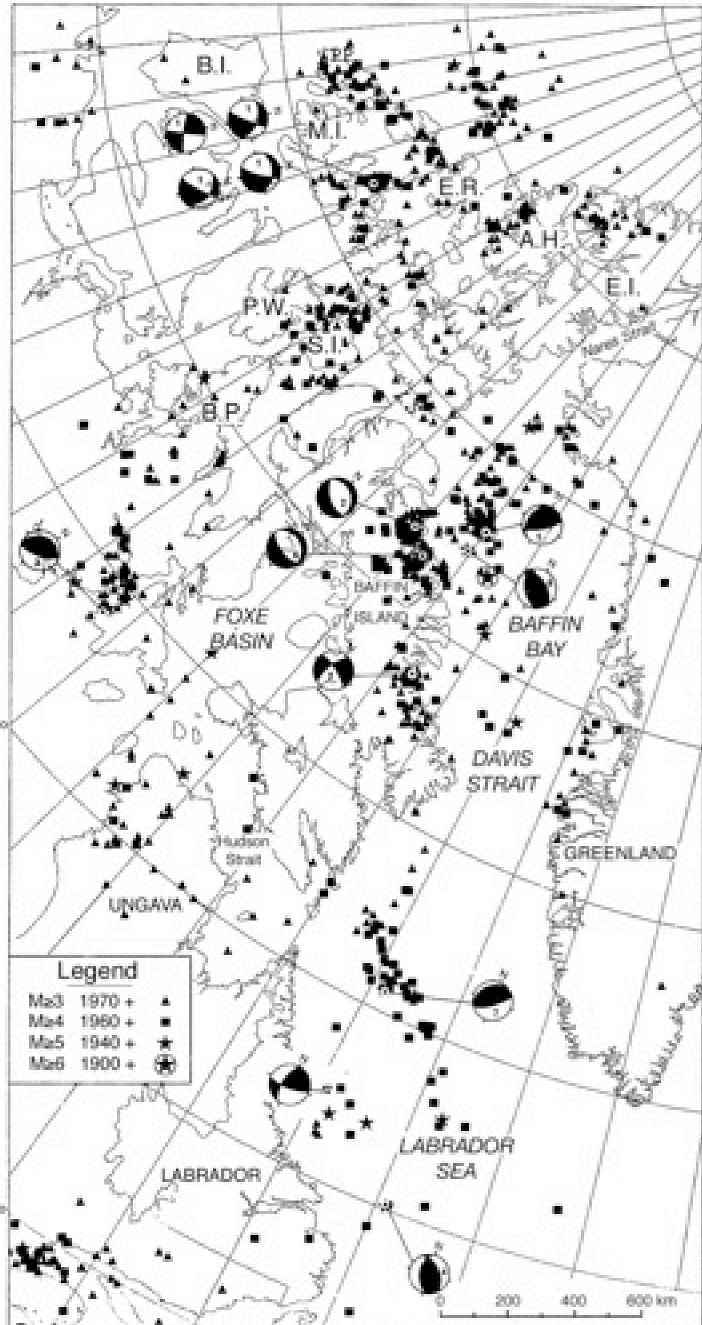
Seismicity in the St. Lawrence lowland and New Foundland, Canada

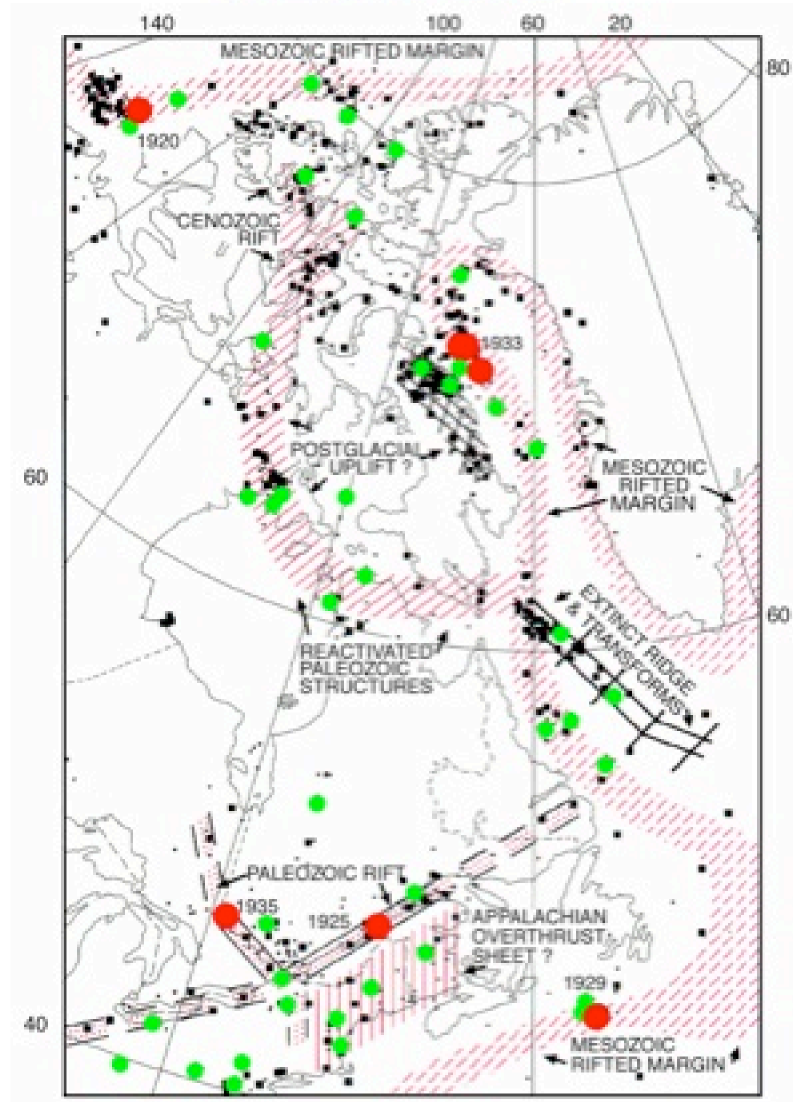




Adams and Basham, 1991

Seismicity in NE Canada

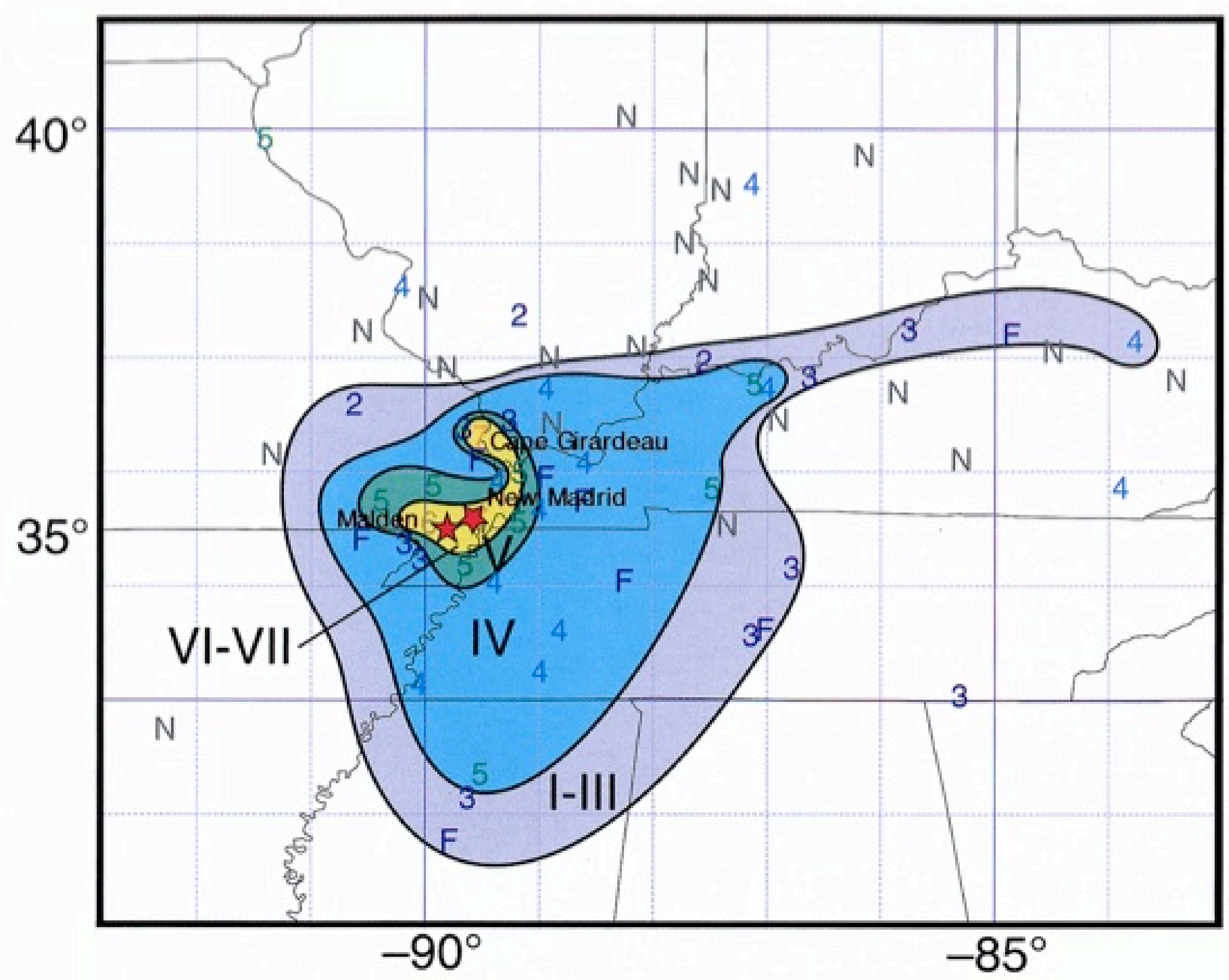




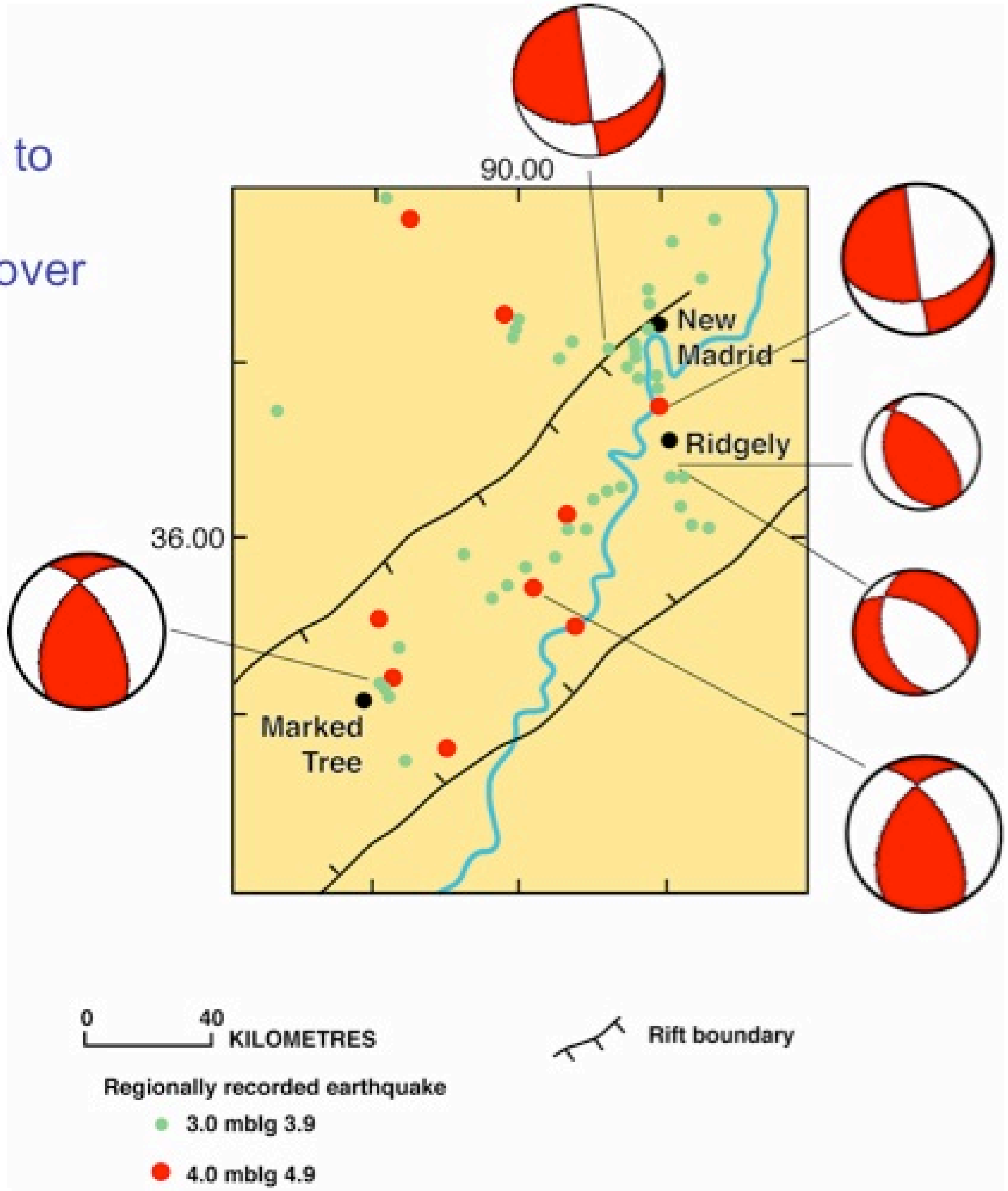
Adams and Basham, 1991

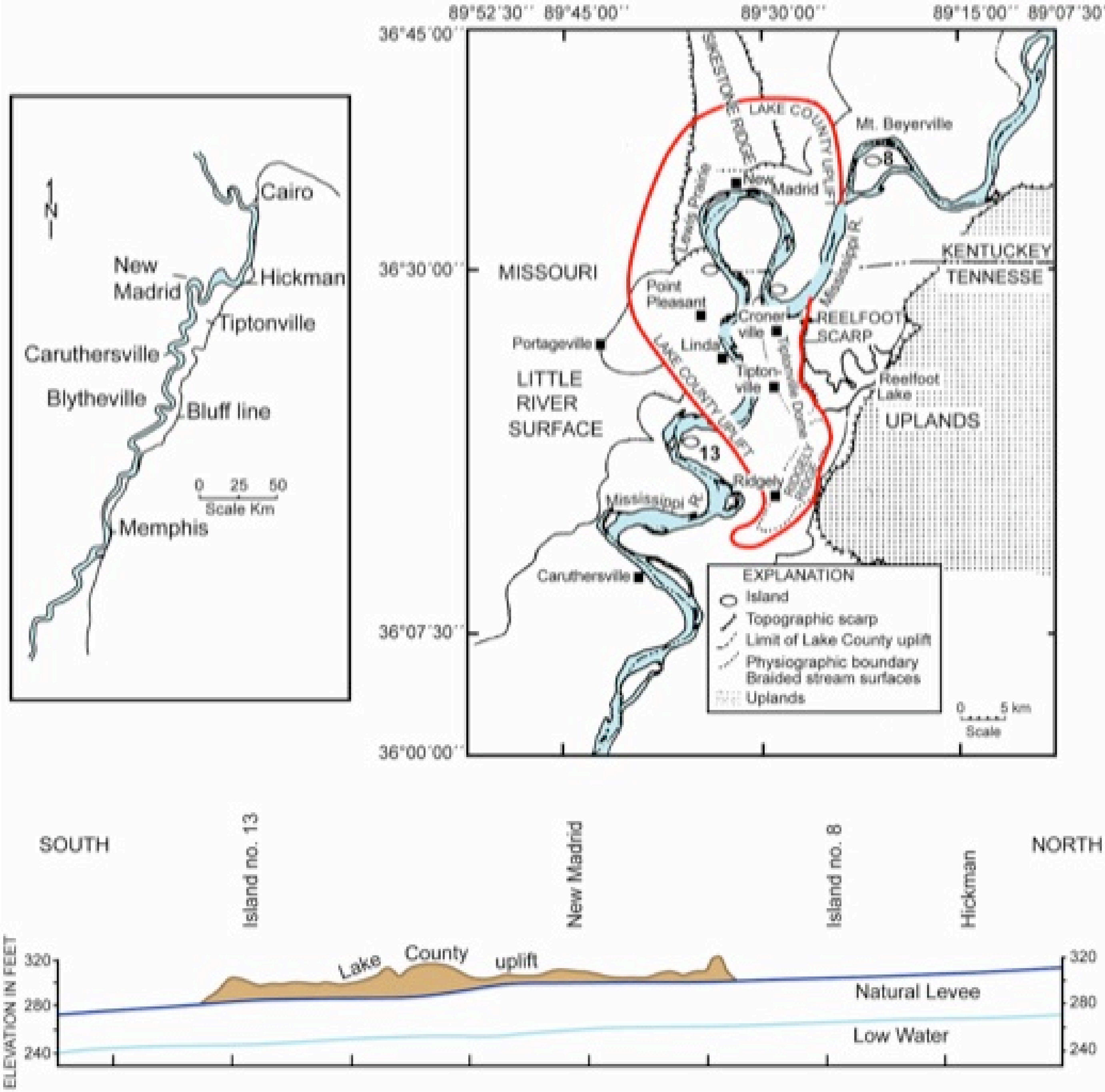
Neotectonic deformation and seismicity in the Reelfoot Rift, New Madrid seismic zone

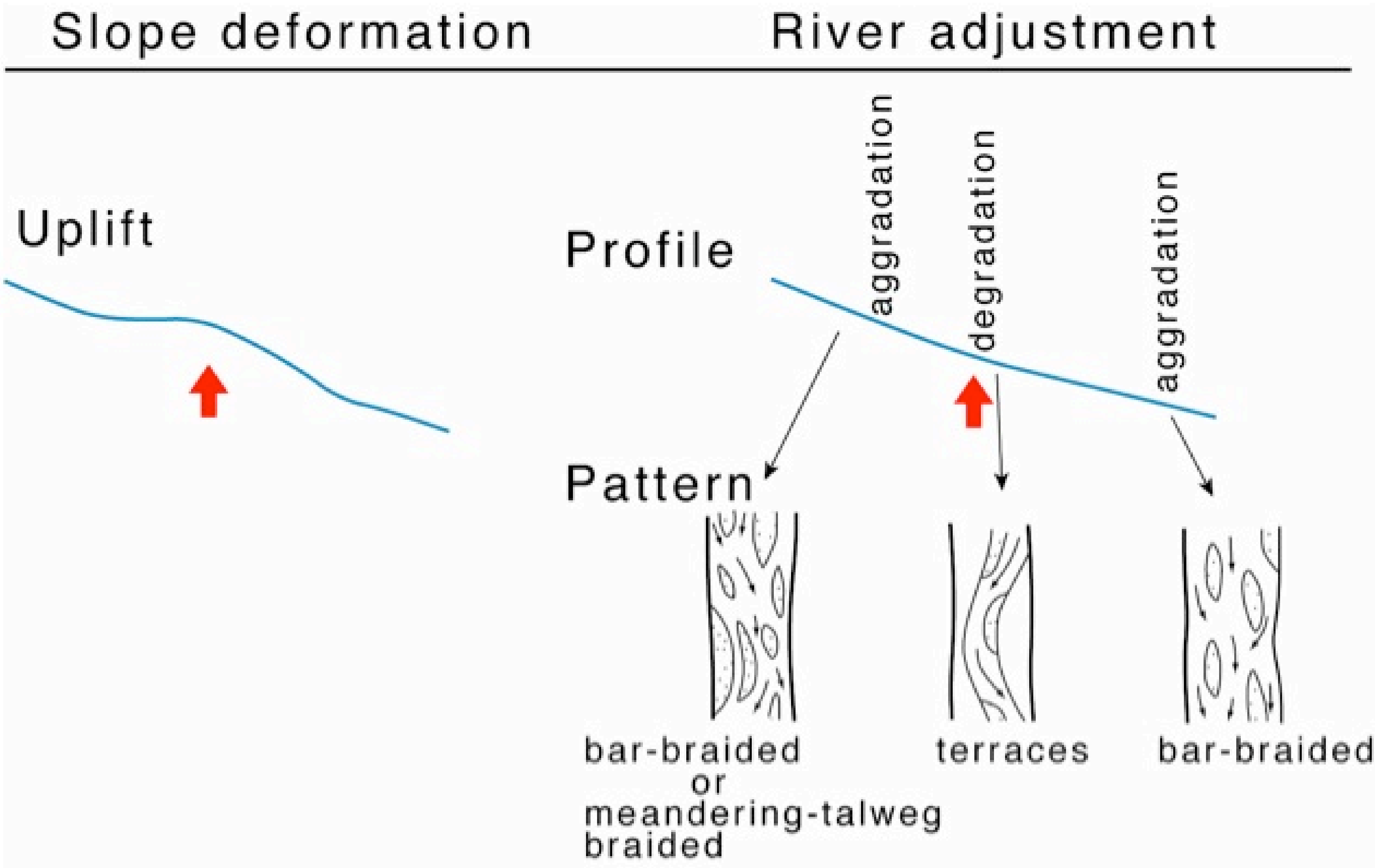
New Madrid earthquakes, 1811, 1812

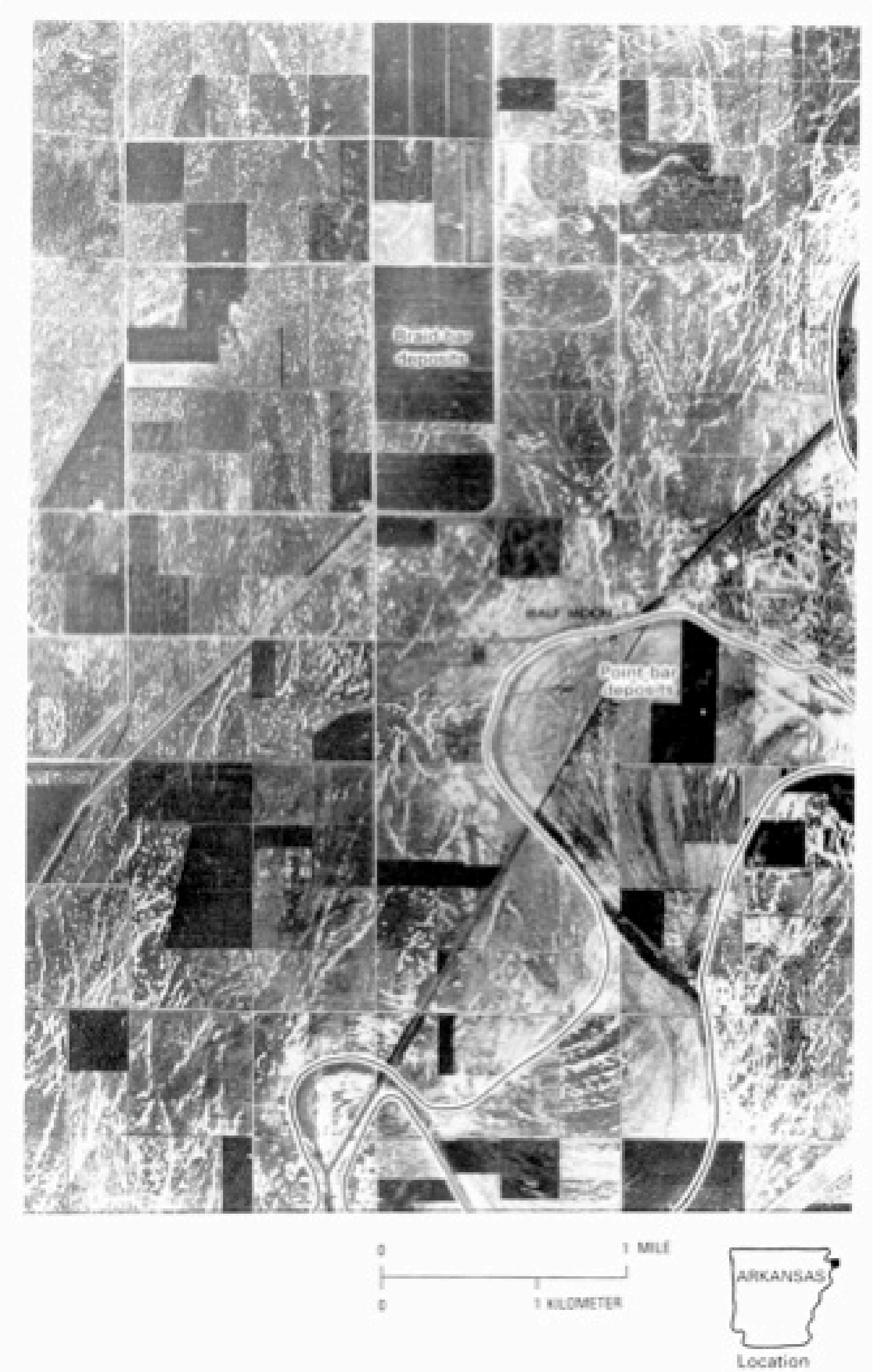


Earthquake occurred due to dextral slip on two right-lateral faults in a left stepover

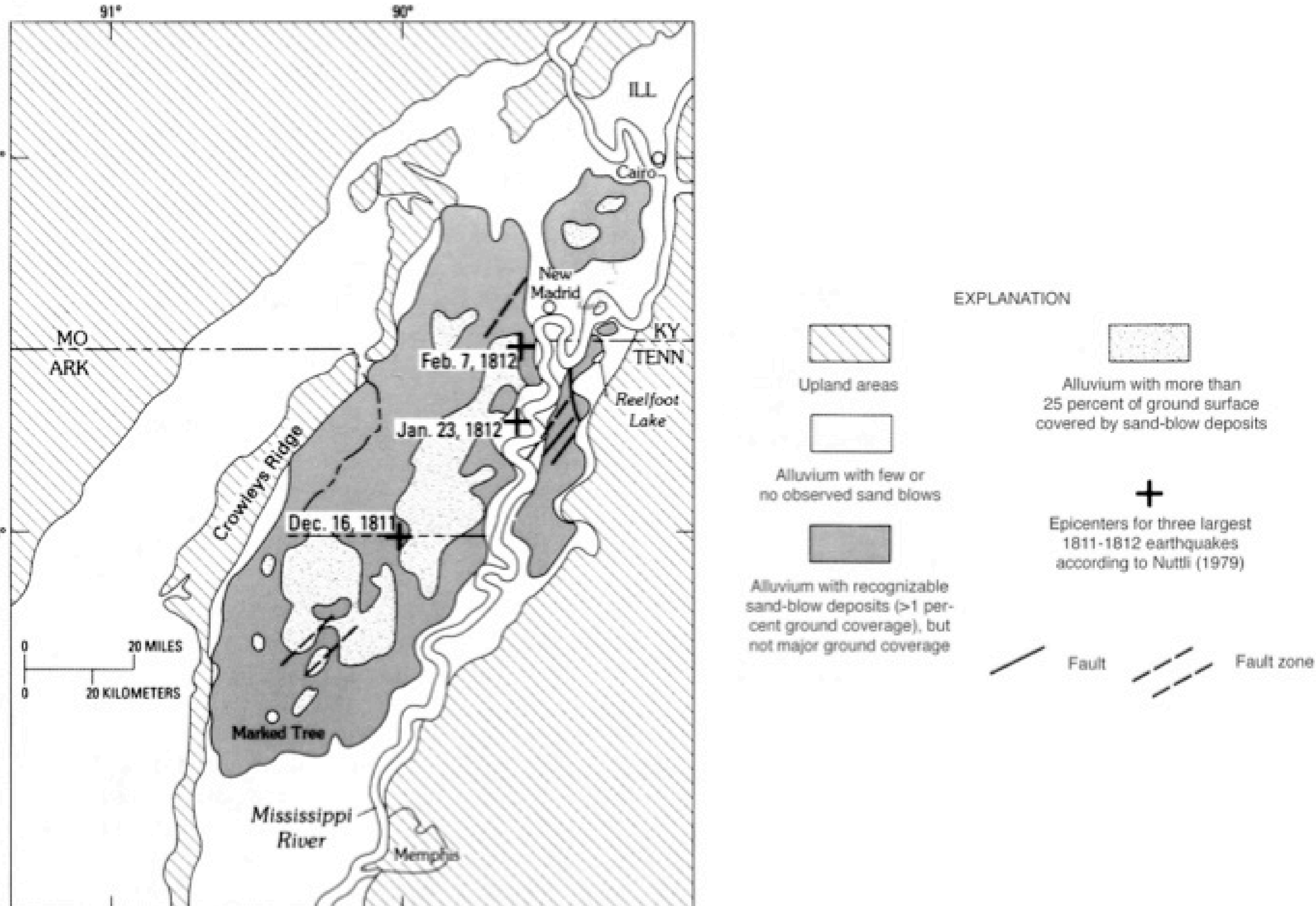



N
Cairo
New Madrid
Hickman
Tiptonville
Caruthersville
Blytheville
Bluff line
Memphis
0 25 50
Scale Km
89°52'30'' 89°45'00'' 89°30'00'' 89°15'00'' 89°07'30''
36°45'00''
36°30'00''
36°07'30''
36°00'00''
SIKESTONE RIDGE
LAKE COUNTY UPLIFT
Mt. Beyerville
8
New Madrid
Lewis Prairie
Mississippi R.
KENTUCKEY
TENNESSE
MISSOURI
Point Pleasant
Croner-ville
REELFOOT SCARP
Portageville
Linda
Tipton-ville
Tiptonville Dome
Reelfoot Lake
LITTLE RIVER SURFACE
LAKE COUNTY UPLIFT
UPLANDS
13
Ridgely
Mississippi R.
Caruthersville
EXPLANATION
Island
Topographic scarp
Limit of Lake County uplift
Physiographic boundary
Braided stream surfaces
Uplands
0 5 km
Scale
SOUTH
Island no. 13
New Madrid
Island no. 8
Hickman
NORTH
Lake County uplift
Natural Levee
Low Water
ELEVATION IN FEET
320
280
240

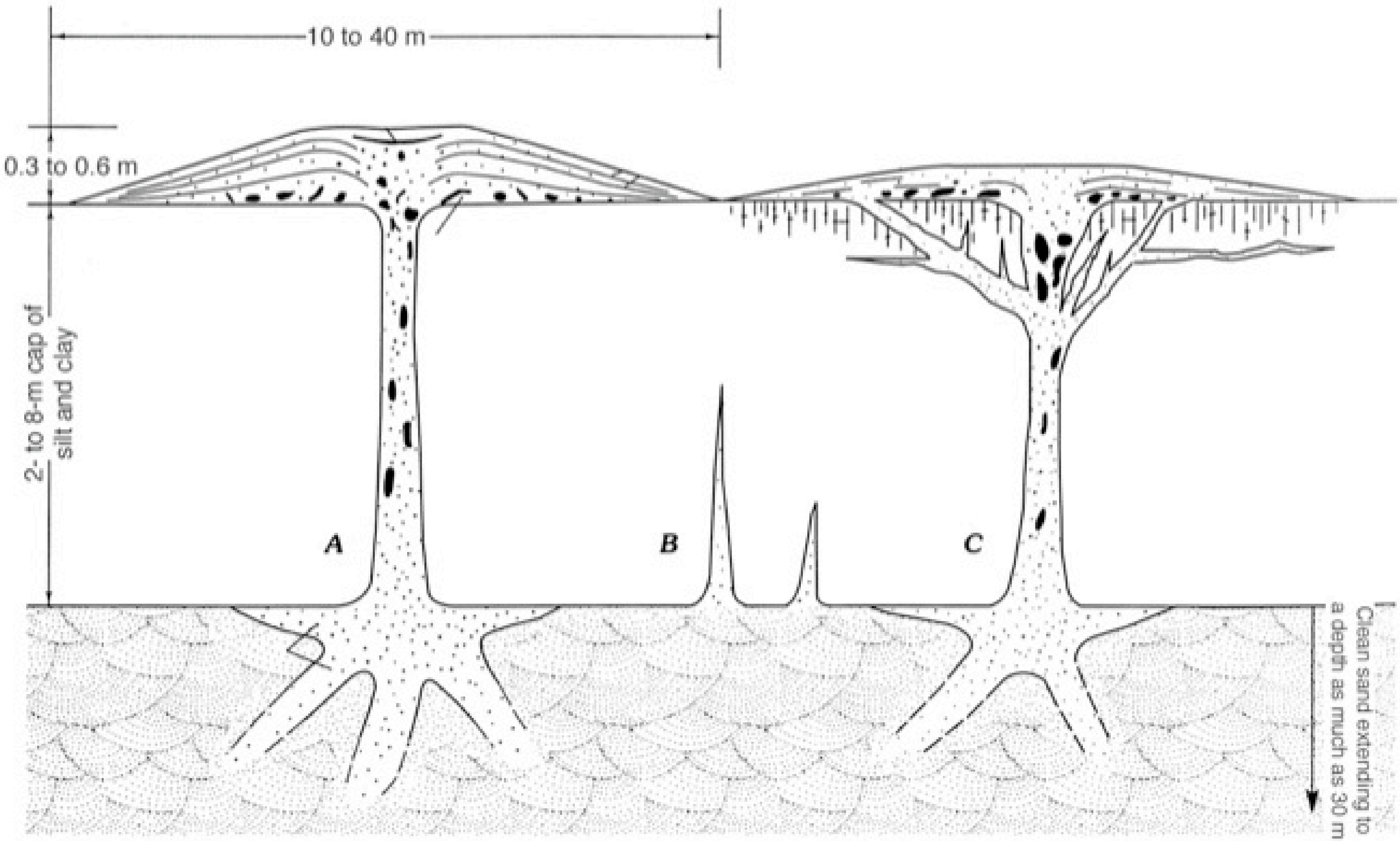

Slope deformation
River adjustment
Uplift
Profile
aggradation
degradation
aggradation
Pattern
bar-braided
or
meandering-talweg
braided
terraces
bar-braided



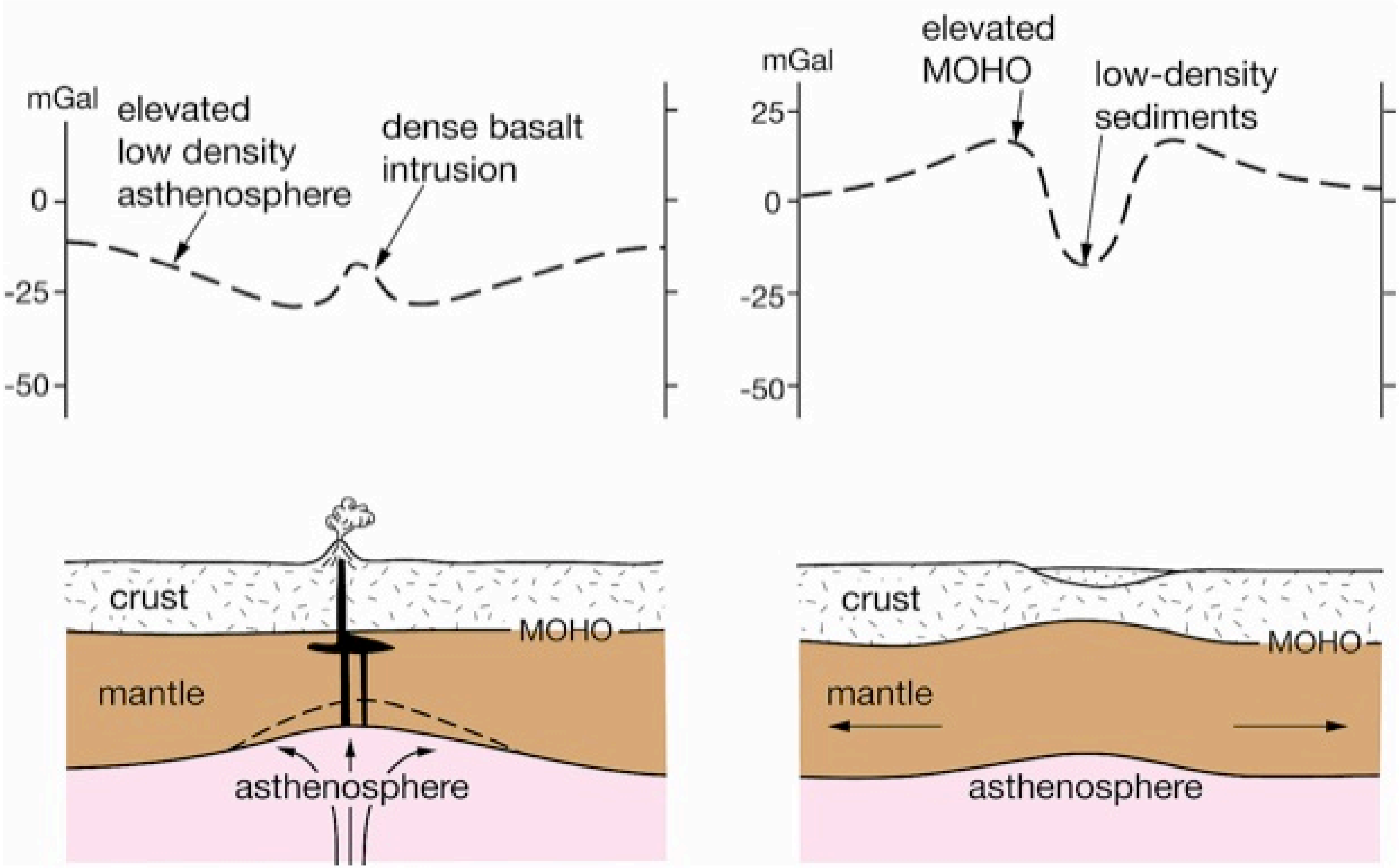
sand blows and dykes



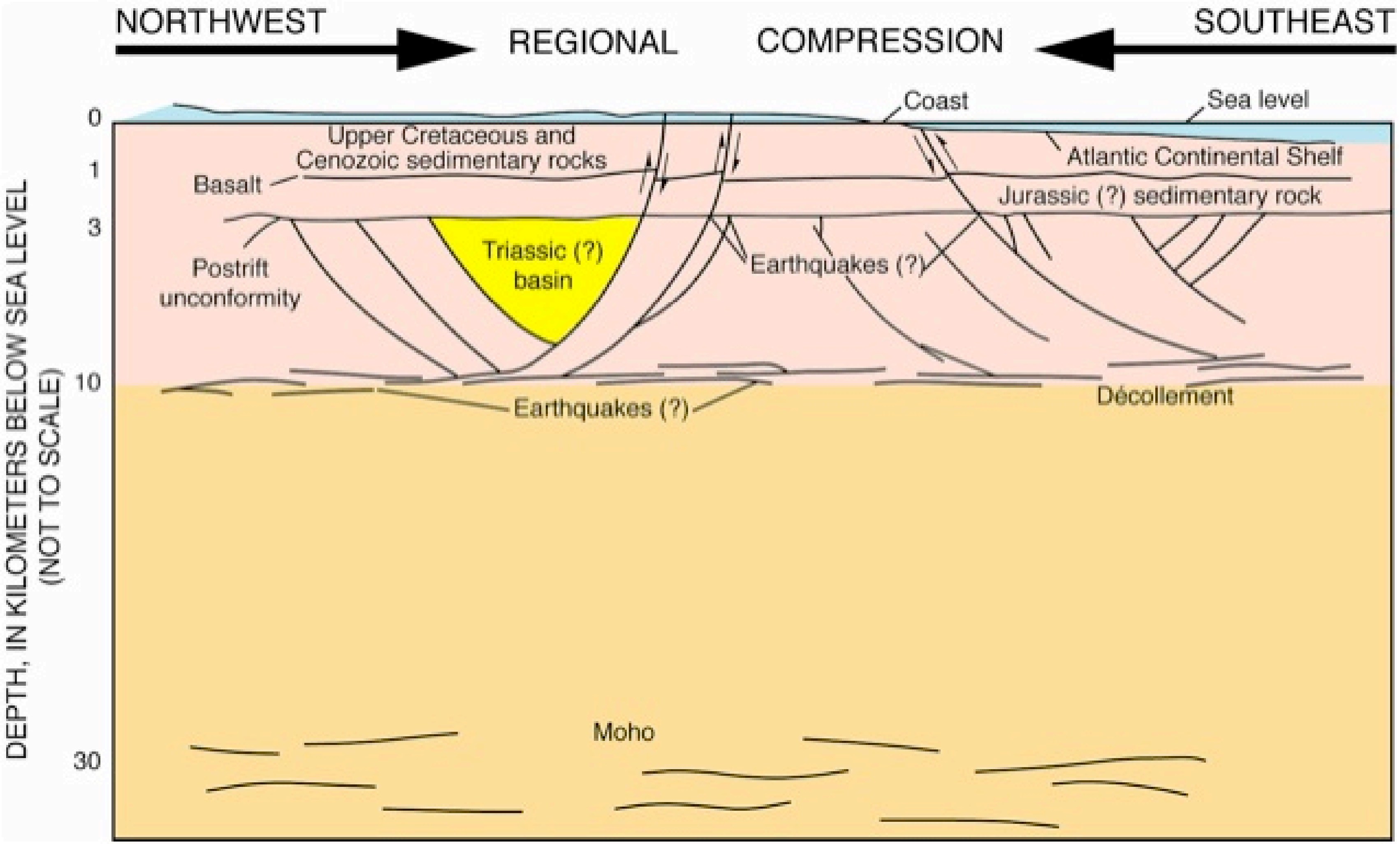
91°
90°
37°
36°
ILL
Cairo
New
Madrid
MO
ARK
KY
TENN
Feb. 7, 1812
Jan. 23, 1812
Dec. 16, 1811
Reelfoot
Lake
Crowleys Ridge
0
20 MILES
0
20 KILOMETERS
Marked Tree
Mississippi
River
Memphis
EXPLANATION
Upland areas
Alluvium with few or
no observed sand blows
Alluvium with recognizable
sand-blow deposits (>1 per-
cent ground coverage), but
not major ground coverage
Alluvium with more than
25 percent of ground surface
covered by sand-blow deposits
Epicenters for three largest
1811-1812 earthquakes
according to Nuttli (1979)
Fault
Fault zone


10 to 40 m
0.3 to 0.6 m
2- to 8-m cap of silt and clay
A
B
C
Clean sand extending to a depth as much as 30 m

Seismicity in continental interiors and paleo-rifts



Seismicity along the U.S. East coast



Gravity signatures of paleo-rifts