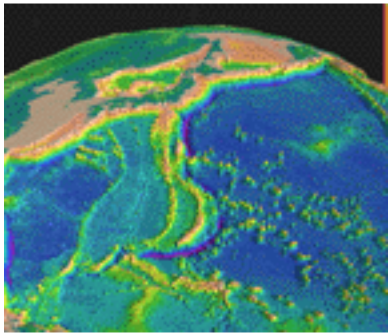
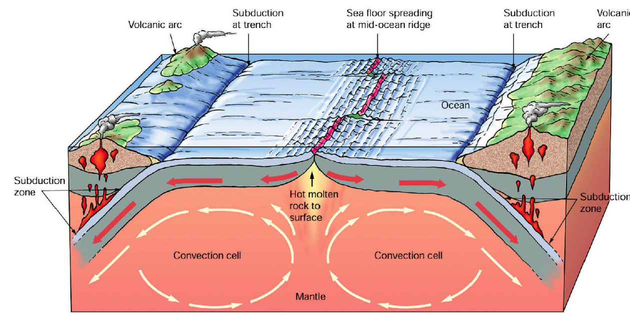


Observations Related Plate Tectonics

David T. Sandwell
Scripps Inst. Of Oceanography



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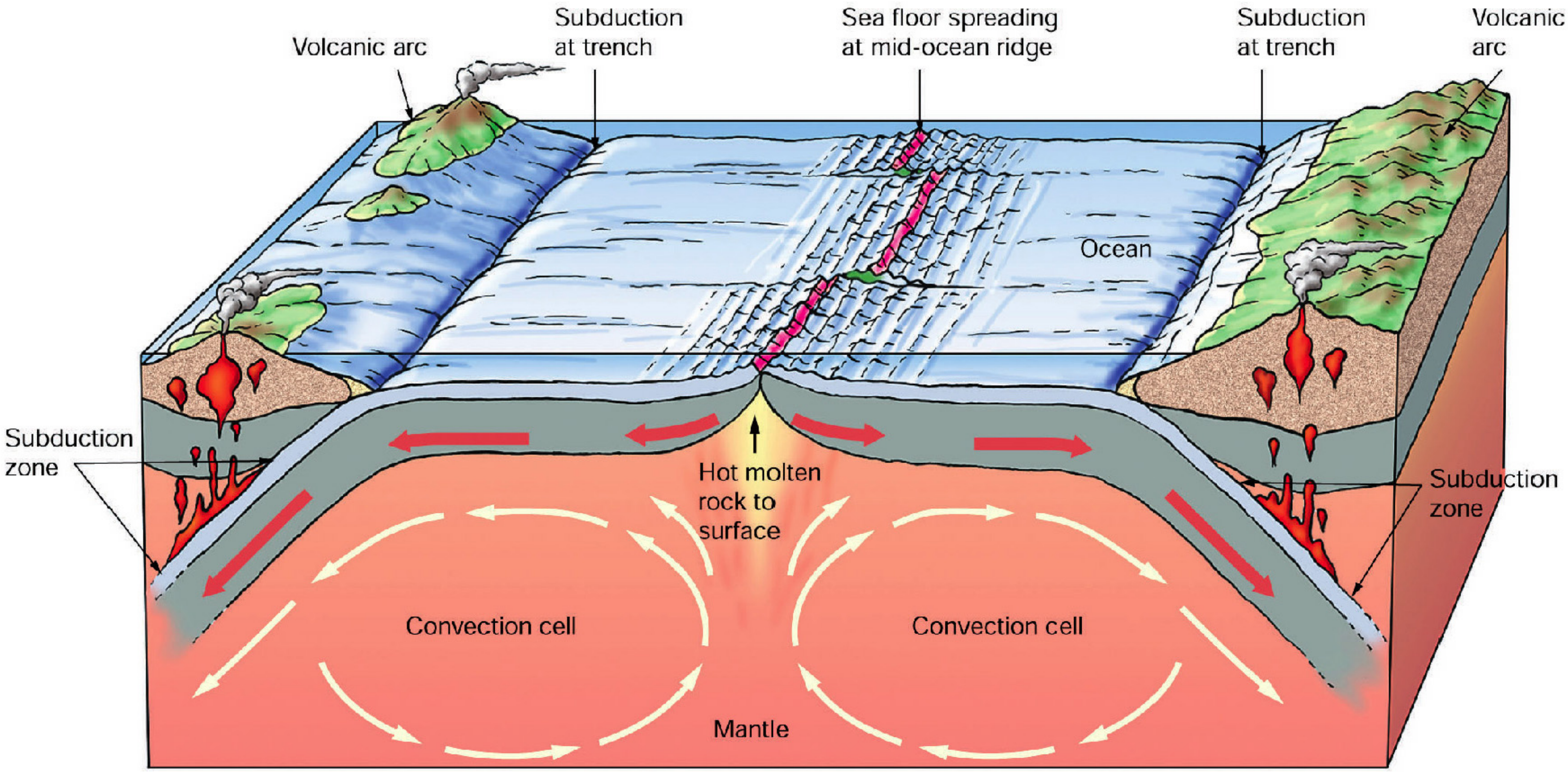
- Ocean and continent topography, hypsometry, and crustal thickness.
- Global seismicity, Benioff zones, and focal mechanisms
- Global volcanic activity
- Geoid Height and gravity anomaly
- Marine magnetic anomalies

plate tectonics



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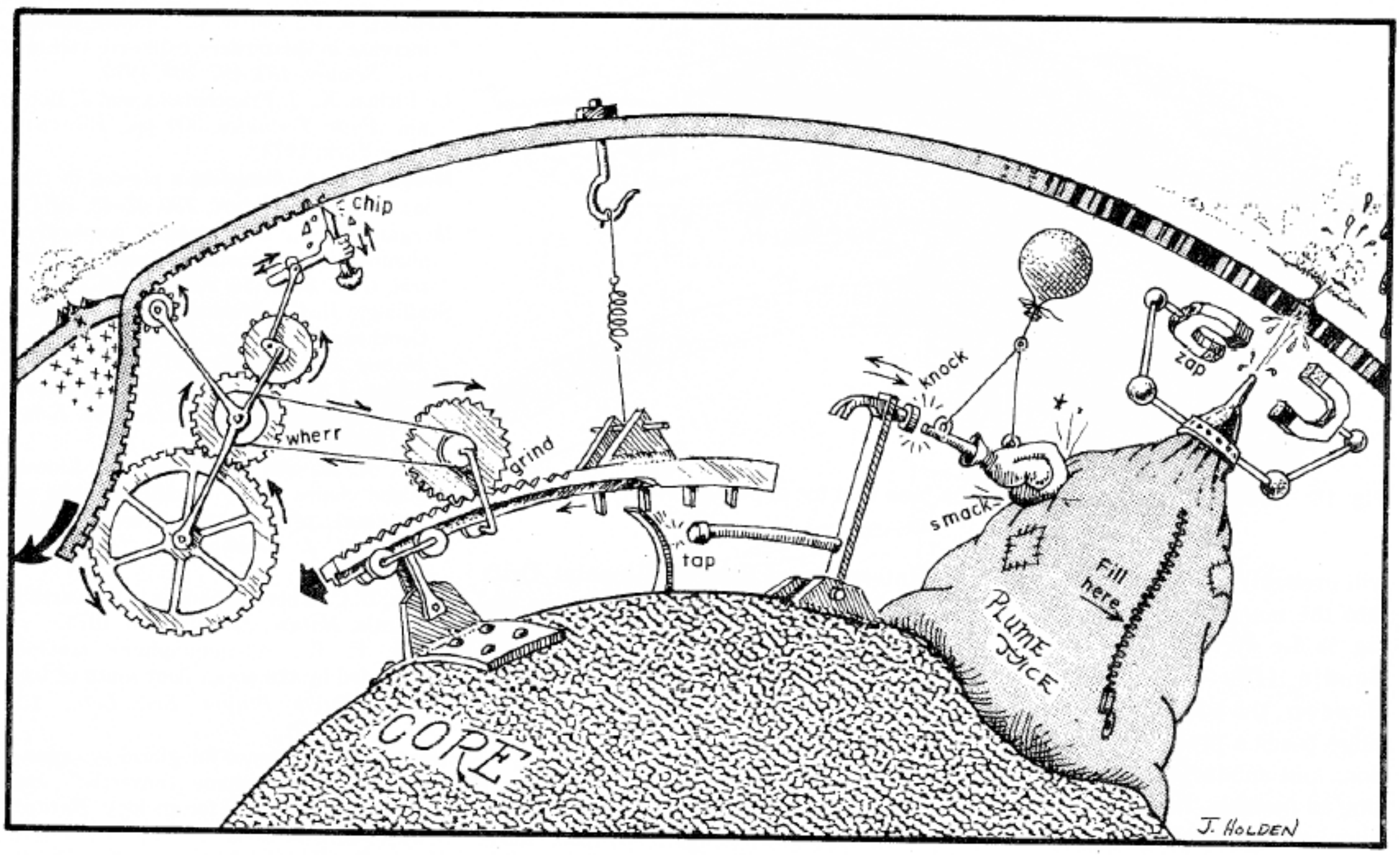
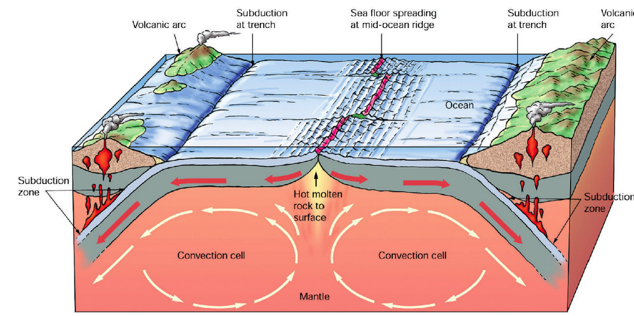
(Trujillo A. P. and H. V. Thurman, Essentials of Oceanography, Prentice Hall, New Jersey, 2004)

What were they smoking in the 60’s?



(Holden, J. C. and P. R. Vogt, Graphic Solutions to Problems of Plumacy, EOS Trans. AGU, 56, 573-560, 1977)

Why wasn't plate tectonics discovered until the 60's?



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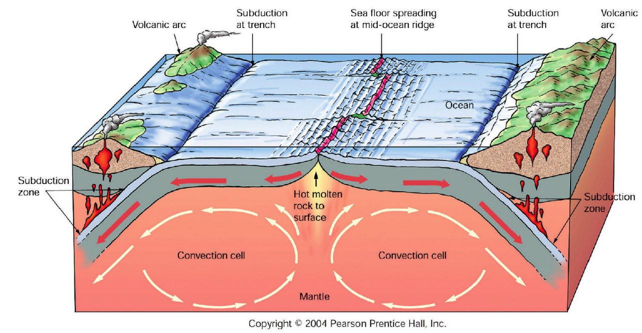
Evidence from the continents is indirect

Continental drift theory ≠ plate tectonic theory

- Geologists examined continental rocks.
- Geodesists made maps of shorelines and mountains.
- Paleontologists studied the 500 million-year old fossil record in sedimentary rocks.
- Glaciologists found evidence for glaciers at low latitudes.

Why wasn’t plate tectonics discovered until the 60’s?



- Plate Tectonic evidence mainly from seafloor

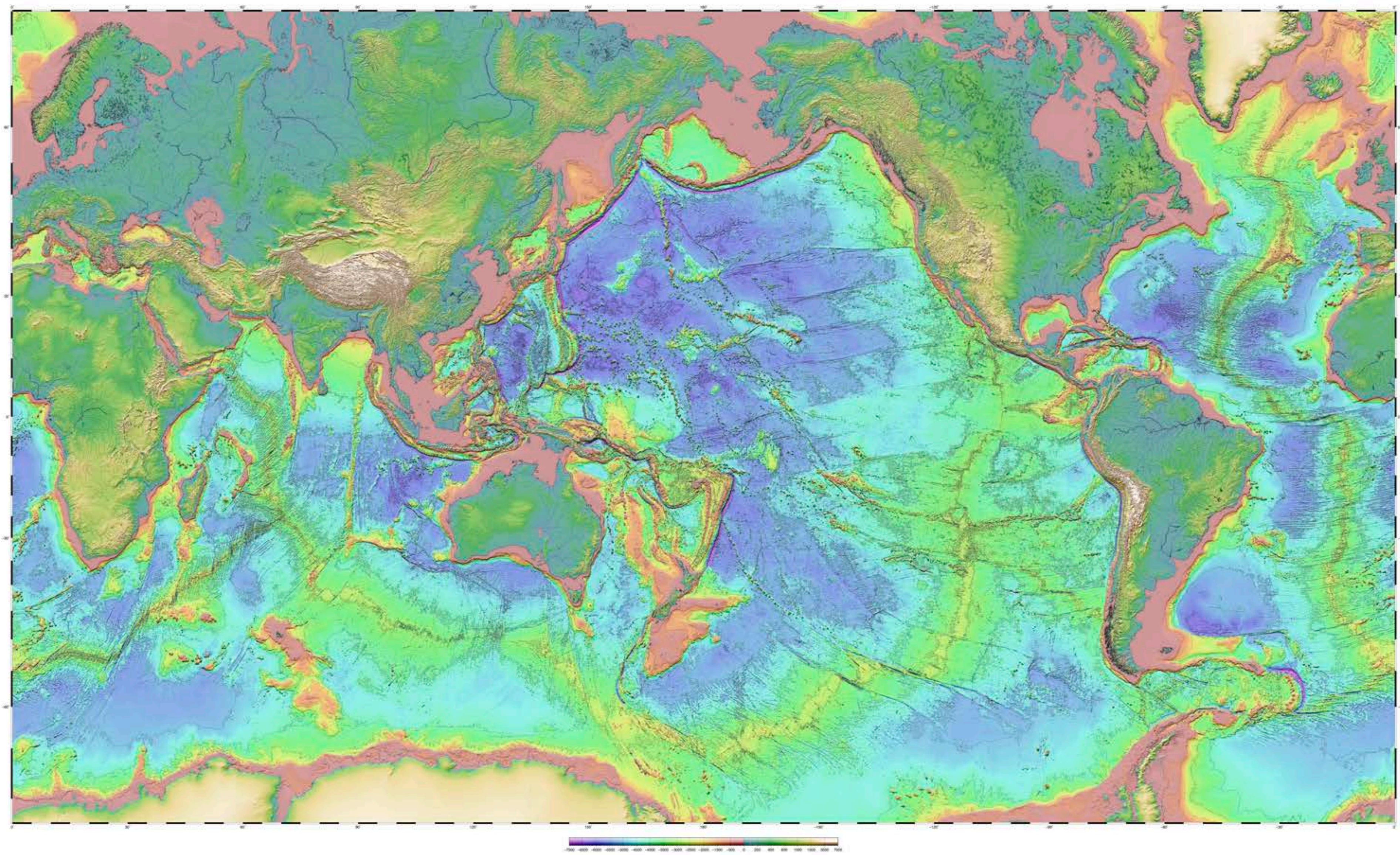
seafloor bathymetry - ridges, fracture zones, trenches

seafloor and backarc volcanism

seismicity and focal mechanisms

marine magnetic anomalies

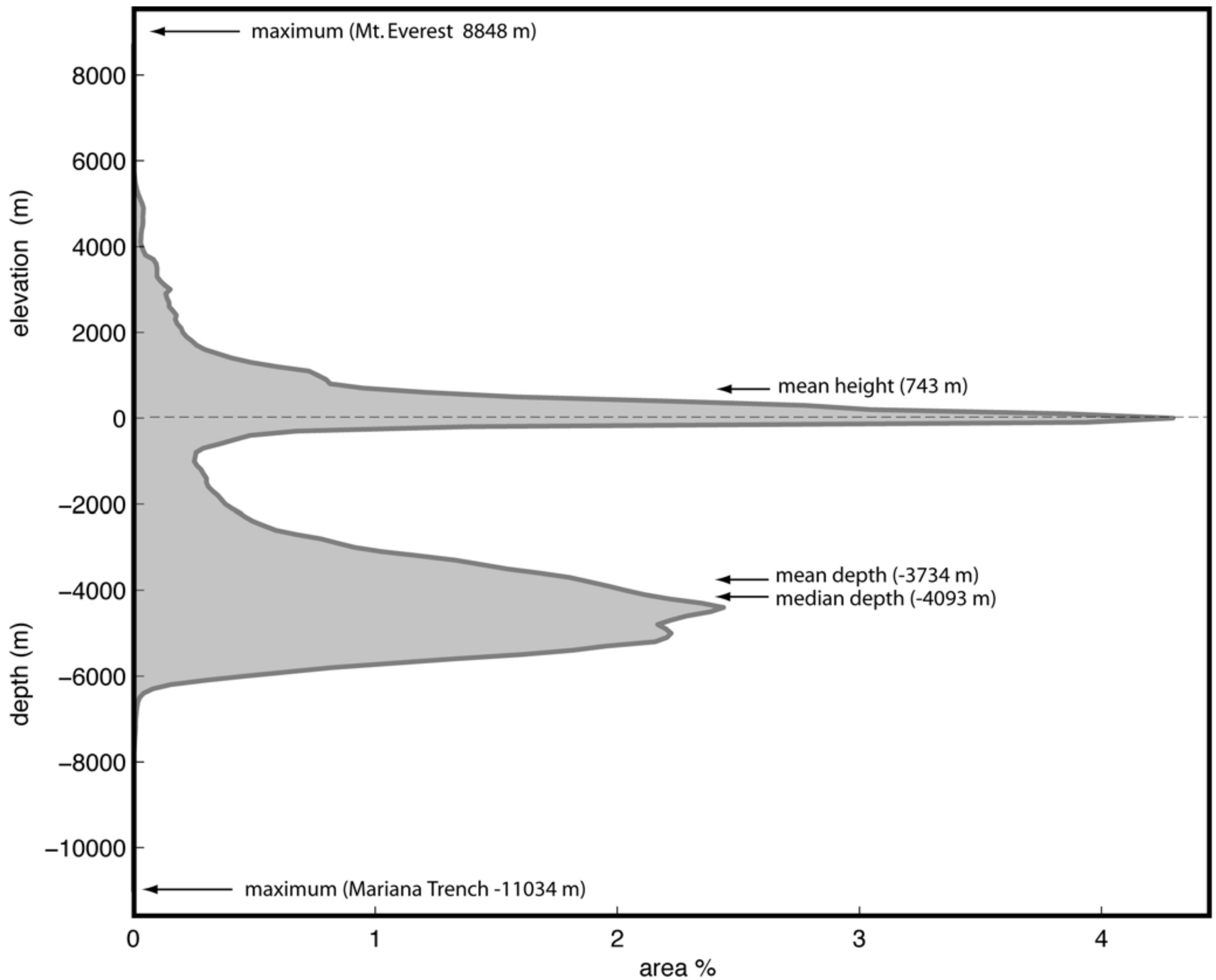
- Need ships, echo sounders, magnetometers, seismometers mostly developed after WW2 and during the Cold War.



Google Earth version at http://topex.ucsd.edu or
ftp://topex.ucsd.edu/pub/srtm30_plus/SRTM30_PLUS.kmz

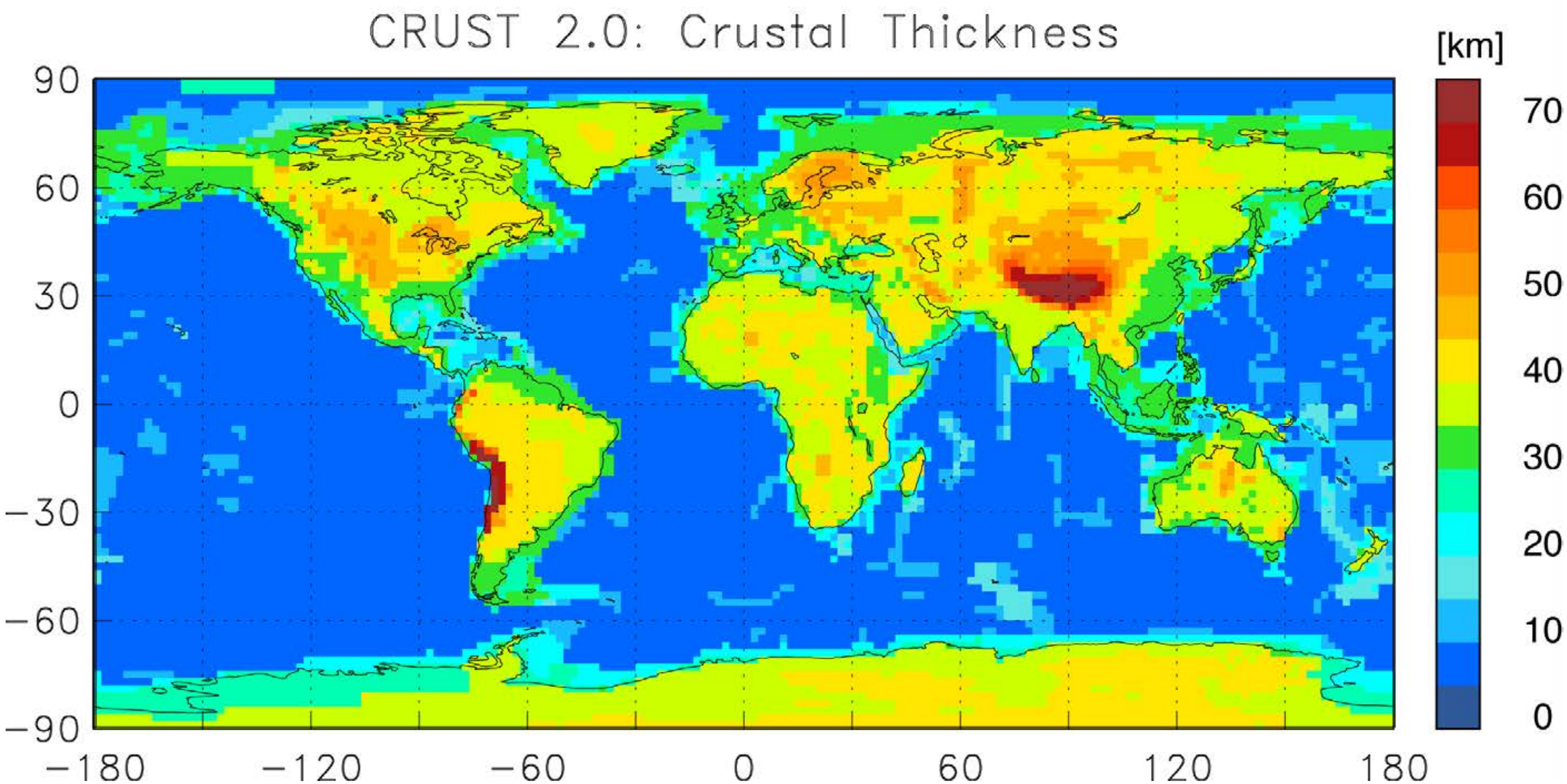
[Smith and Sandwell, 1997]

hypometric curve



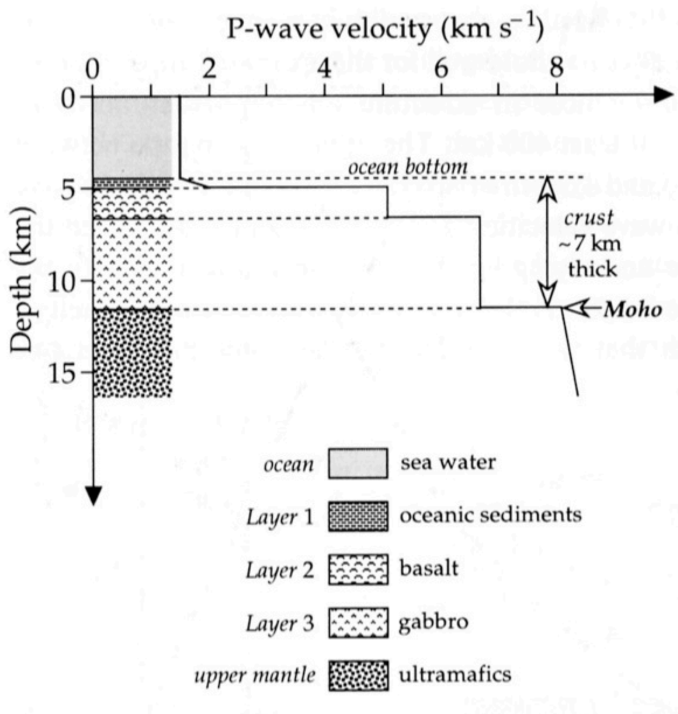
EXERCISE:

The median seaflooor depth is ~4 km and the median ocean crustal thickness is ~6 km. The most likely elevation of the continent is 0 km. Assume oceanic and continental crust have the same density. How thick is the continental crust?

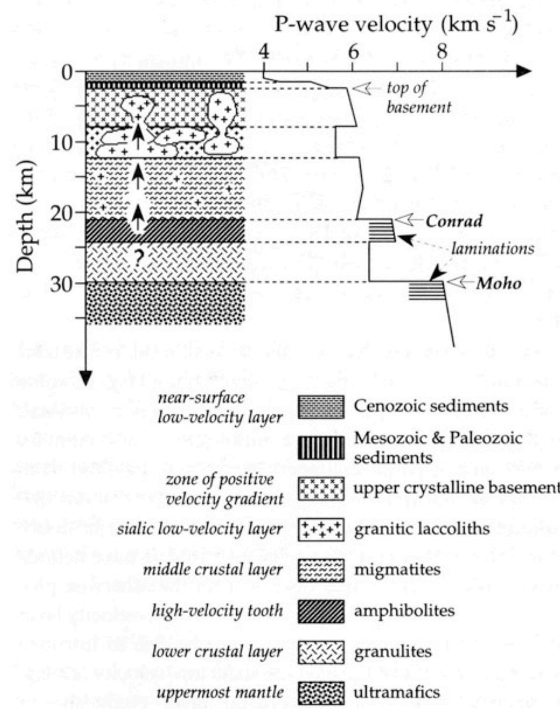


[Laske et al., 2000]

Oceanic vs. continental crust

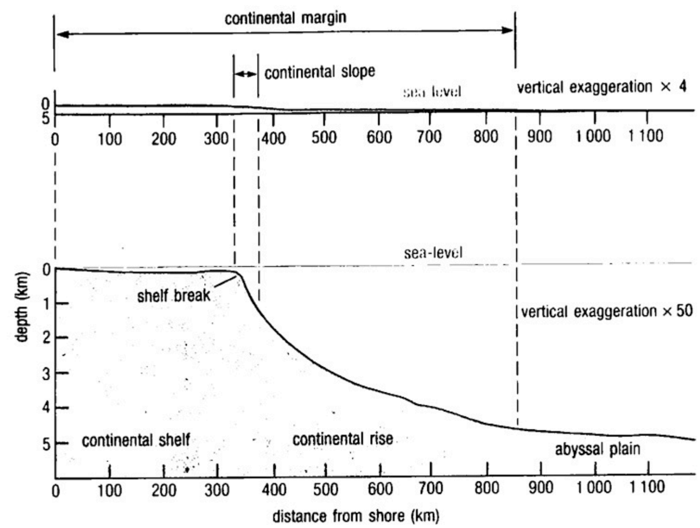


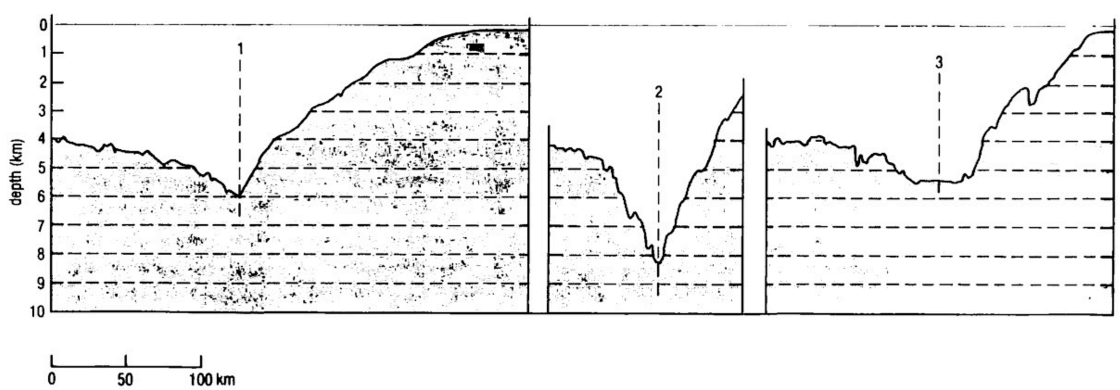
Oceanic crust



Continental crust

active and passive margins





(The Ocean Basins, Open University)

Atlantic profile

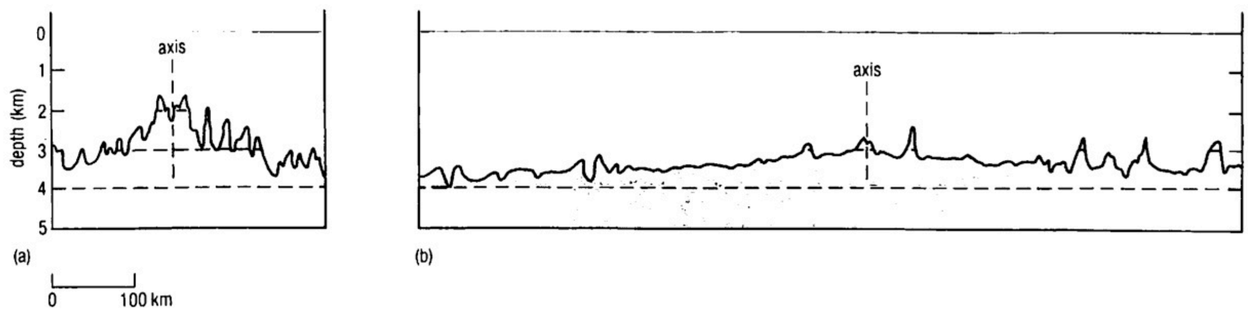


Figure 2.11 Representative east–west topographic (bathymetric) profiles across the Mid-Atlantic Ridge and across the East Pacific Rise (see Question 2.5). The vertical exaggeration is ×50.

29

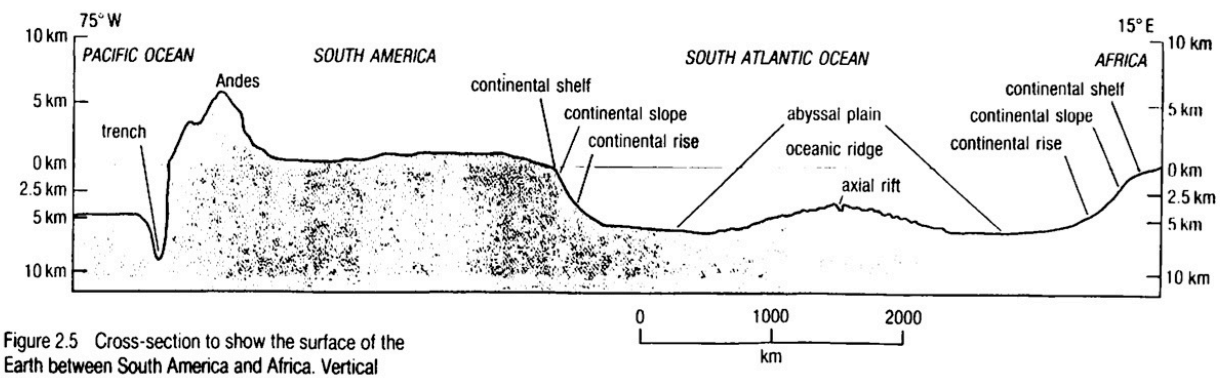
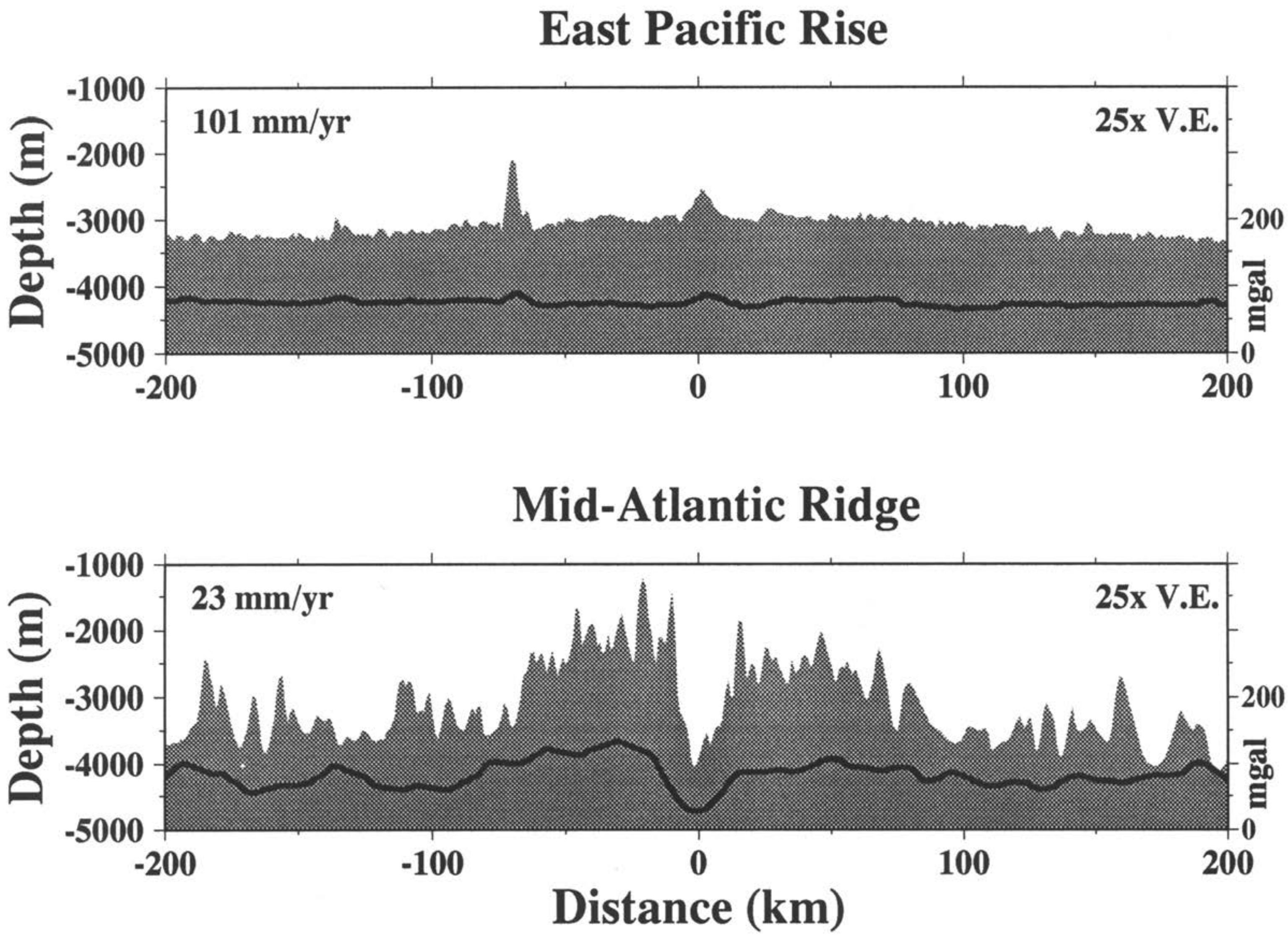


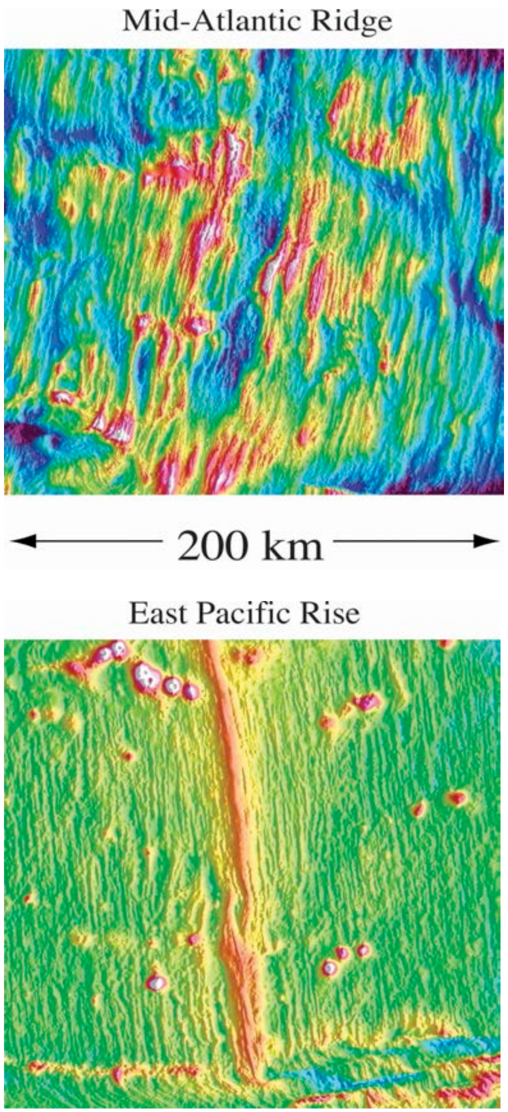
Figure 2.5 Cross-section to show the surface of the Earth between South America and Africa. Vertical exaggeration ×100.

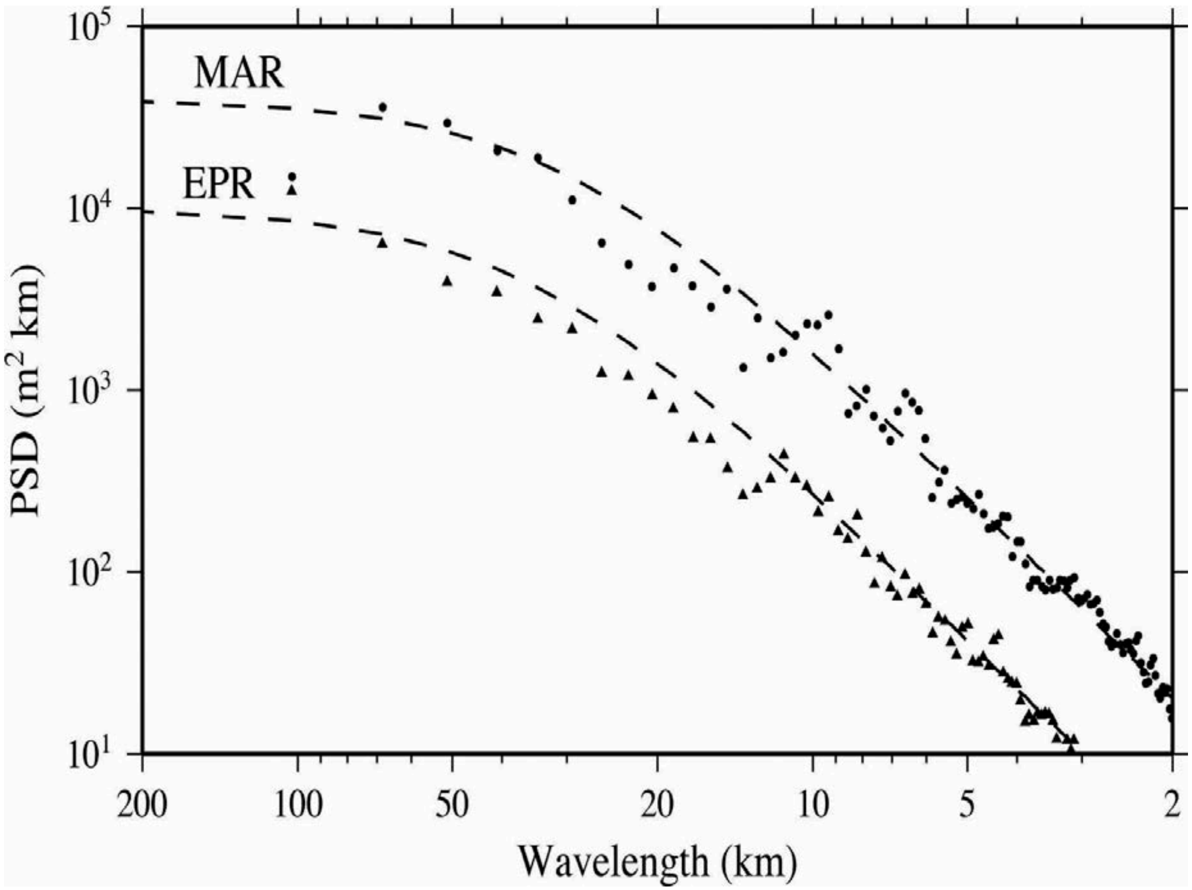
(The Ocean Basins, Open University)

fast vs. slow spreading



abyssal hills: fast v. slow spreading rate





[Smith, W.H.F.: personal communication]

volcanoes and seamounts

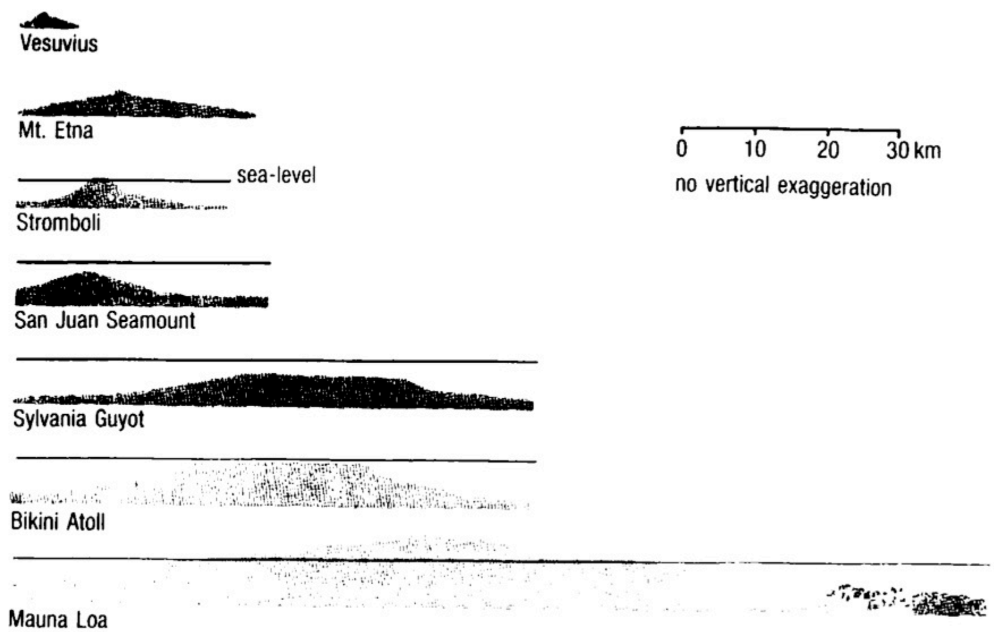
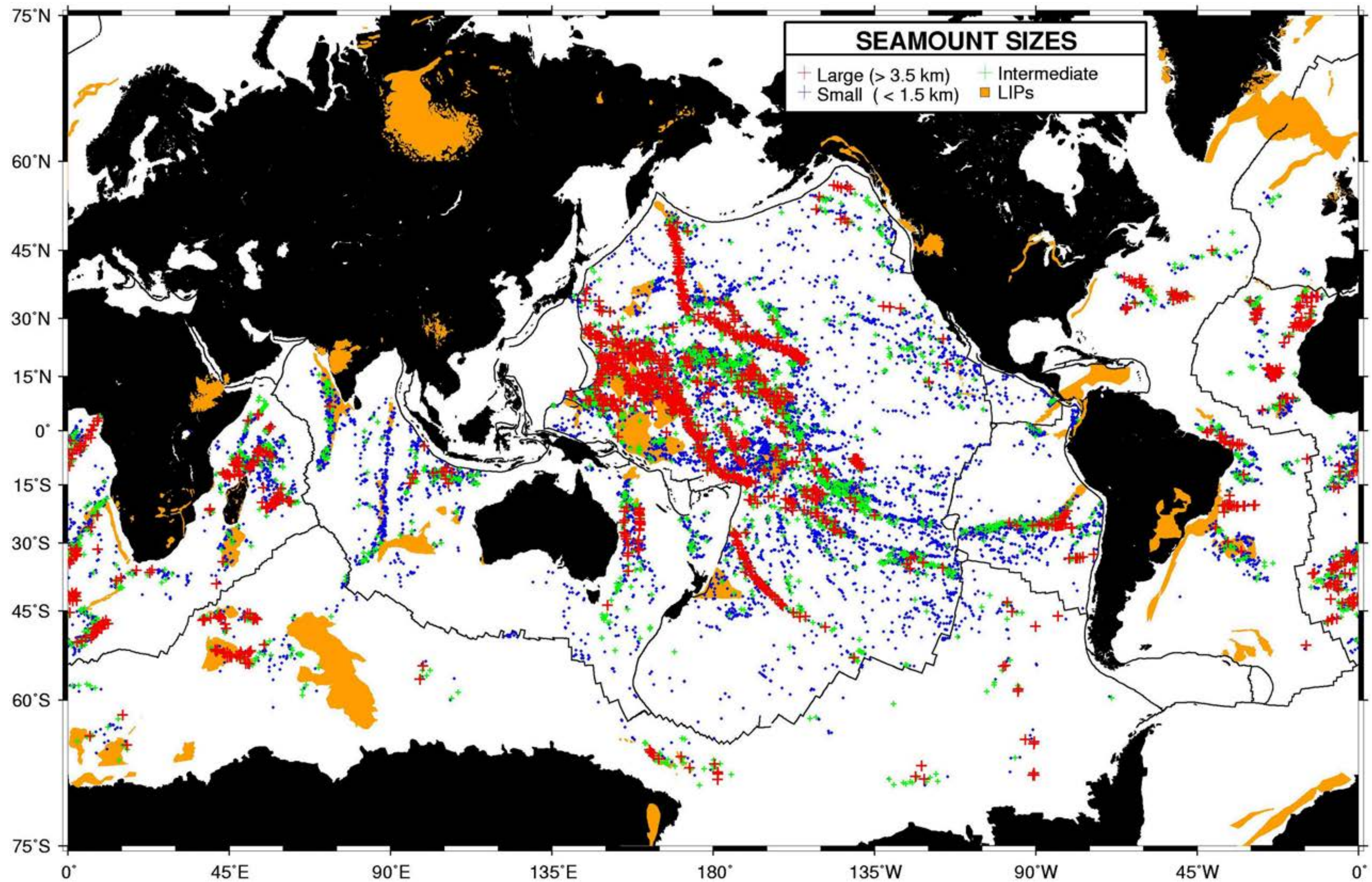


Figure 2.20 Topographic profiles across some on-land volcanoes and seamounts (including guyots).

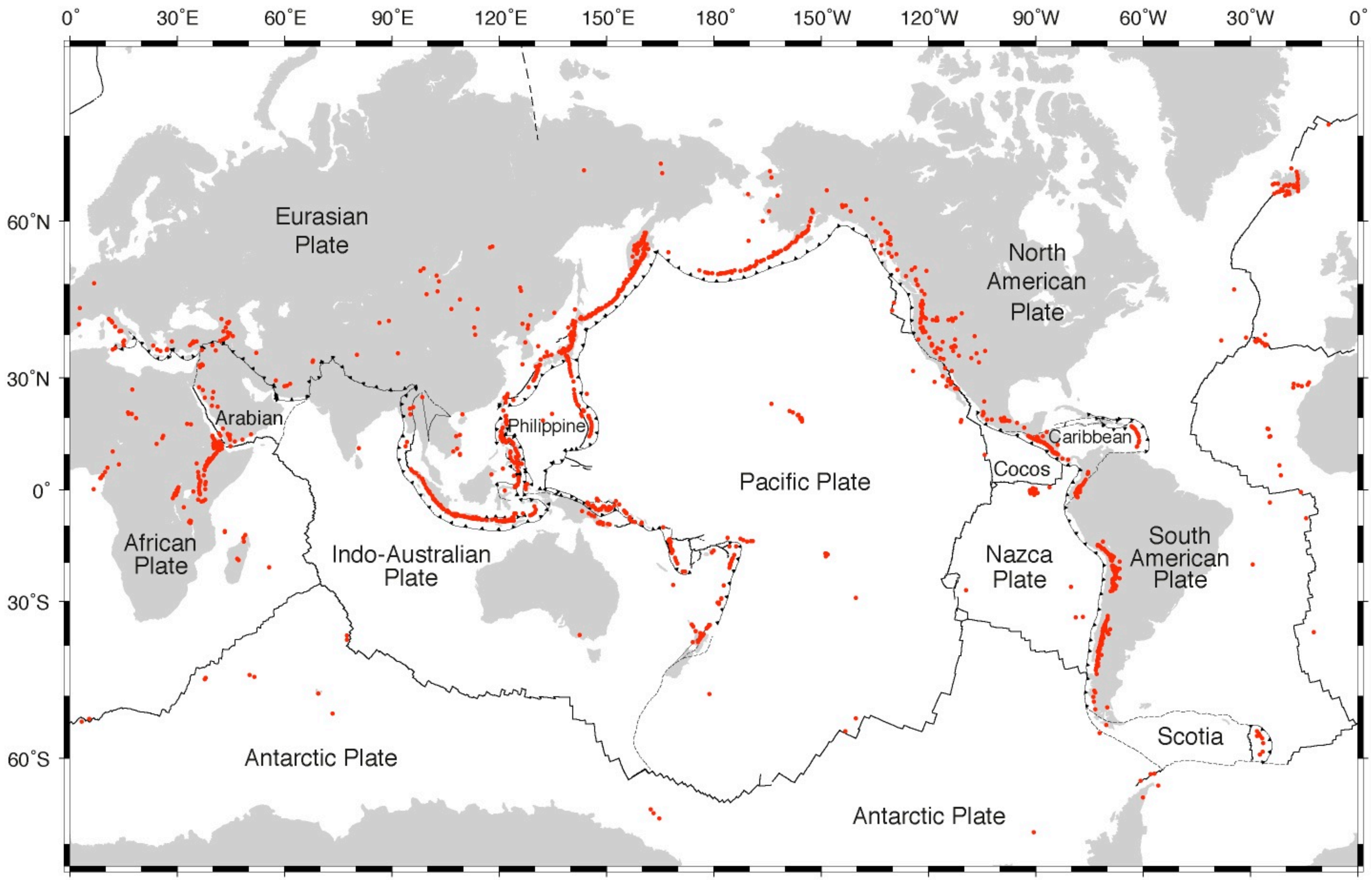
(The Ocean Basins, Open University)

global seamount distribution

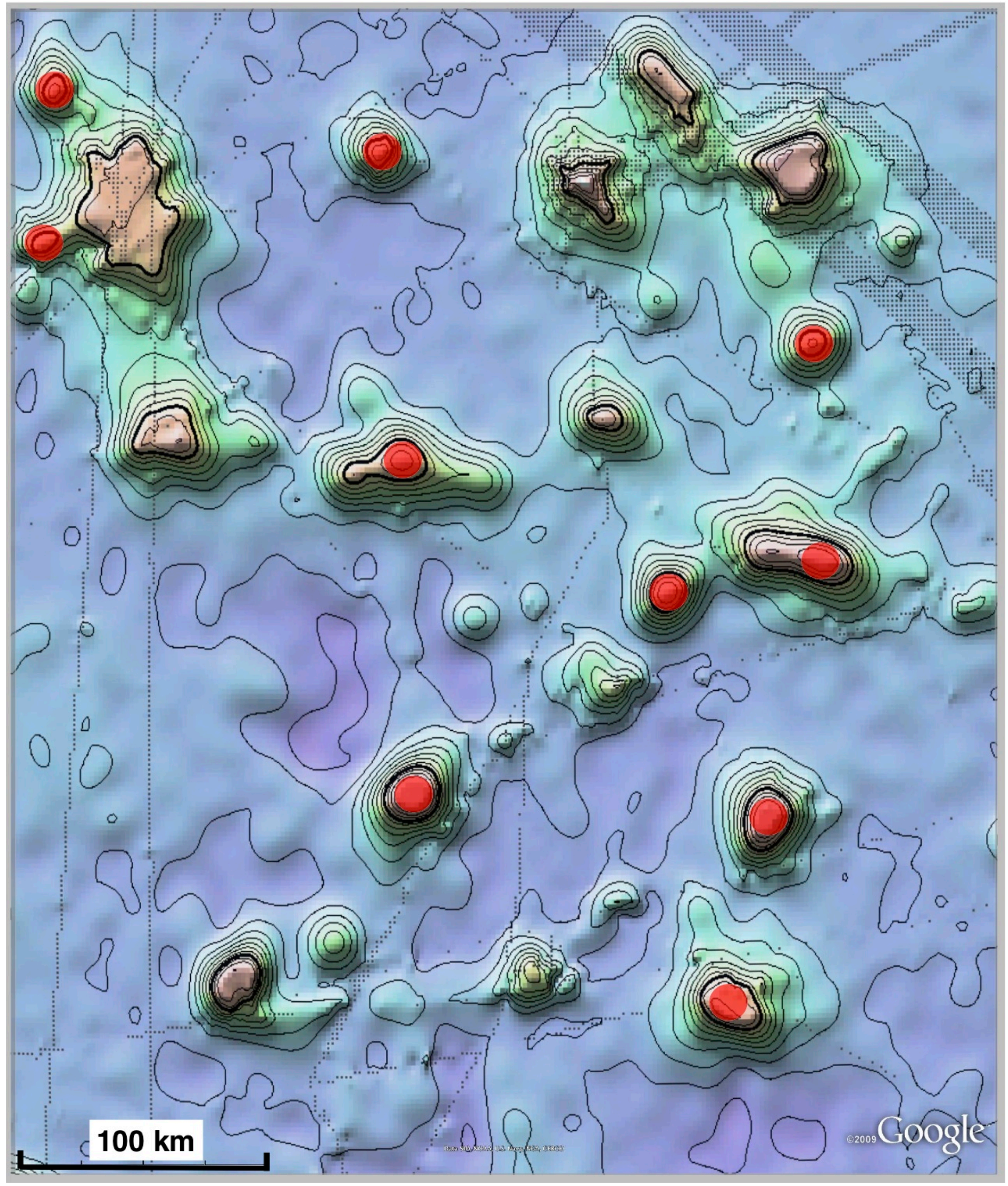


[Wessel JGR, 2001]

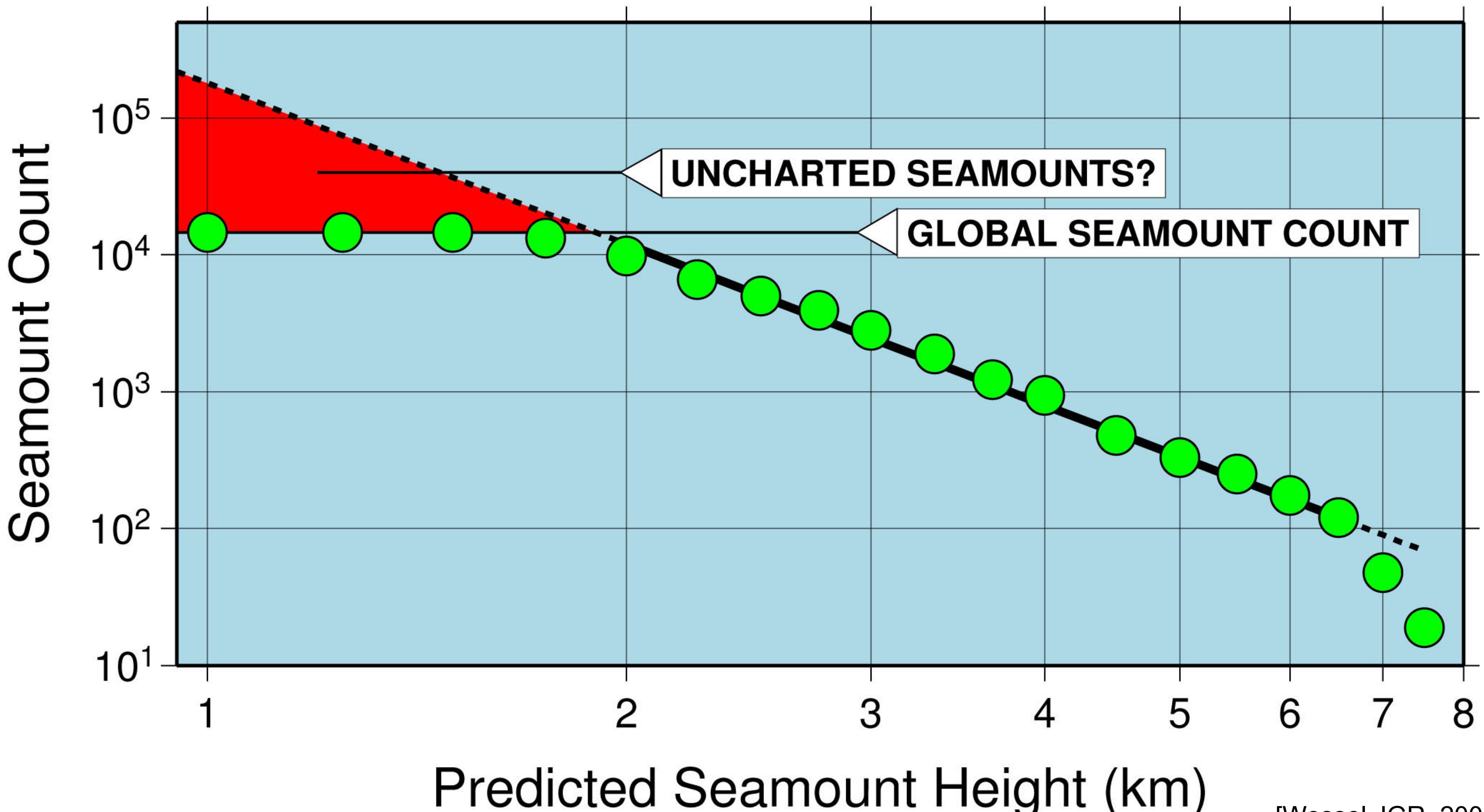
land volcanoes



uncharted seamounts > 3 km tall

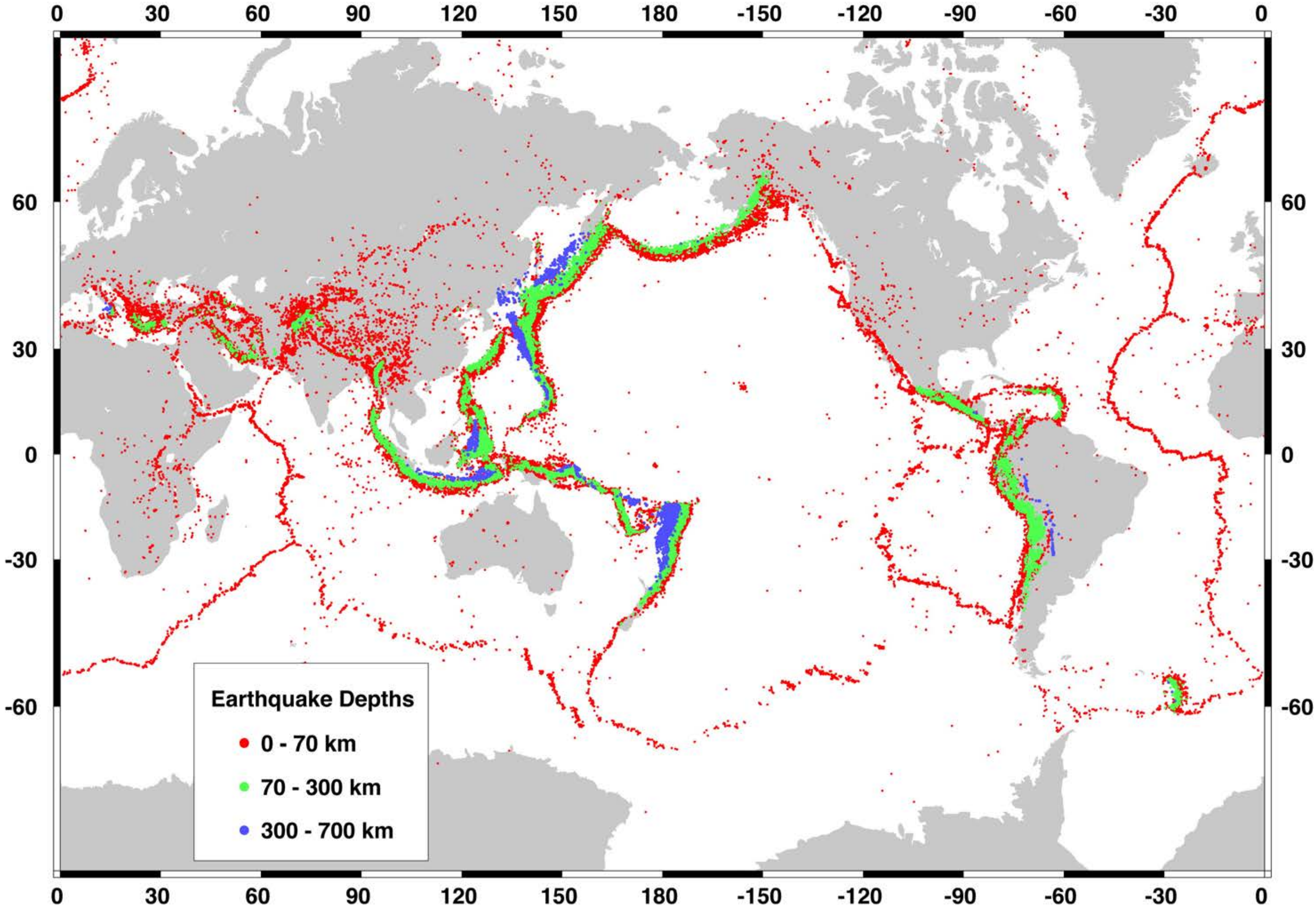


size distribution of seamounts



[Wessel JGR, 2001]

global seismicity



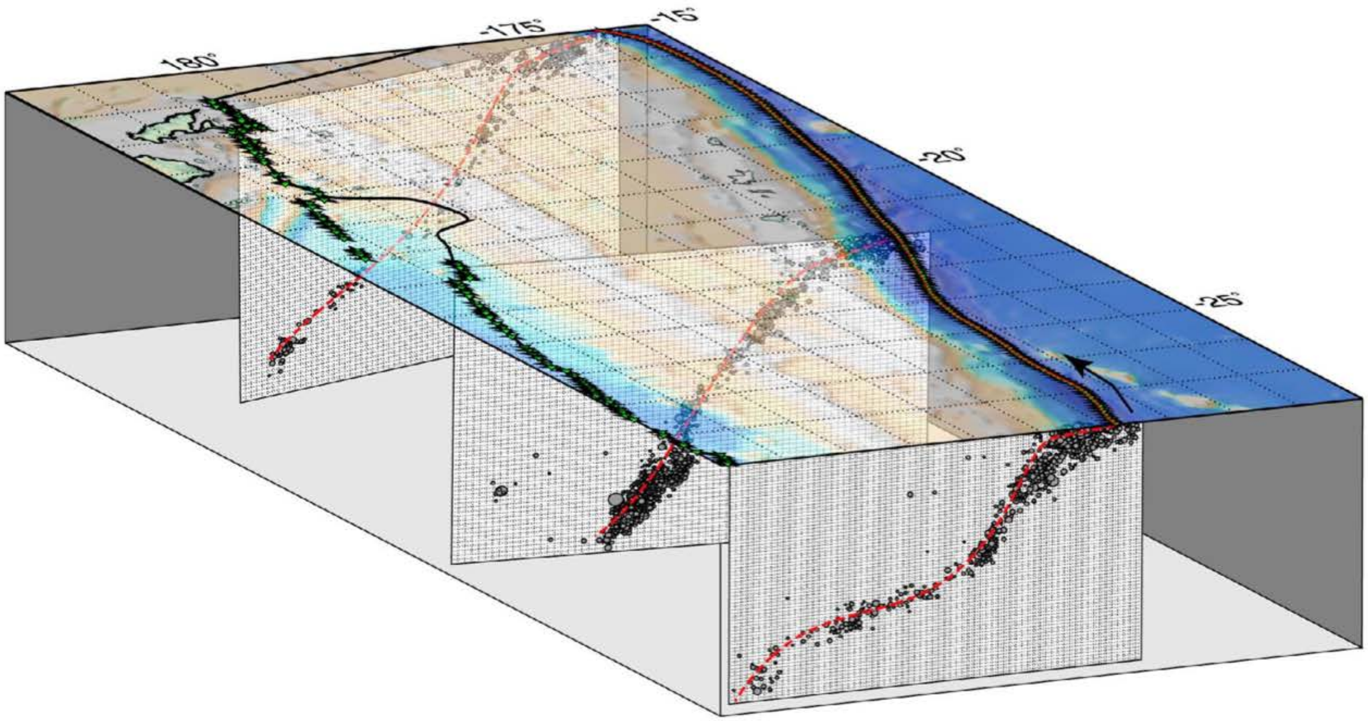
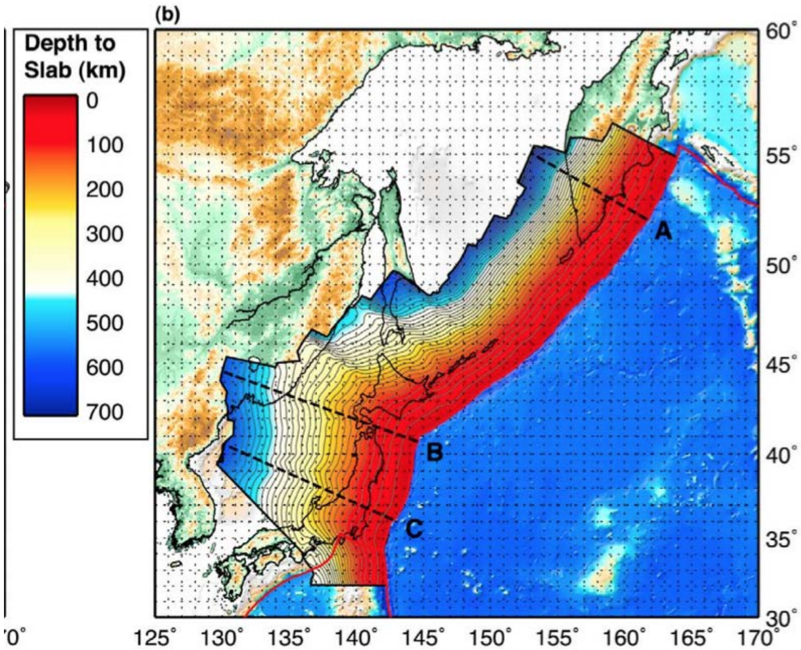
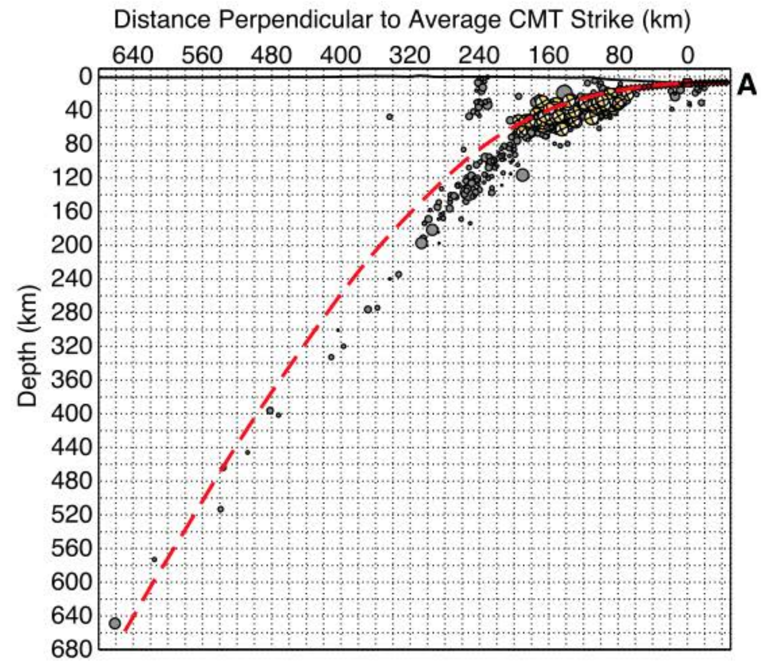
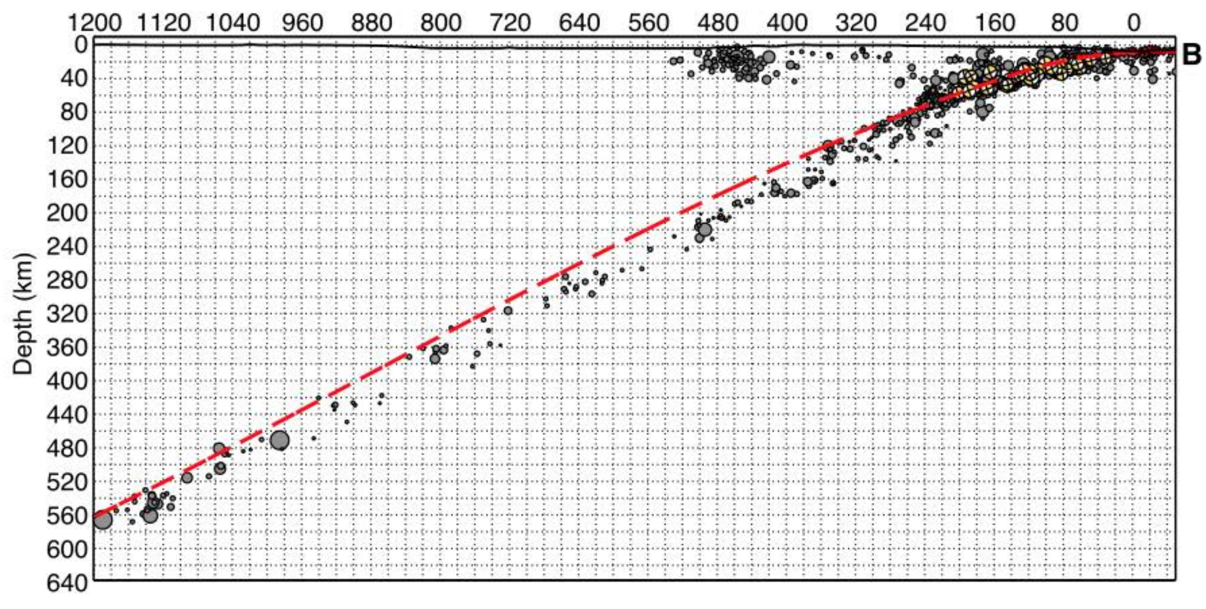


Figure 2. Schematic describing the construction of the Tonga-Kermadec slab three-dimensional geometry model from a collection of two-dimensional profiles. Green stars on the top surface represent the beginning and end of each two-dimensional profile, which extend beyond the seismicity sampled within each profile, and thus may extend beyond the slab interpreted from the profile itself. Profiles are taken every 10 km along the strike of the trench (red), in the direction of strike (black arrow). Three representative 2D profiles are shown; red dashed lines are the best fitting 2D non-planar geometries overlain on background seismicity from the EHB catalog (gray circles) within 100 km of each plane.

[Hayes et al., JGR 2012]

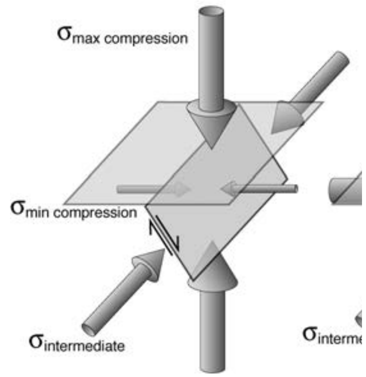

(b)
Depth to Slab (km)
0
100
200
300
400
500
600
700
A
B
C
60˚
55˚
50˚
45˚
40˚
35˚
30˚
125˚ 130˚ 135˚ 140˚ 145˚ 150˚ 155˚ 160˚ 165˚ 170˚

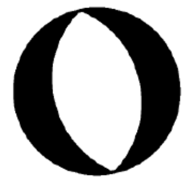

Distance Perpendicular to Average CMT Strike (km)
640 560 480 400 320 240 160 80 0
A
Depth (km)
0 40 80 120 160 200 240 280 320 360 400 440 480 520 560 600 640 680


1200 1120 1040 960 880 800 720 640 560 480 400 320 240 160 80 0
B
Depth (km)
0 40 80 120 160 200 240 280 320 360 400 440 480 520 560 600 640

stress and focal mechanisms

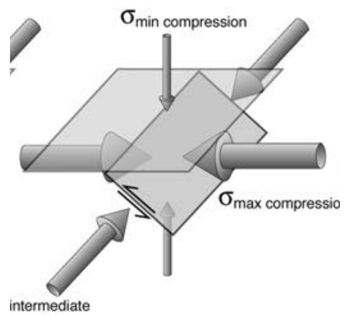
topo
high

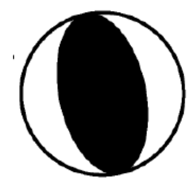




normal fault

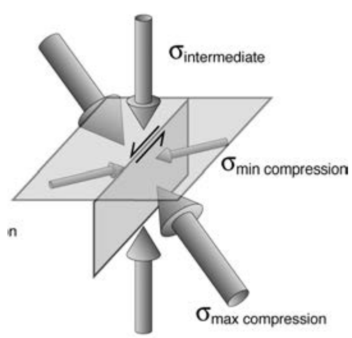
topo
low

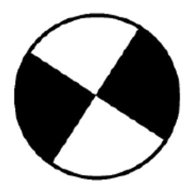




reverse fault

topo
flat



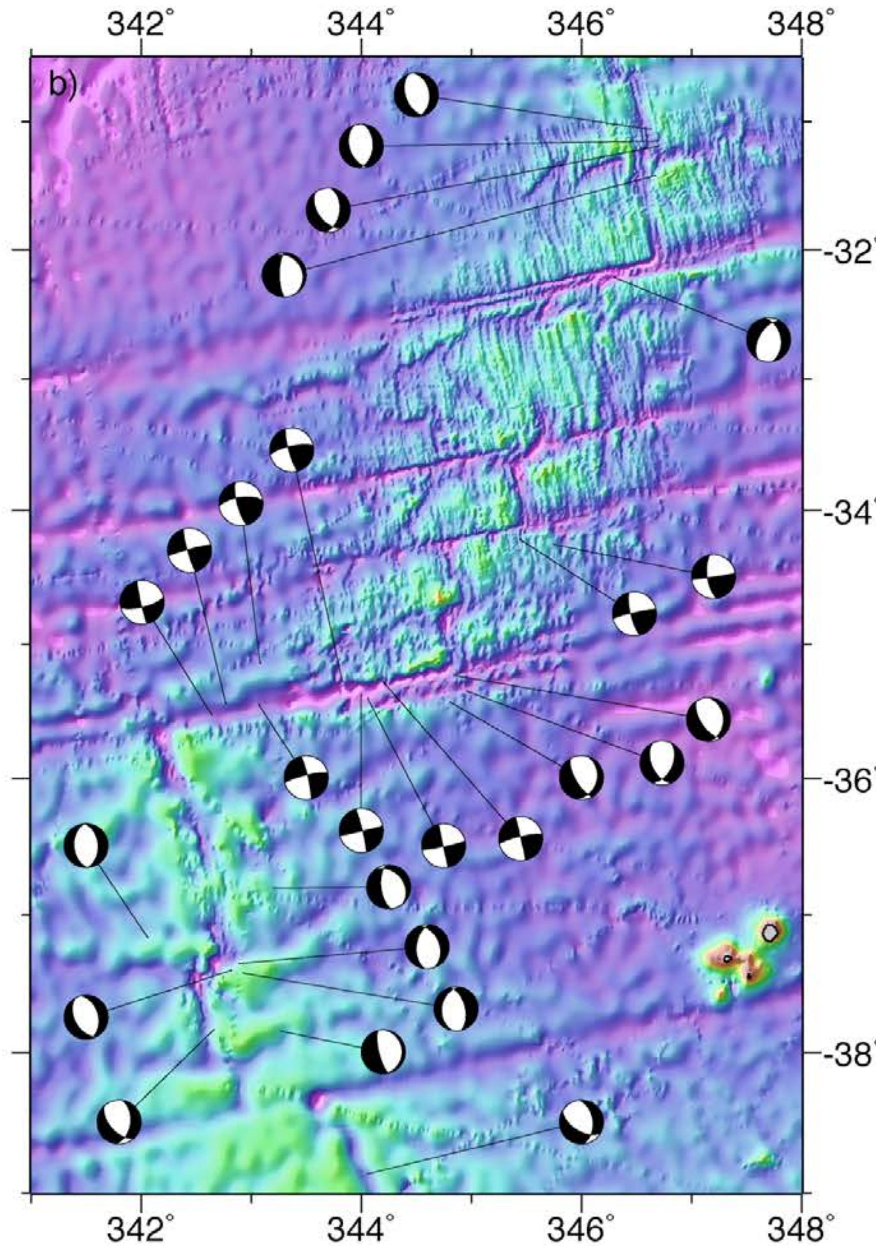


strike-slip
fault

[Luttrell and Sandwell, submitted to JGR, 2011]

global mid-ocean ridge

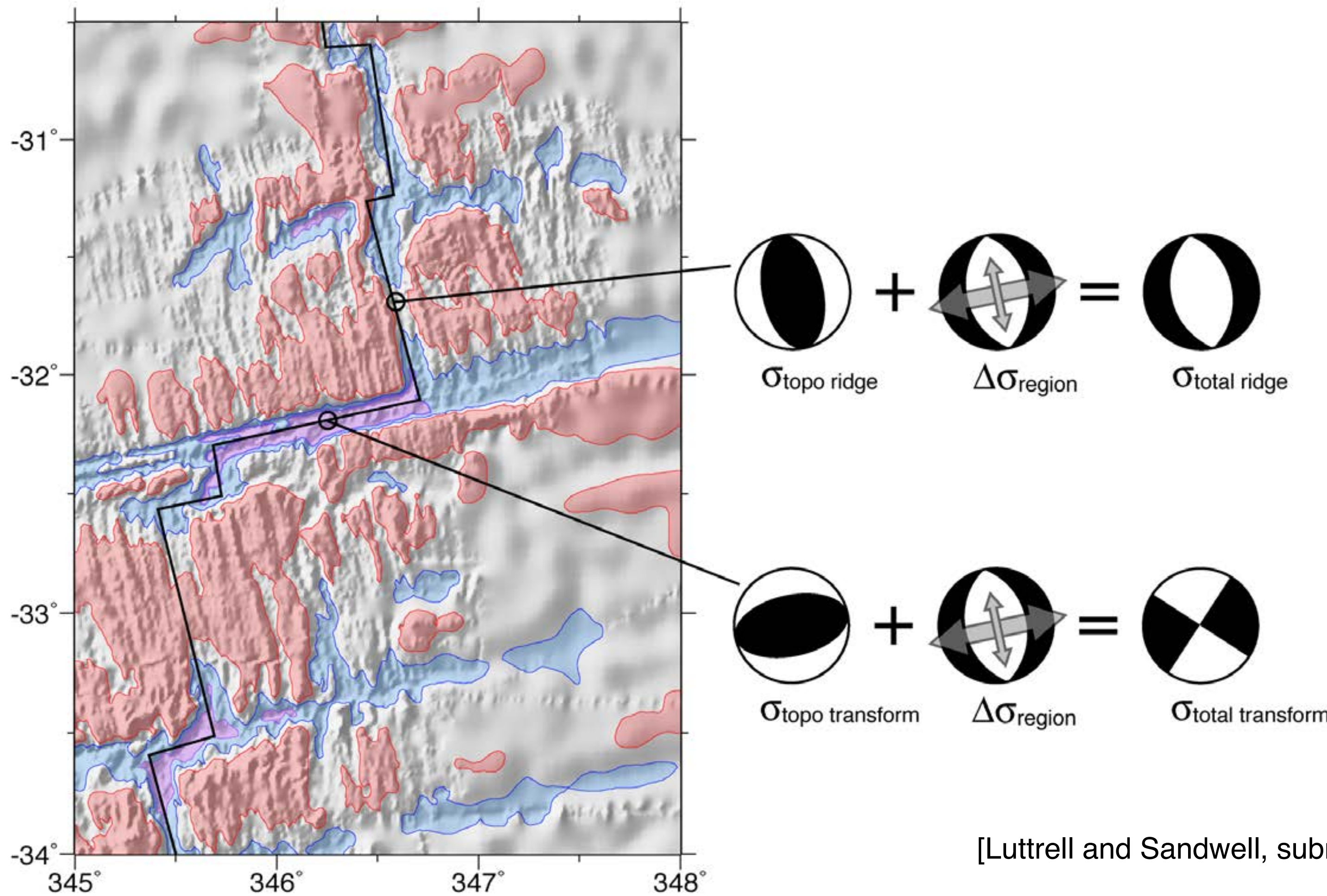
- alternating spreading ridge and transform offset segments
- ridge earthquakes have normal focal mechanism
- transform earthquakes have strike-slip focal mechanism



[Luttrell and Sandwell, submitted to JGR, 2011]

constrain the magnitude of the regional tectonic stress

- calculate topographic stress for wavelength < 350 km
- add to this a regional horizontal stress field
- adjust 3 components of regional stress to match style of faulting

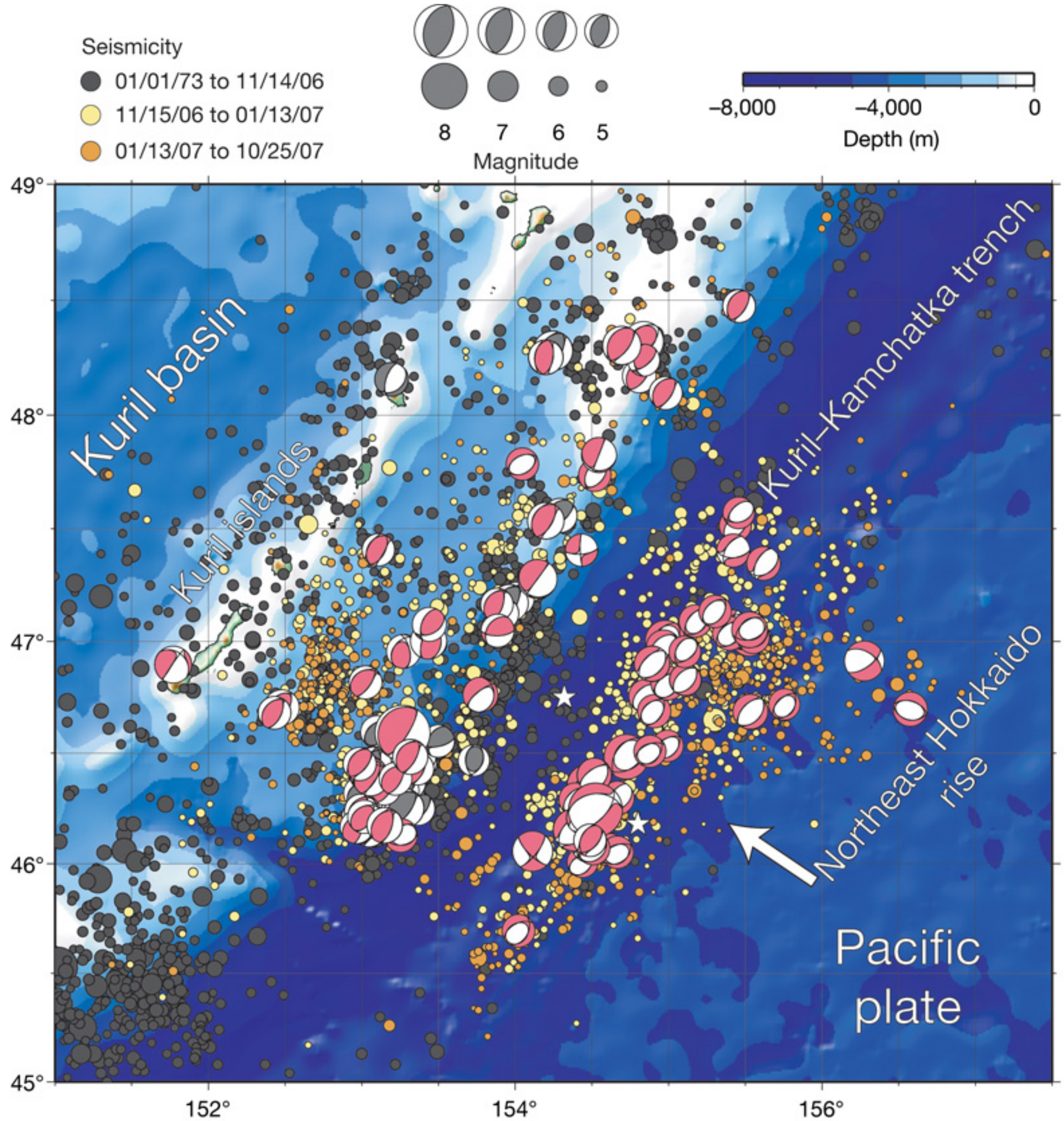


[Luttrell and Sandwell, submitted to JGR, 2011]

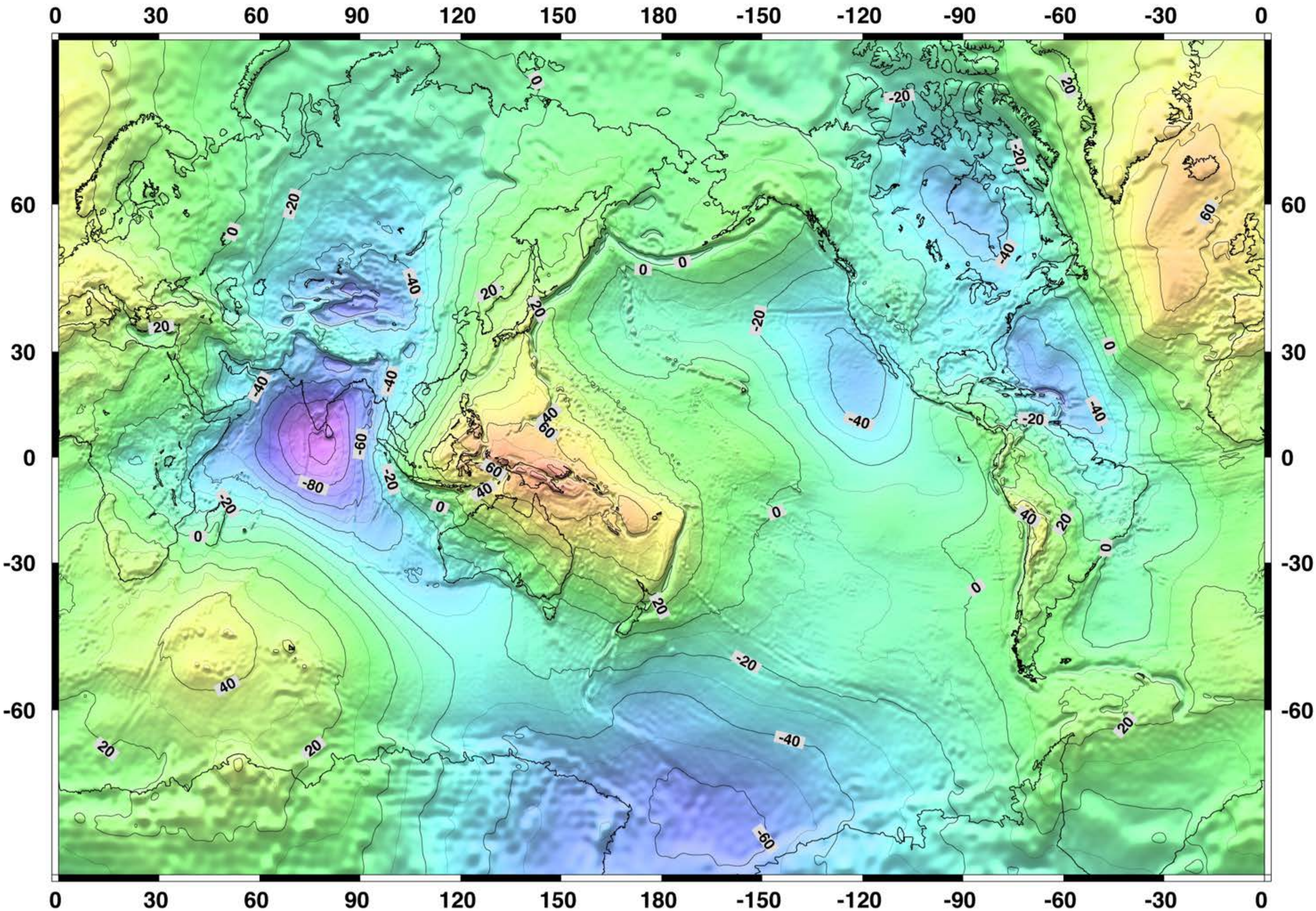
Kurile Subduction Zone

[Ammon, Kanamori & Lay *Nature* 2008)]

Why are there both thrust and normal fault mechanisms at a subduction zone?

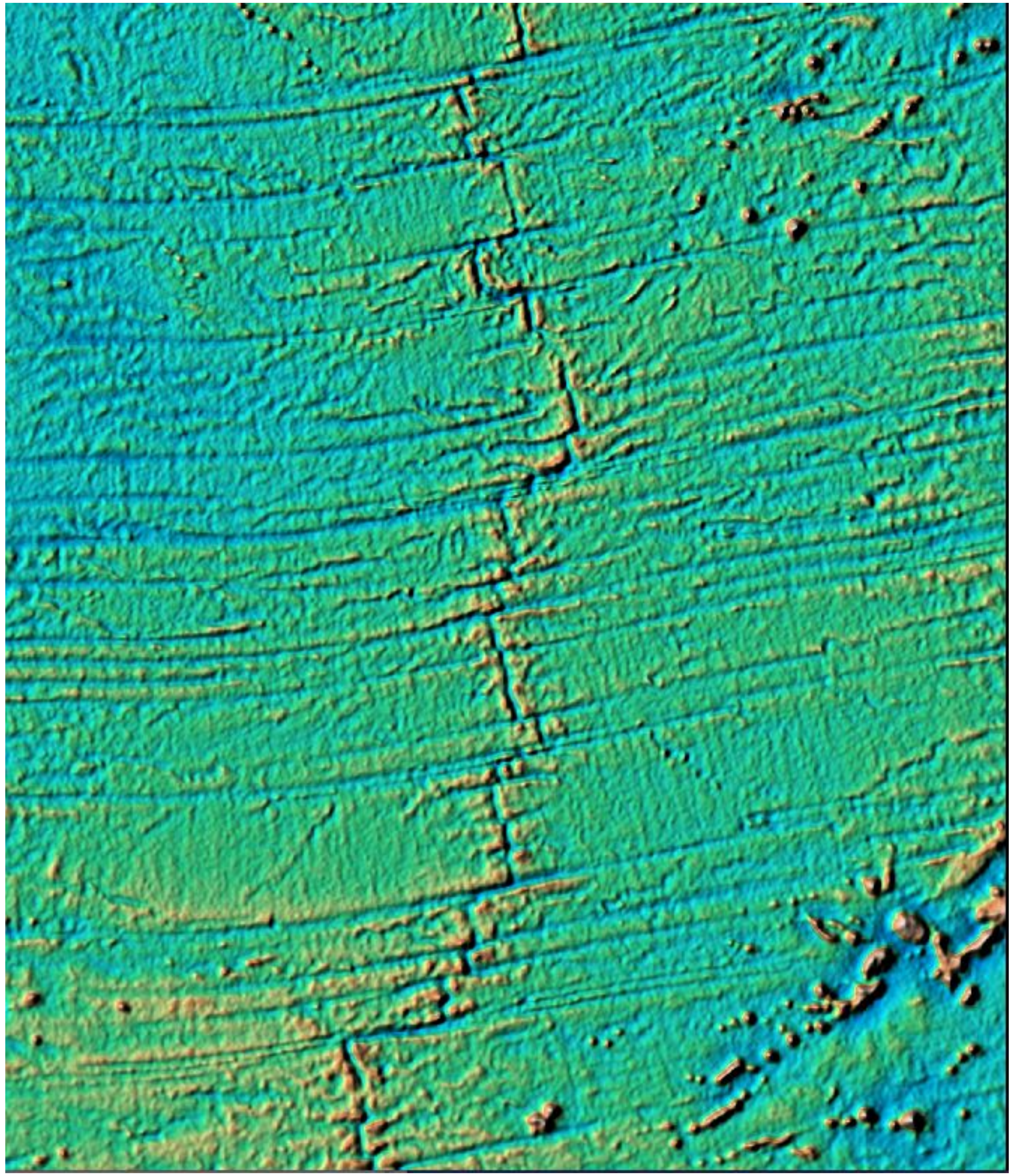


geoid height



ridges and transforms

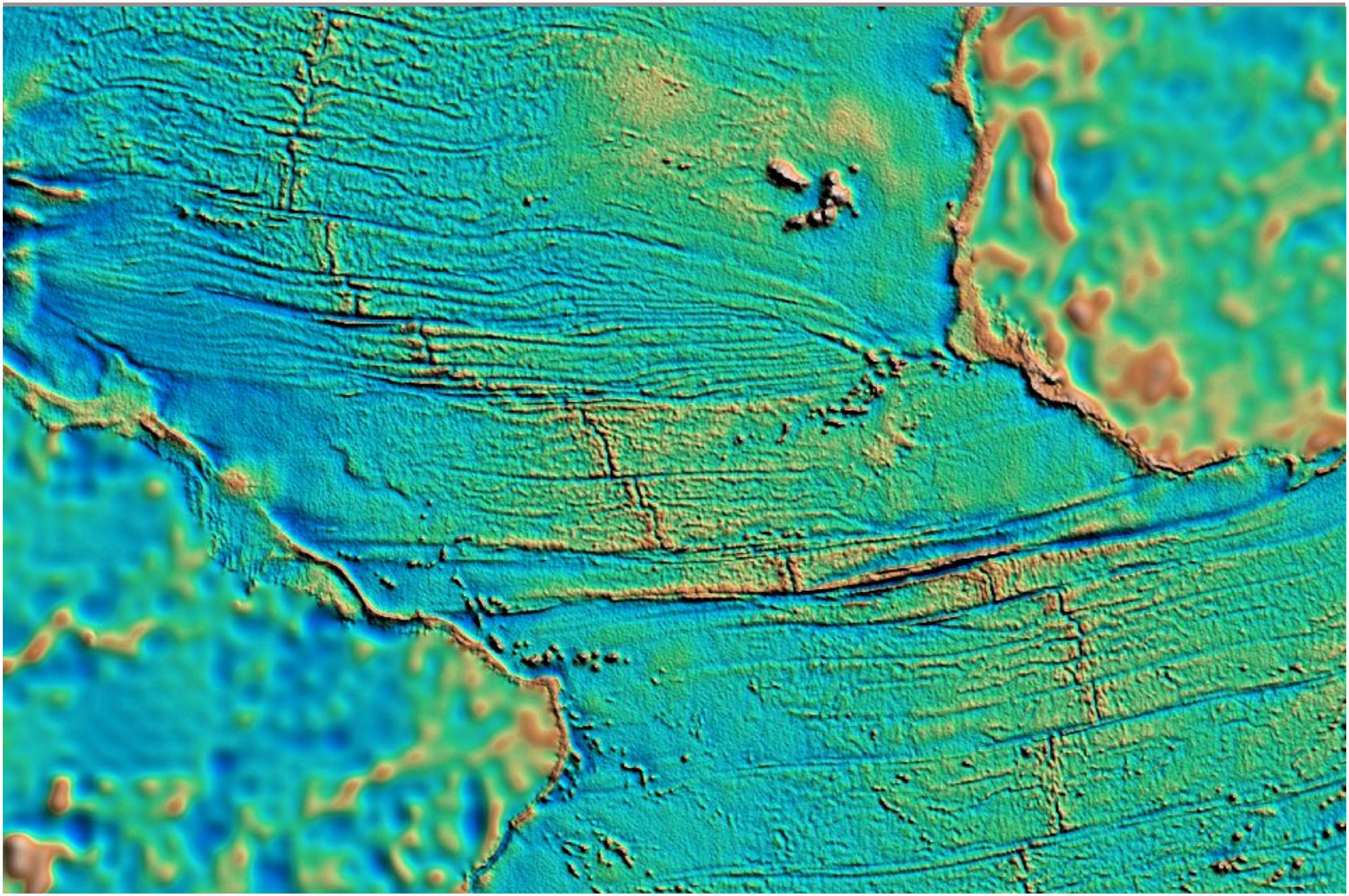
500 km



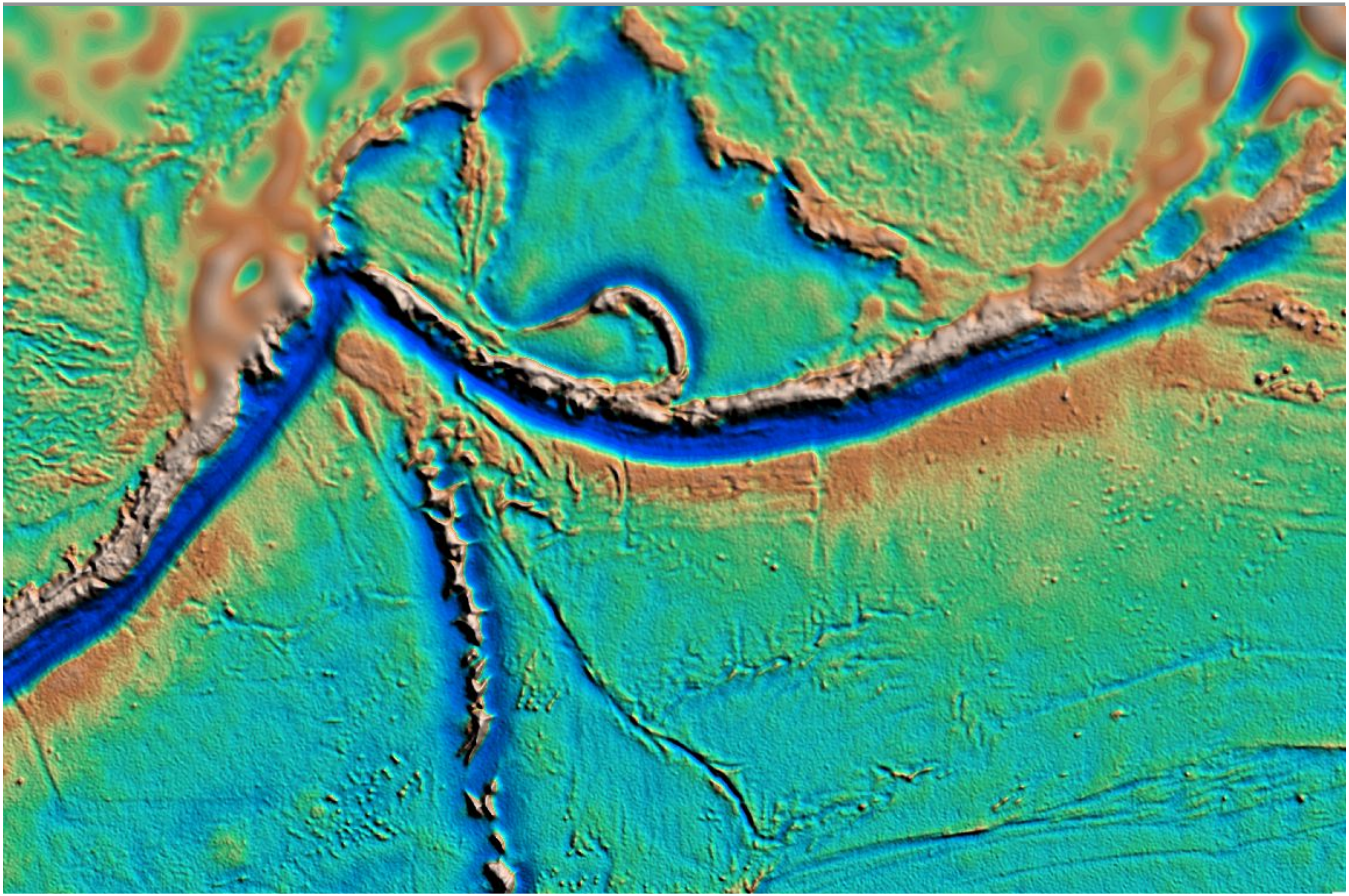
gravity from
satellite altimetry

Google Earth version at http://topex.ucsd.edu

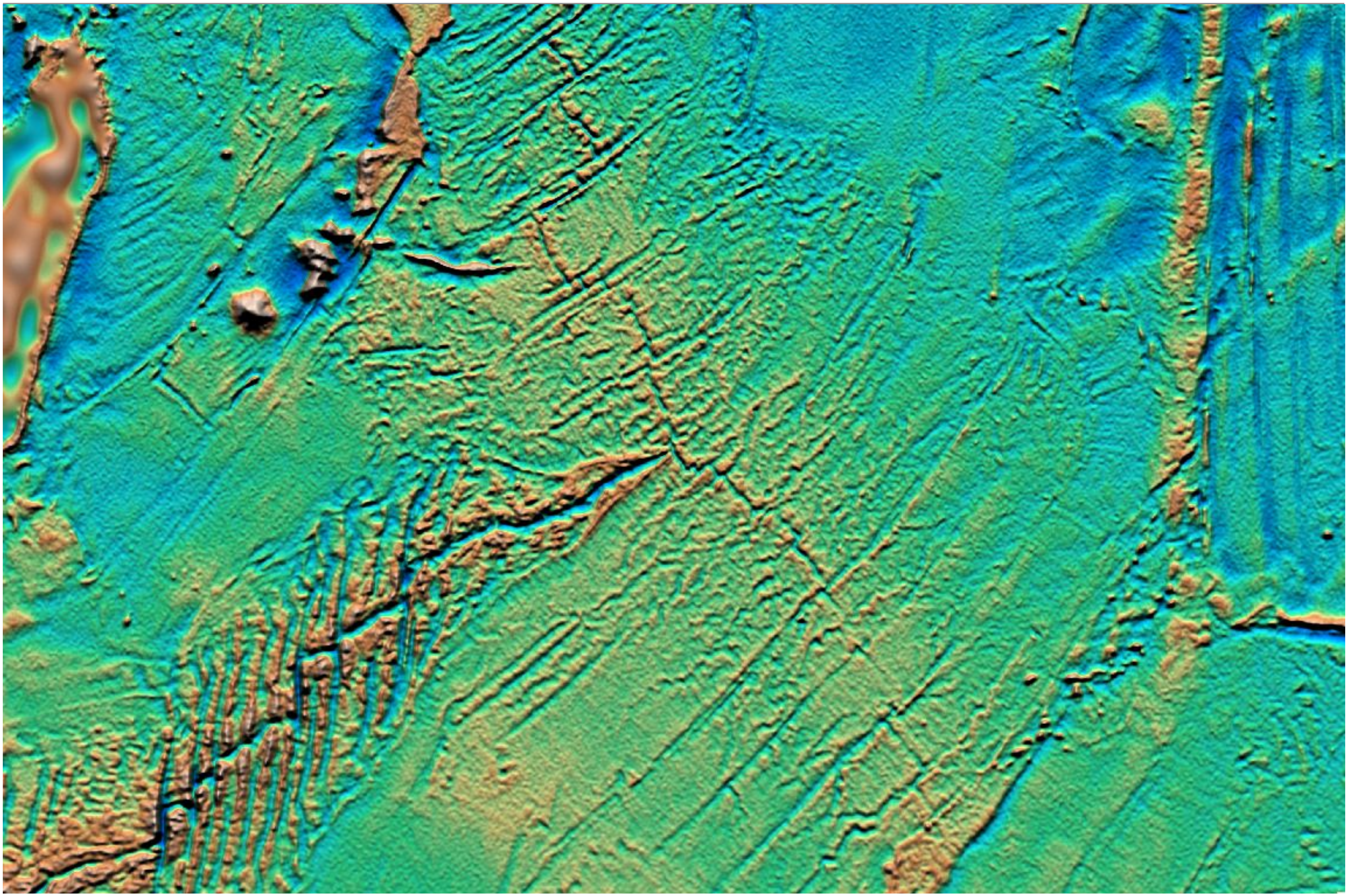
fracture zones



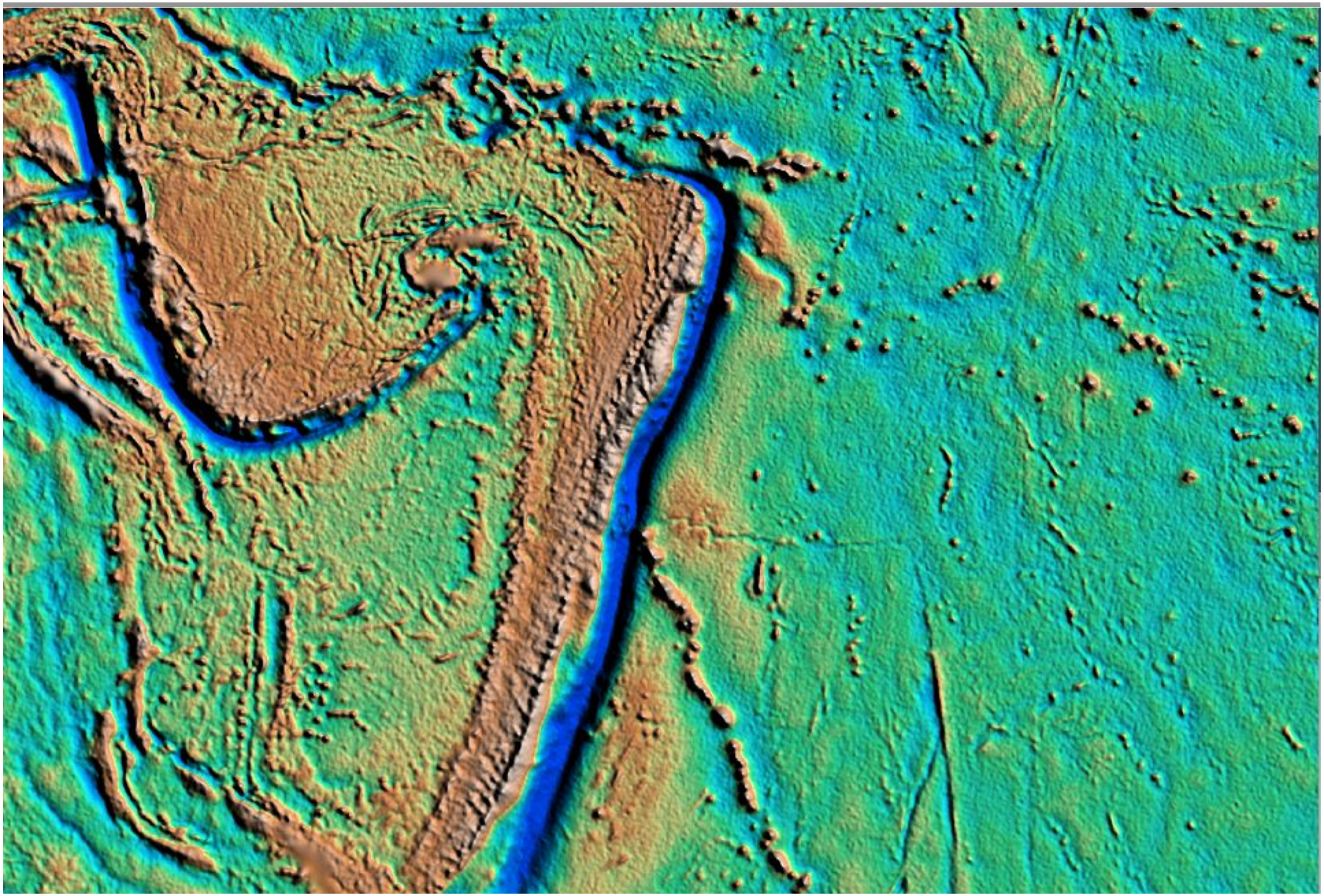
subduction zones



triple junction



back-arc spreading



magnetic reversals

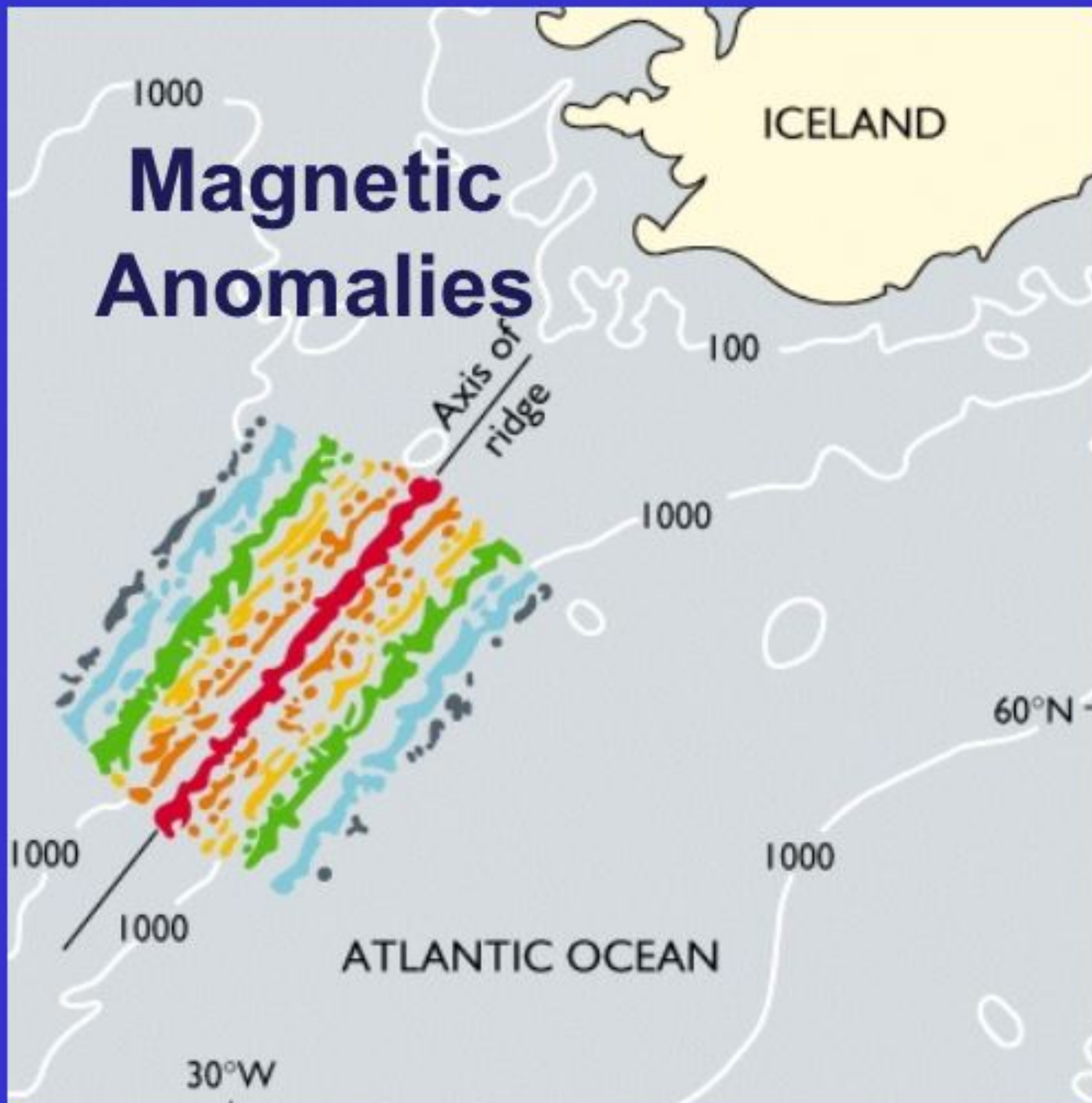


Fig. 20.9

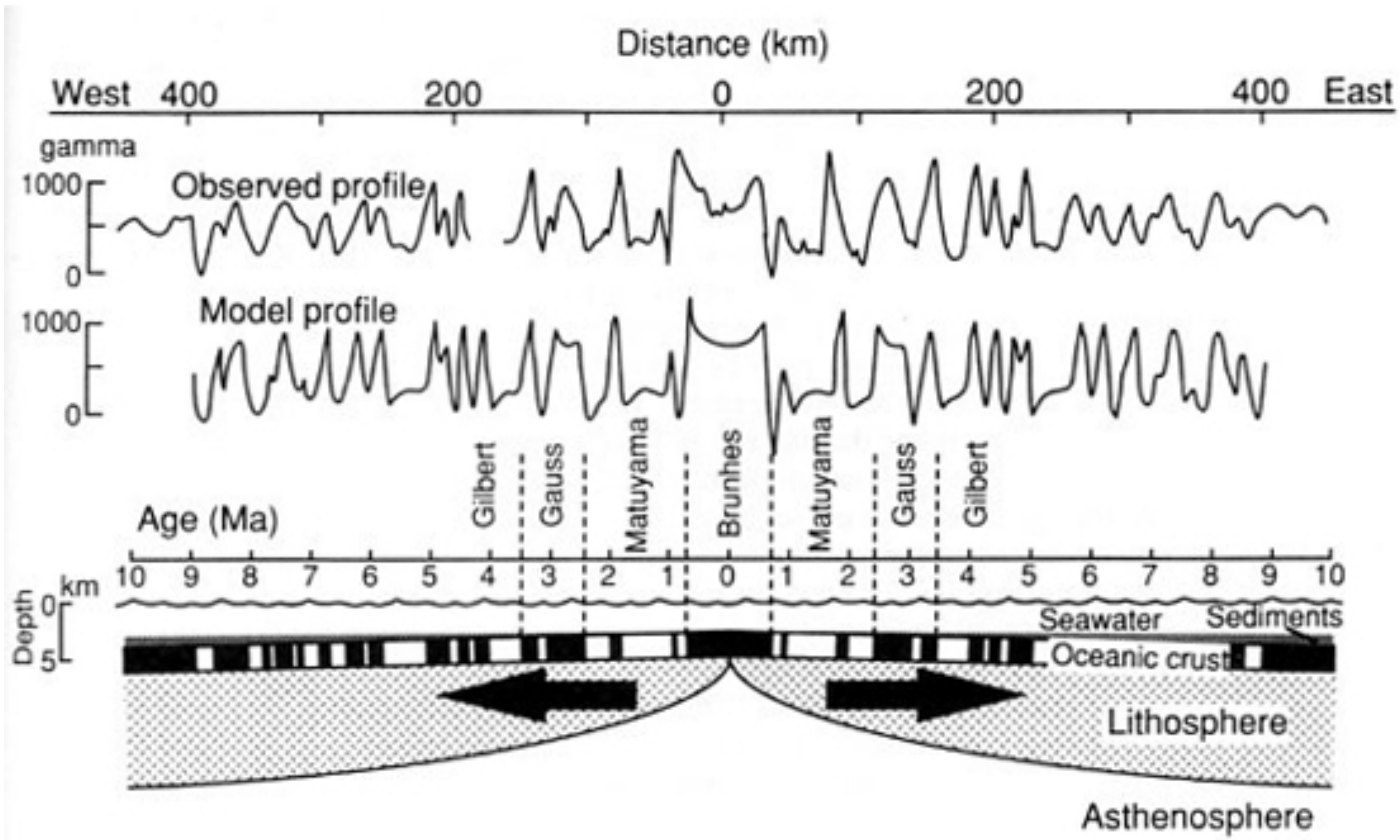
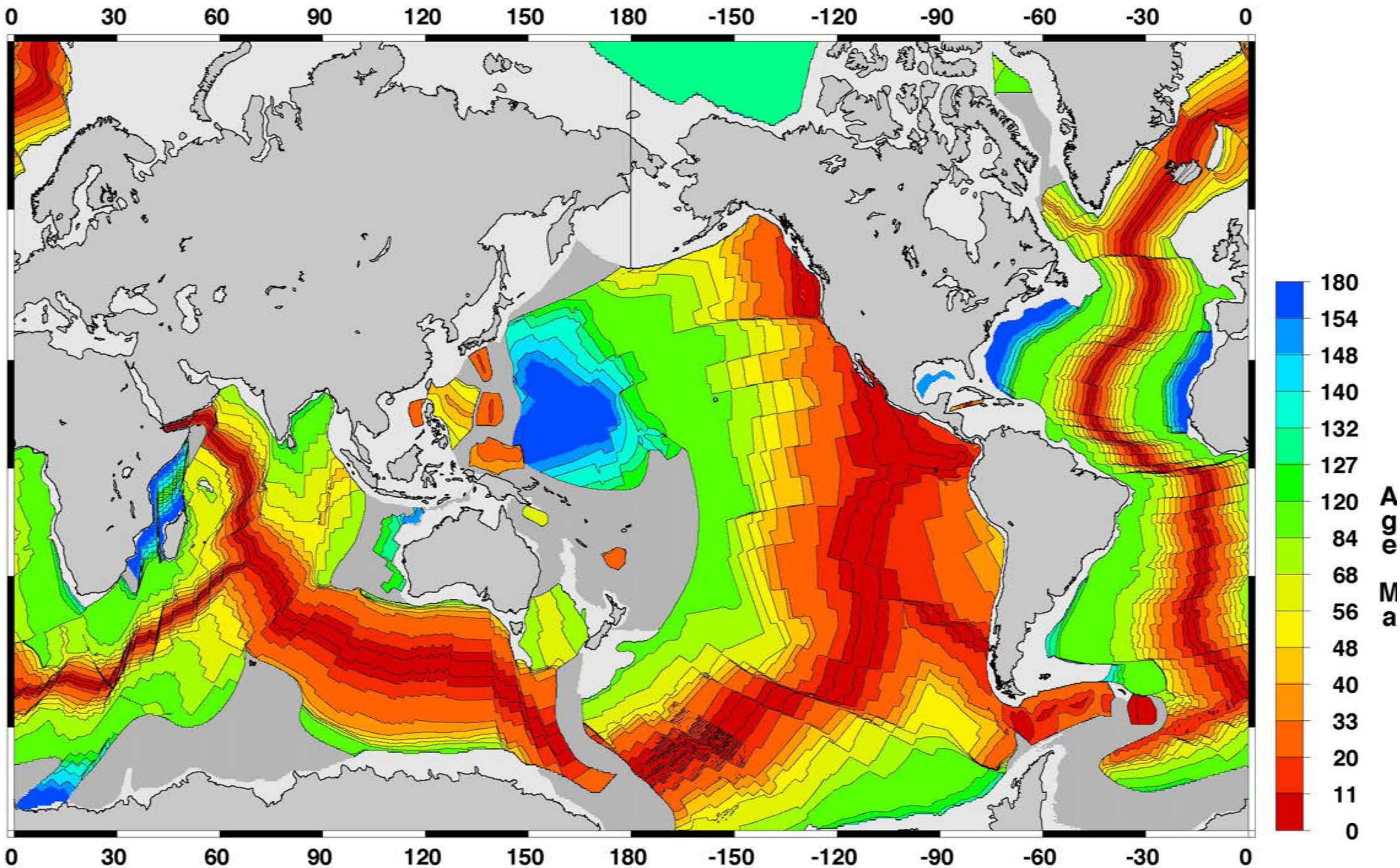
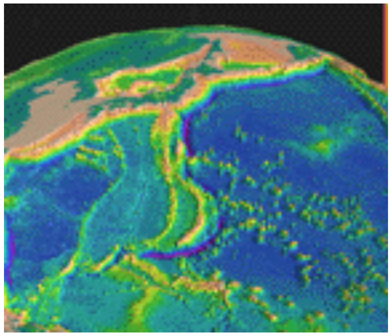


figure: modified from Pitman and Heirtzler, 1966. Science, 154, 1164-1171

FZ direction + magnetic anomalies = seafloor age

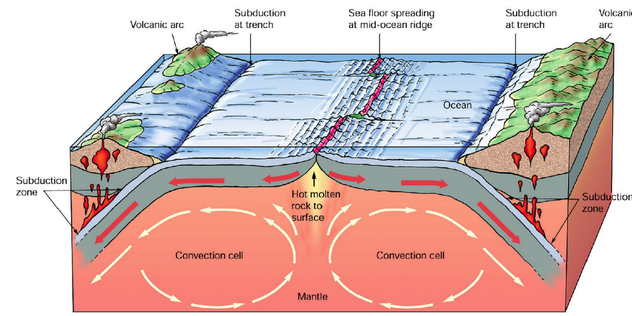
[*Mueller et al.,* 1997]





Observations Related Plate Tectonics

David T. Sandwell
Scripps Inst. Of Oceanography



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- Ocean and continent topography, hypsometry, and crustal thickness.
- Global seismicity, Benioff zones, and focal mechanisms
- Global volcanic activity
- Geoid Height and gravity anomaly
- Marine magnetic anomalies

Next class:

- triple junction closure
- plate motions on a sphere