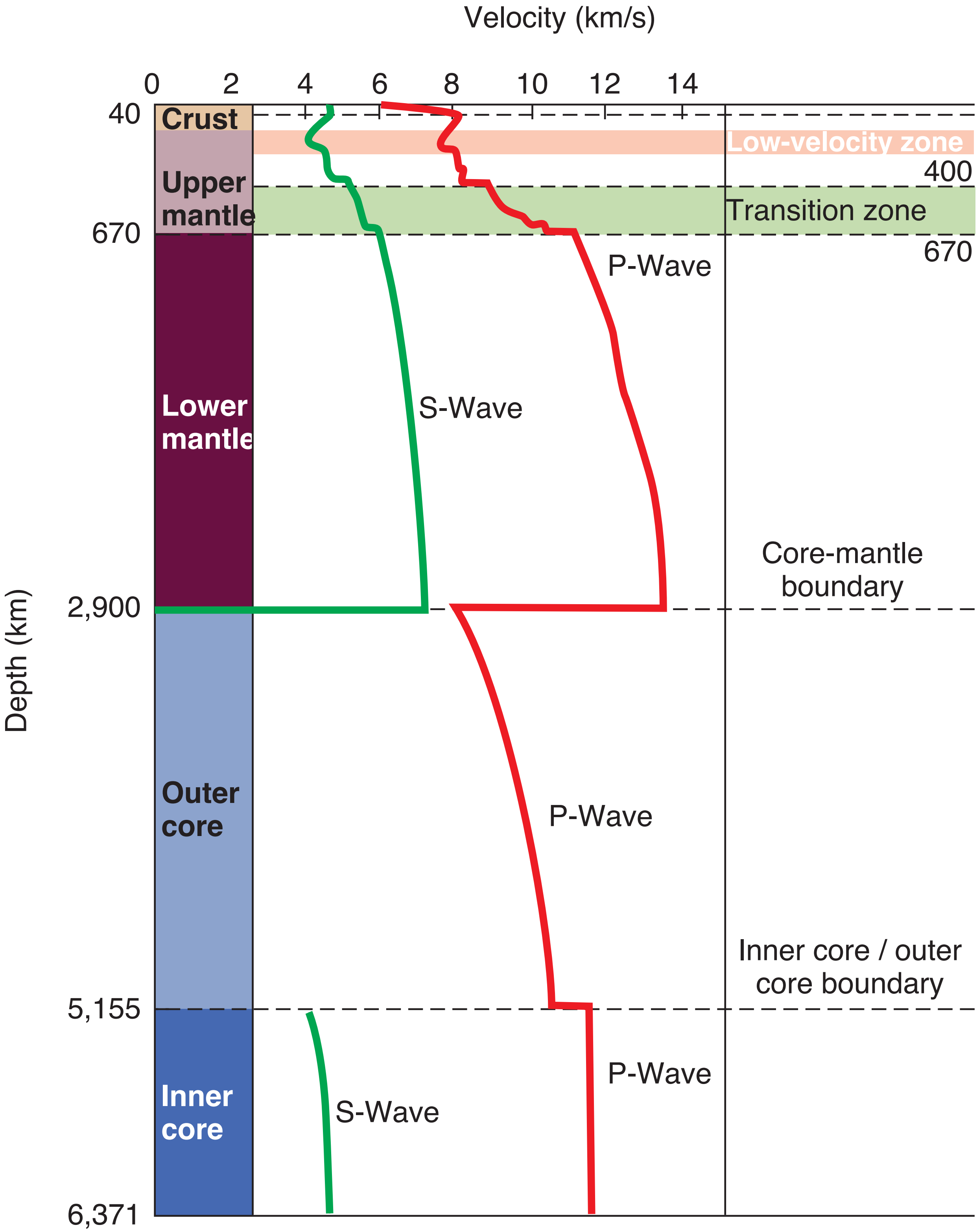
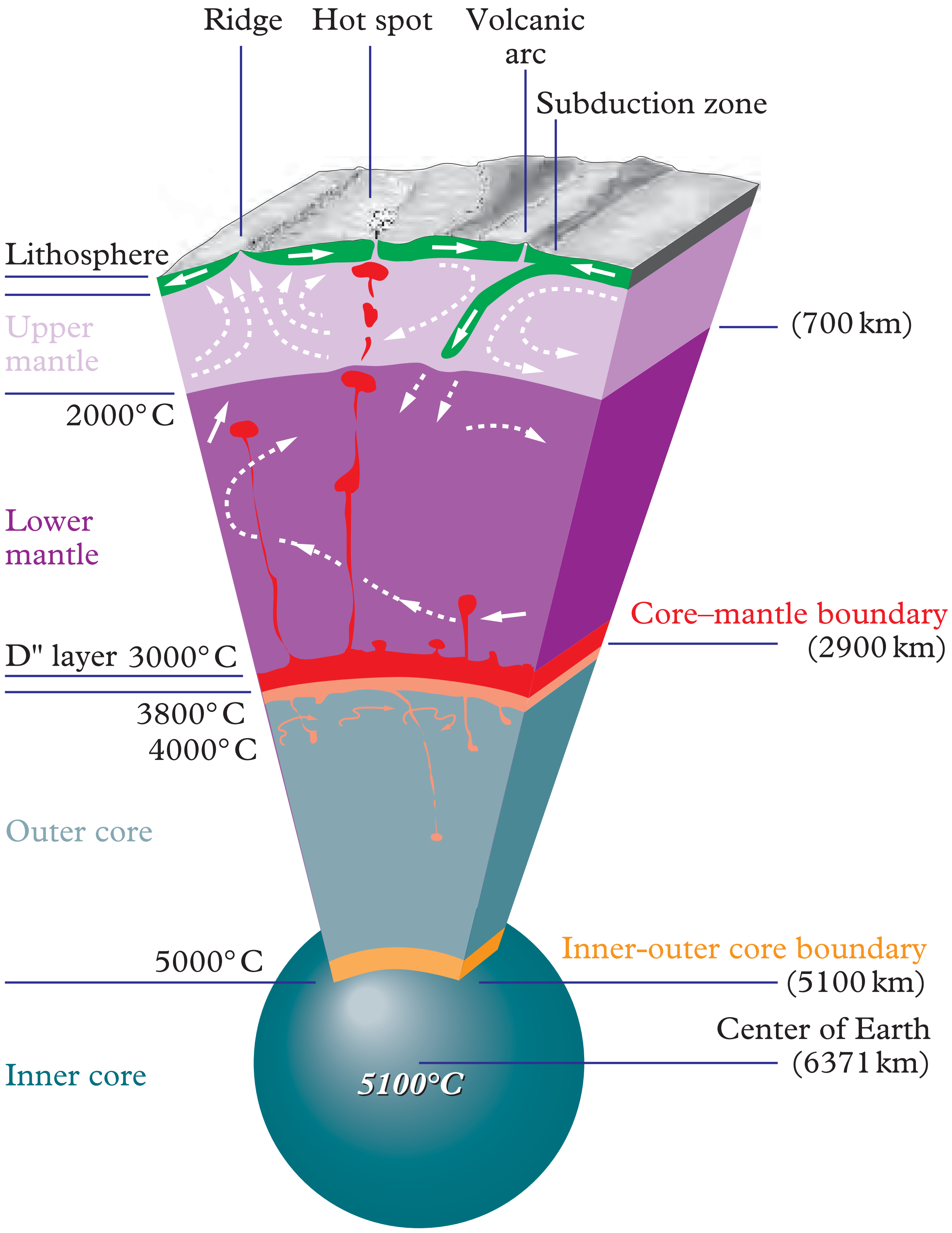
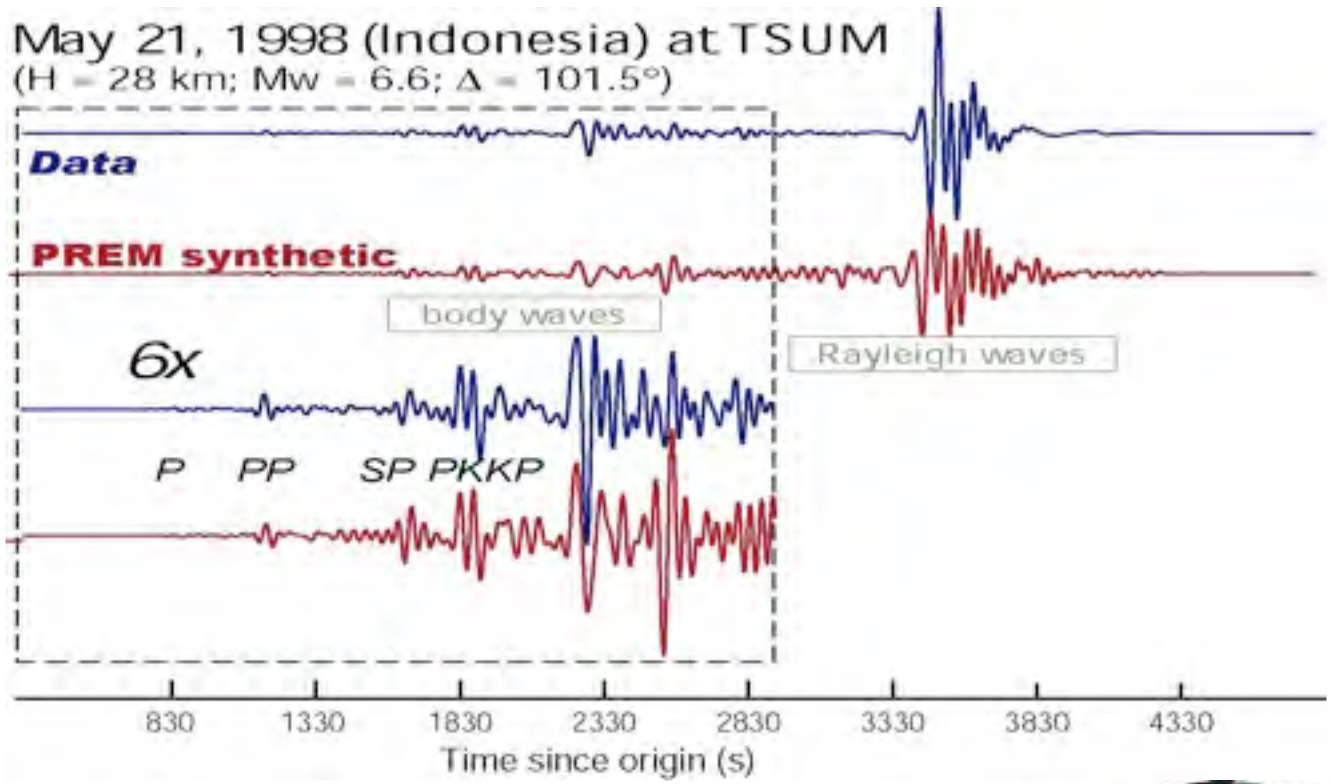
07- Tomographie des Mantels
Kontinentale Rift-Zonen

PREM model


Velocity (km/s)
0
2
4
6
8
10
12
14
Depth (km)
40
670
2,900
5,155
6,371
Crust
Upper mantle
Lower mantle
Outer core
Inner core
Low-velocity zone
400
Transition zone
670
P-Wave
S-Wave
Core-mantle boundary
P-Wave
Inner core / outer core boundary
P-Wave
S-Wave

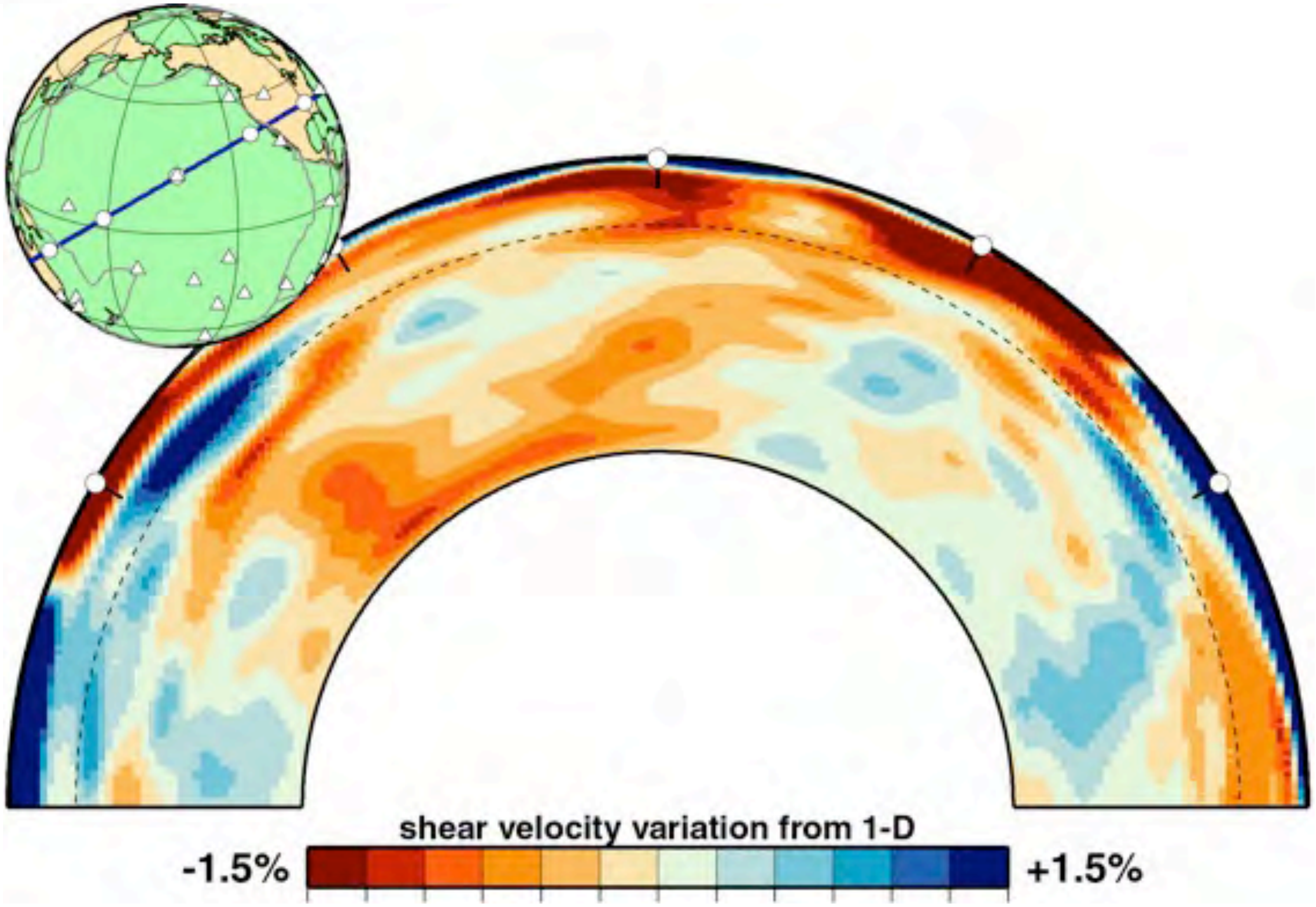

Ridge
Hot spot
Volcanic arc
Subduction zone
Lithosphere
Upper mantle
(700 km)
2000° C
Lower mantle
Core–mantle boundary
(2900 km)
D" layer 3000° C
3800° C
4000° C
Outer core
5000° C
Inner-outer core boundary
(5100 km)
Center of Earth
(6371 km)
Inner core
5100°C

Seismic tomography

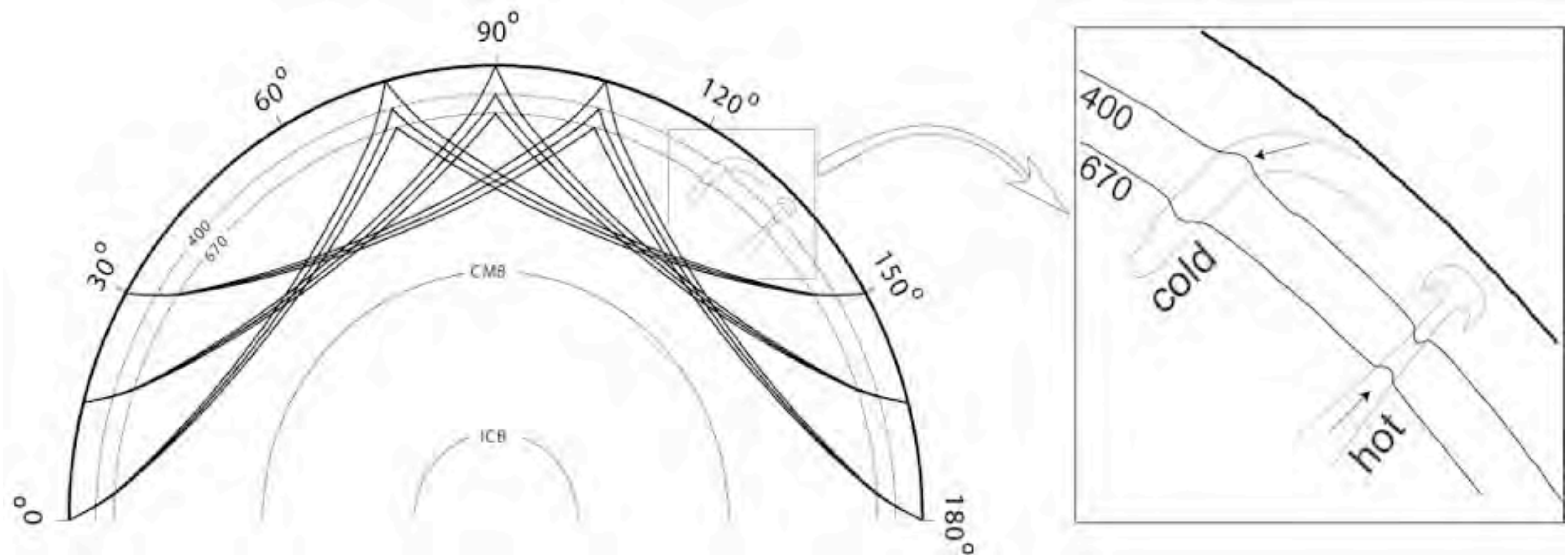


ANALYSIS OF WAVEFORM ANOMALIES

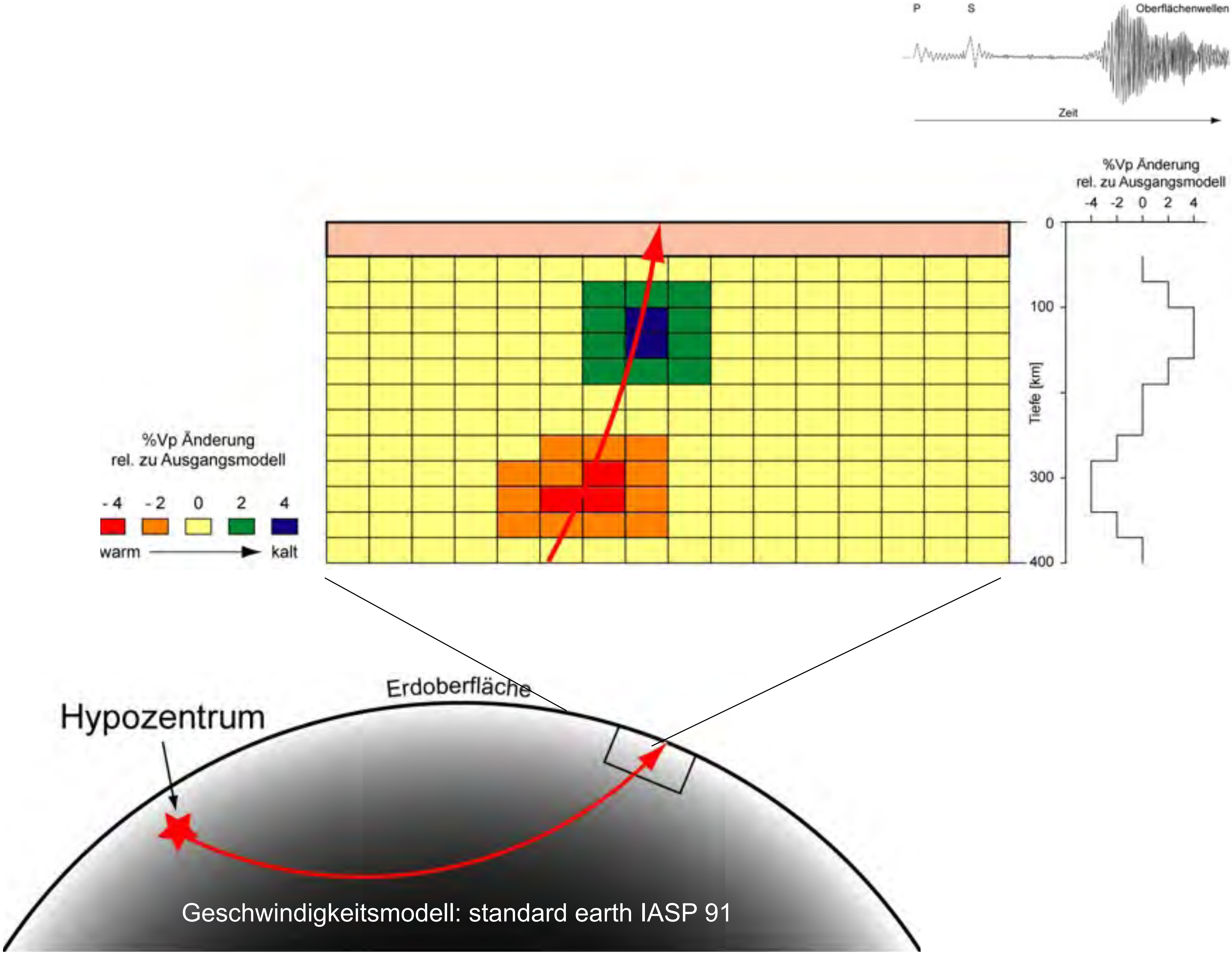
SEISMIC IMAGE



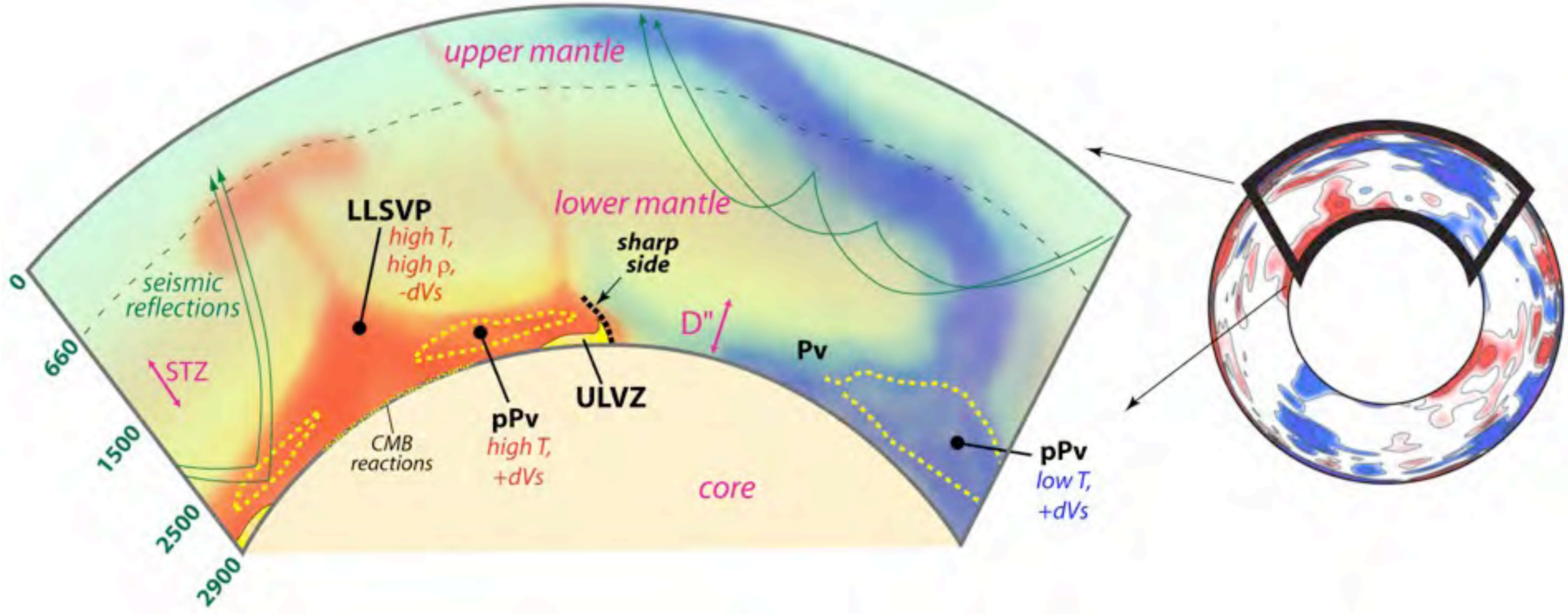
Imaging upper mantle discontinuities



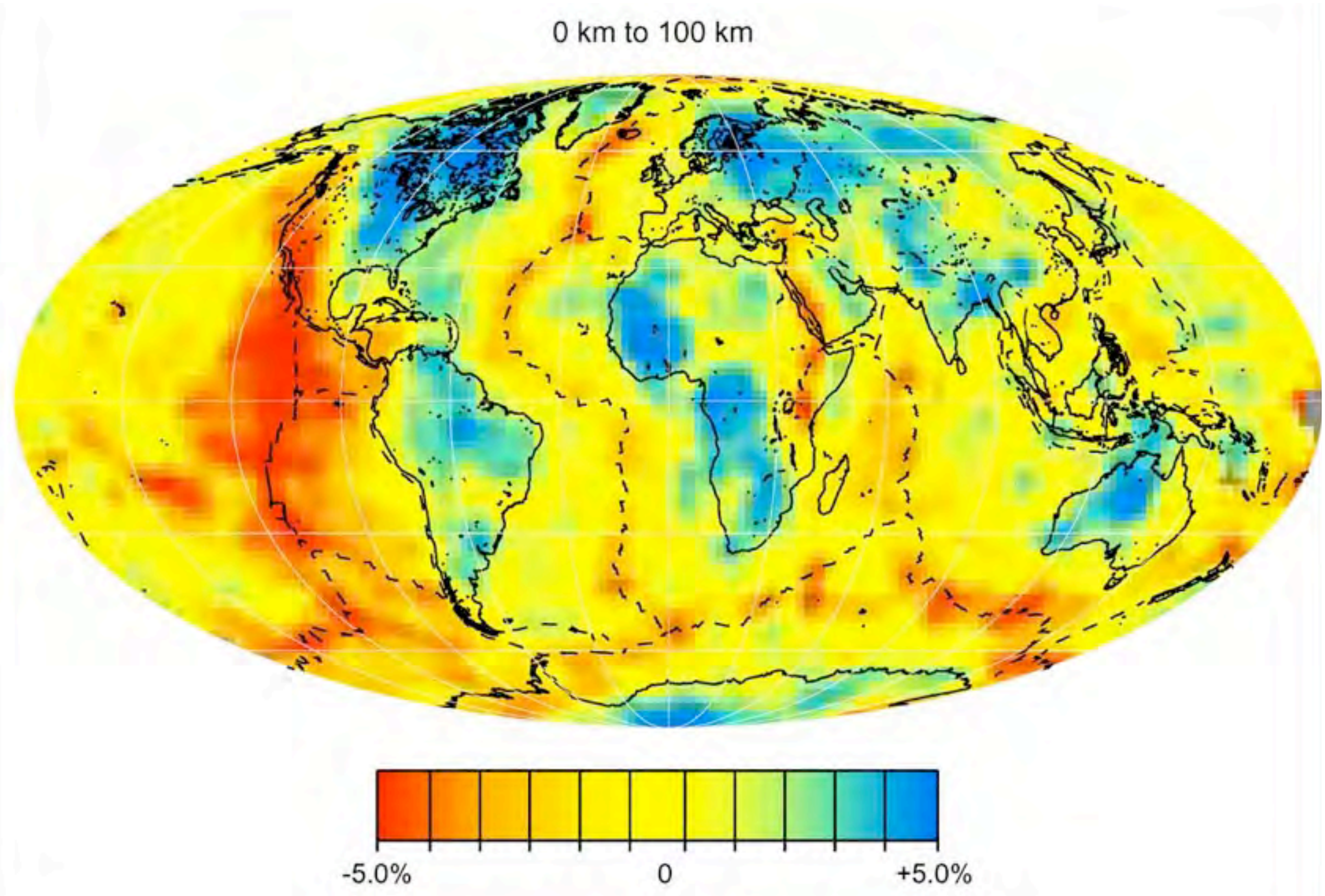
Seismic tomography



Seismic tomography

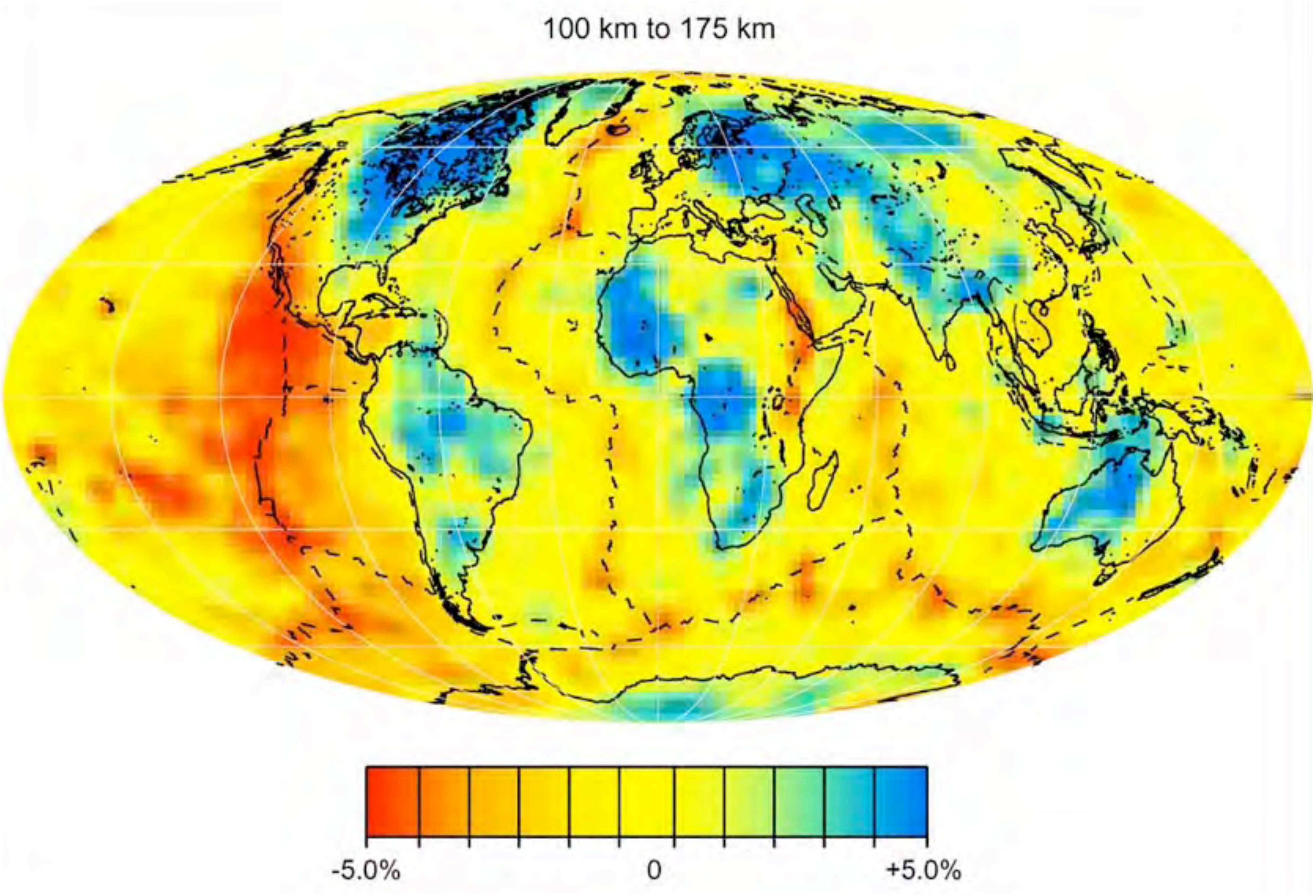


Tomography of the Mantle



Ridges = hot, continents = cool

Tomography of the Mantle



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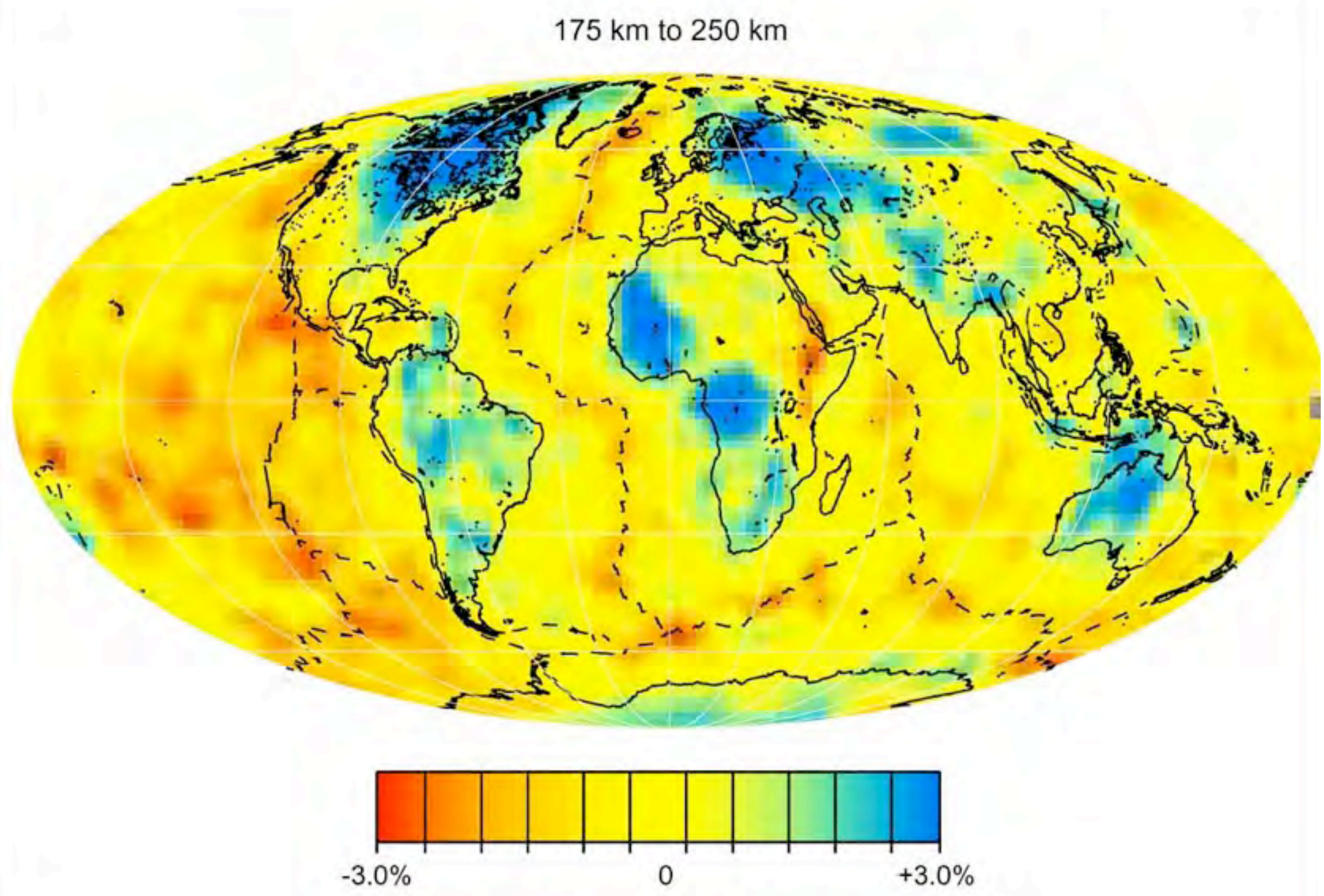

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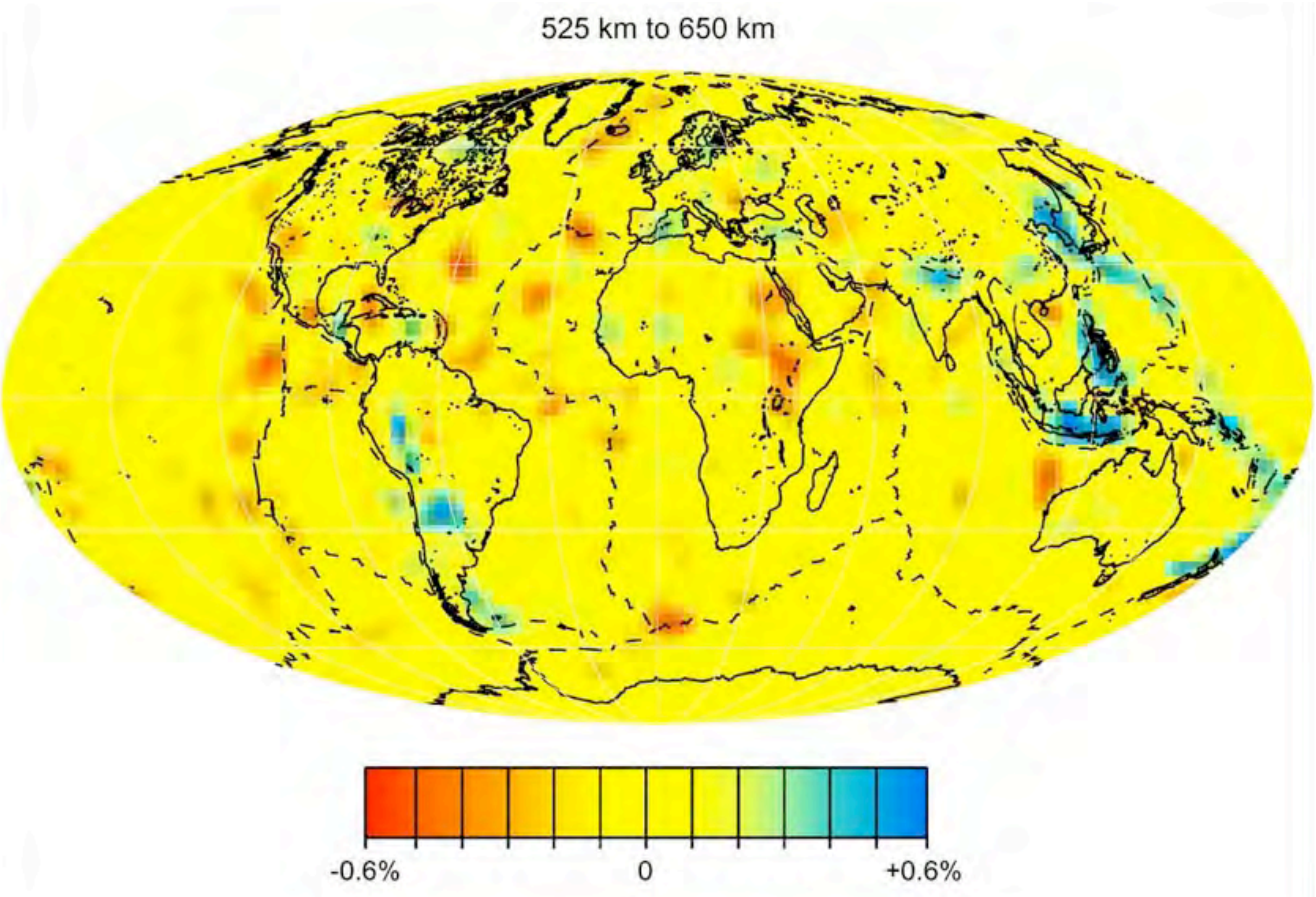
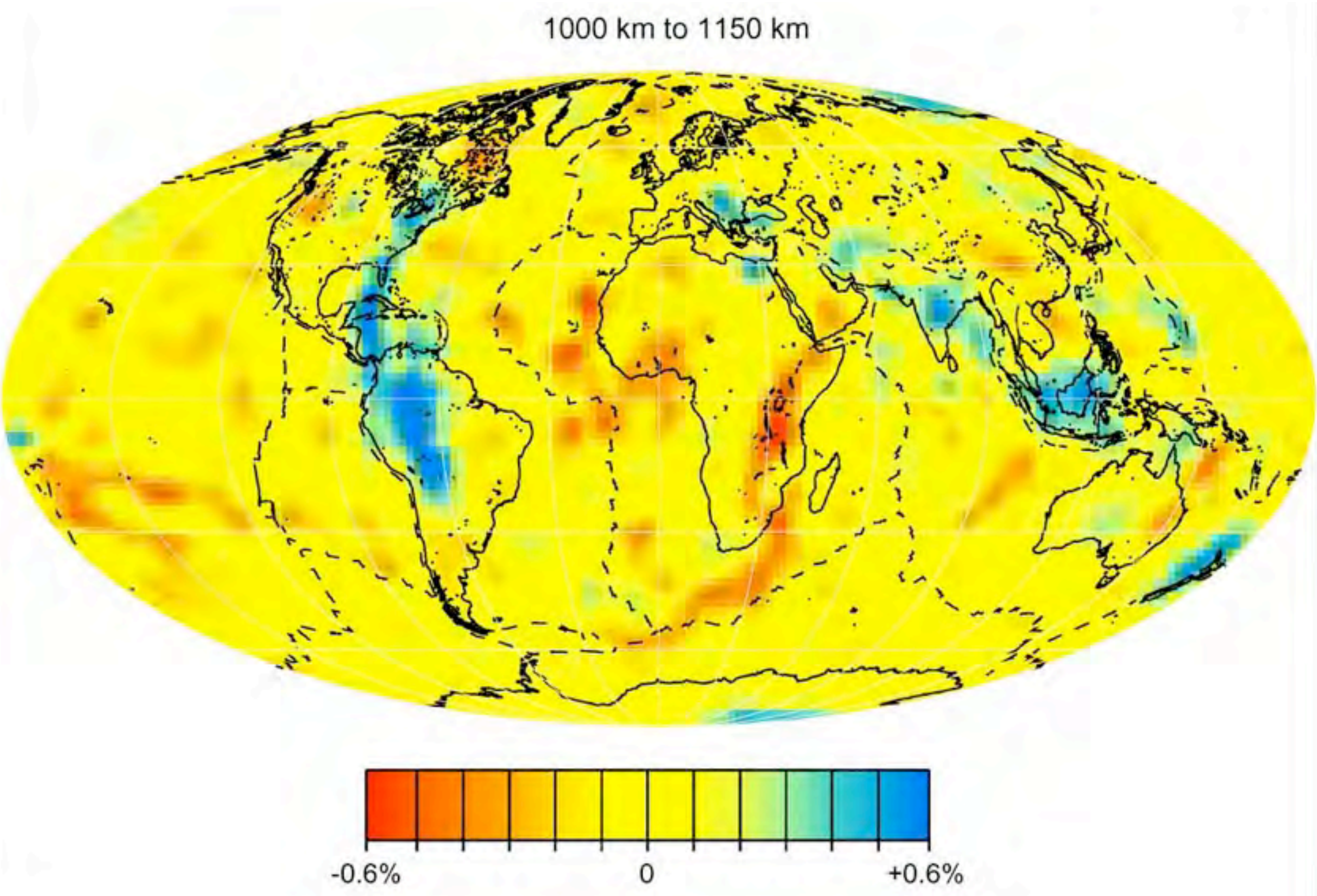


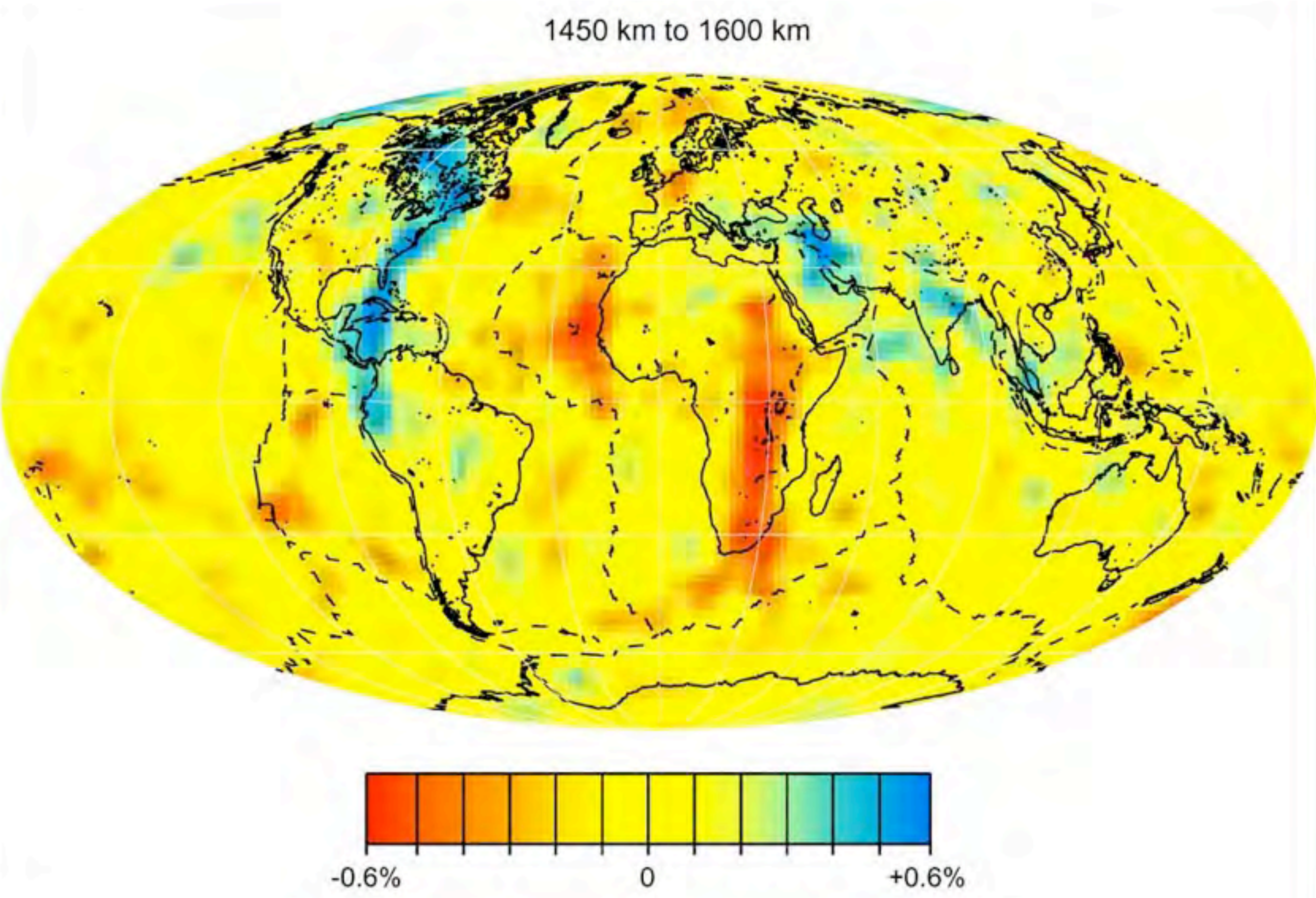
Subduction zones = cool

Tomography of the Mantle



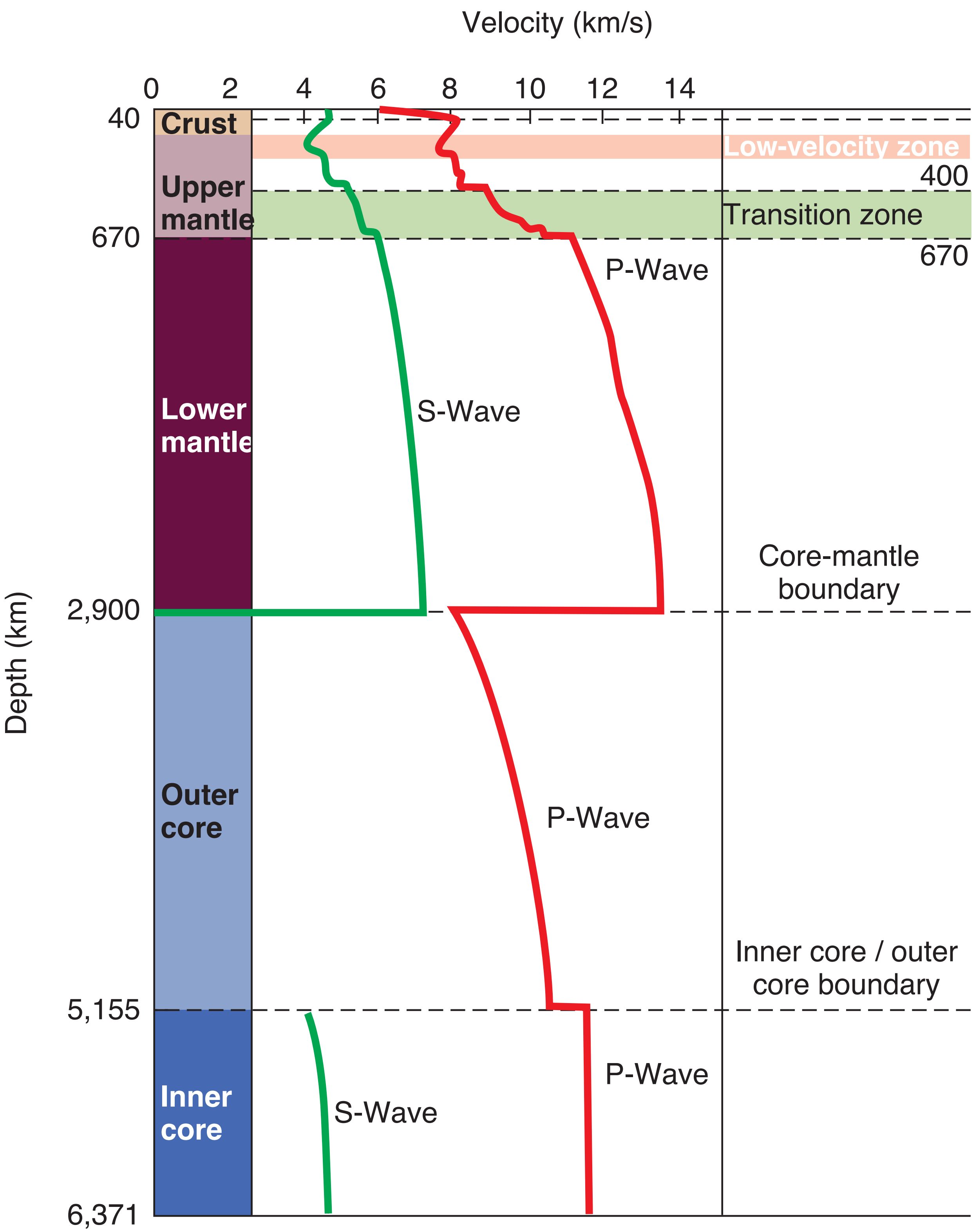
Subduction zones = cool & East Africa = hot

Tomography of the Mantle



East Africa = hot

PREM model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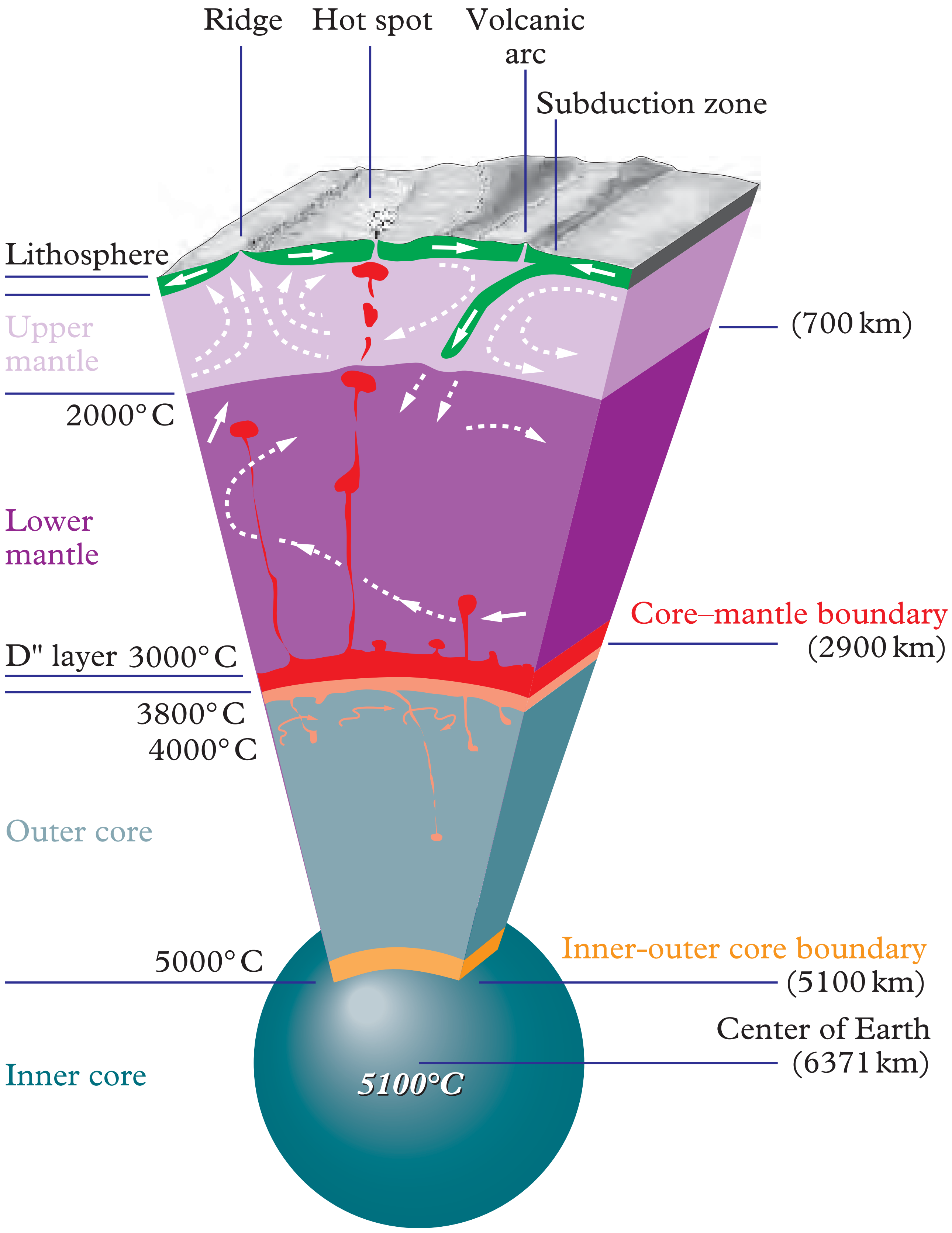
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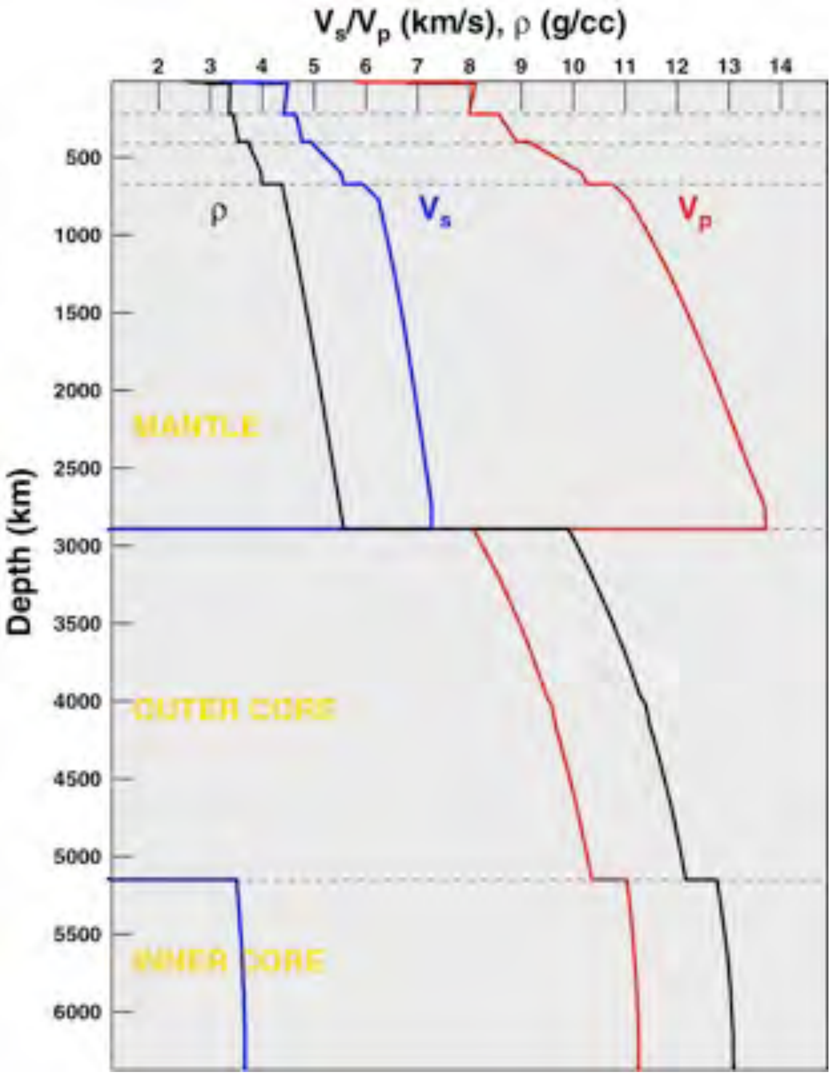
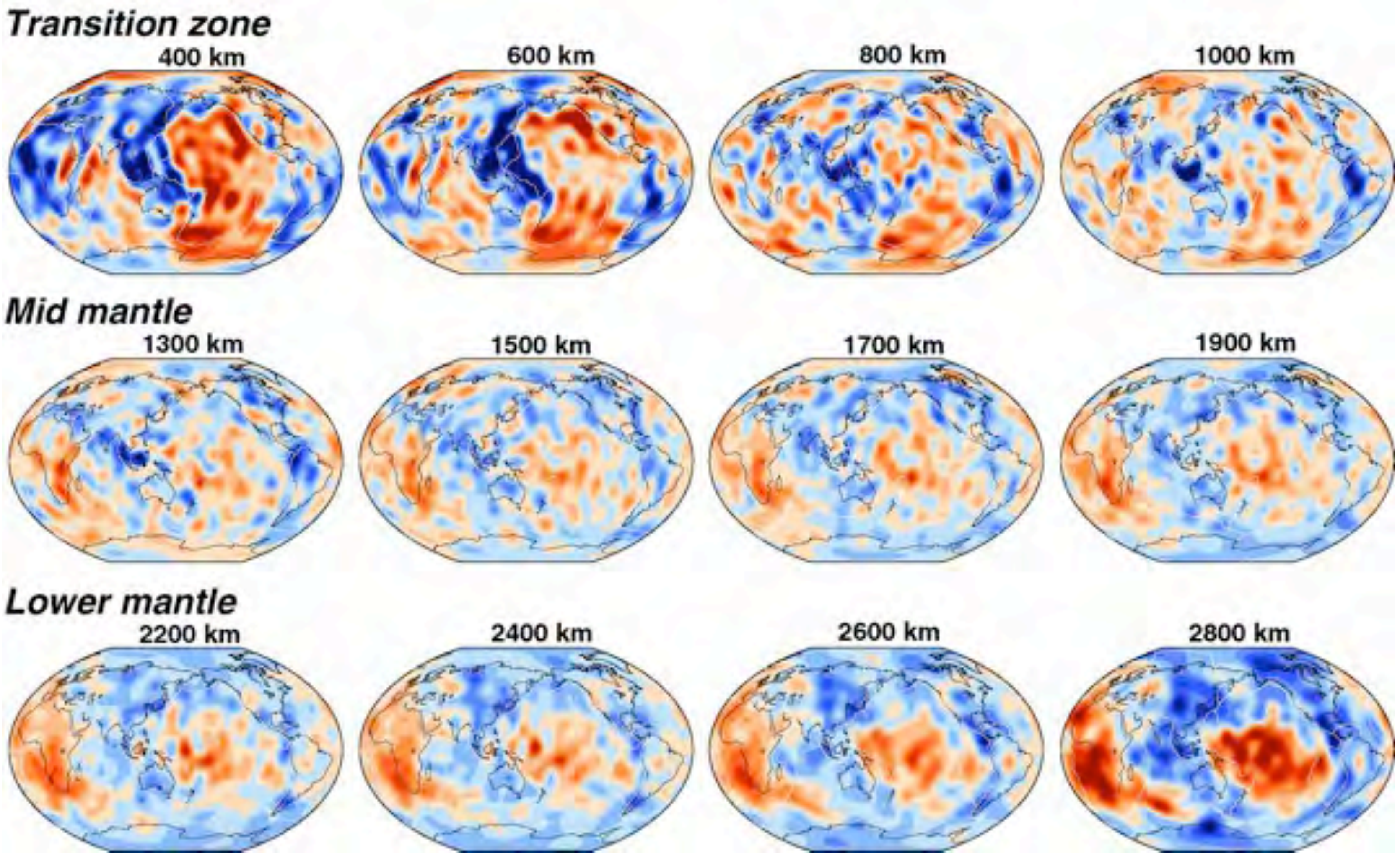
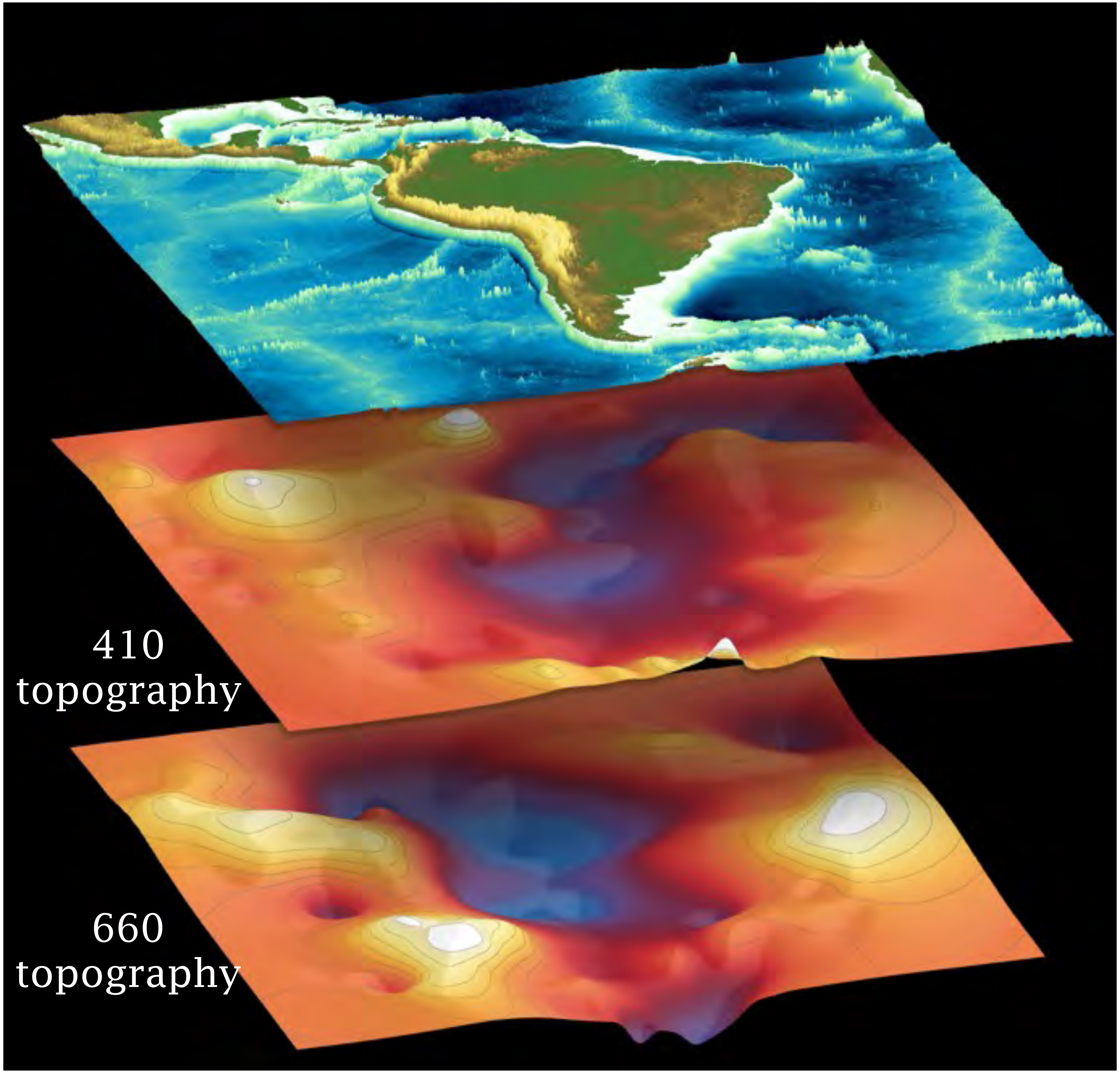




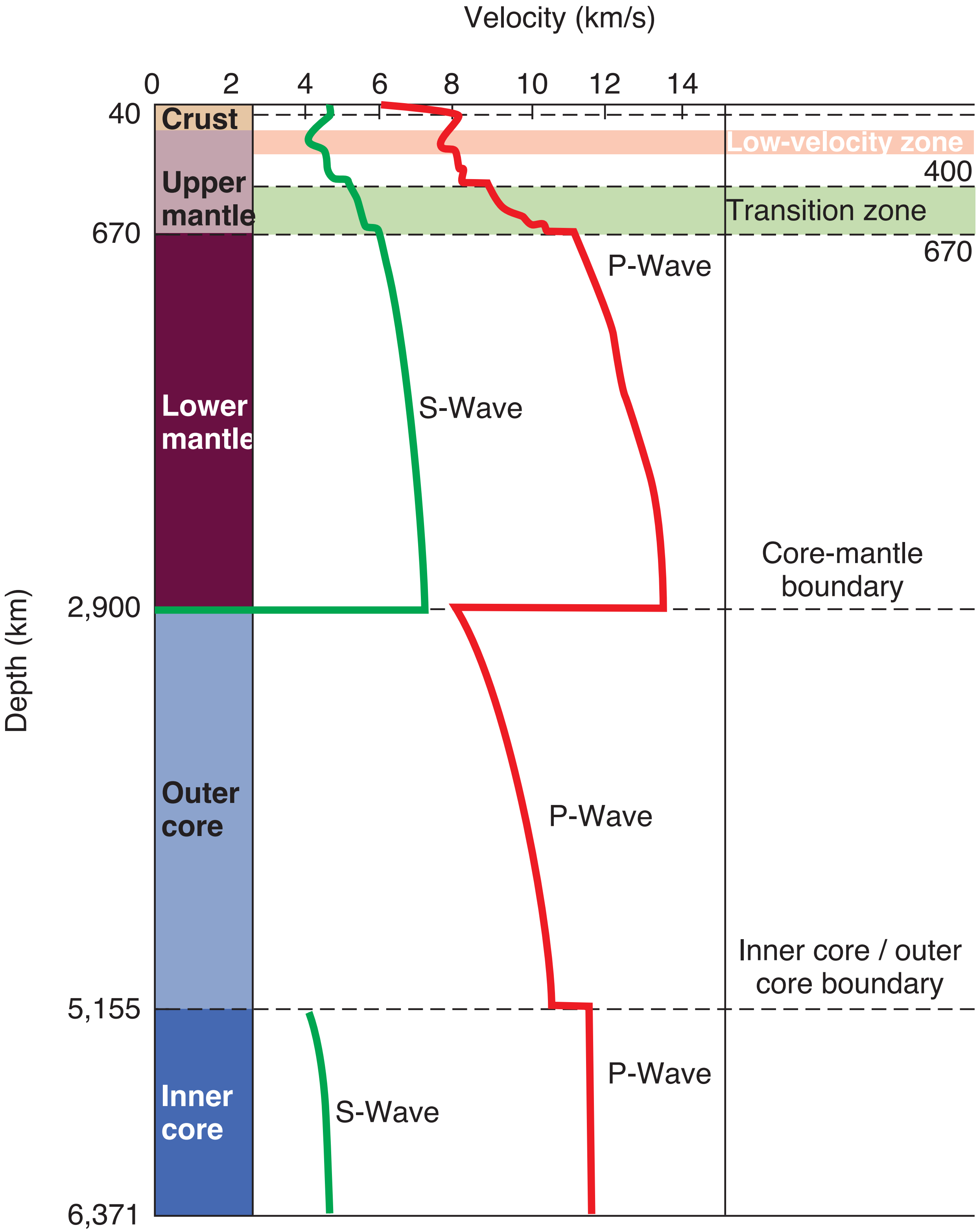
- PREM includes layers with an uncertain geophysical origin
- PREM is already a product of the modeling of seismic data
- In tomography, PREM is modified

Upper mantle discontinuity topography



Schmerr and Garnero [2007, Science]

PREM model



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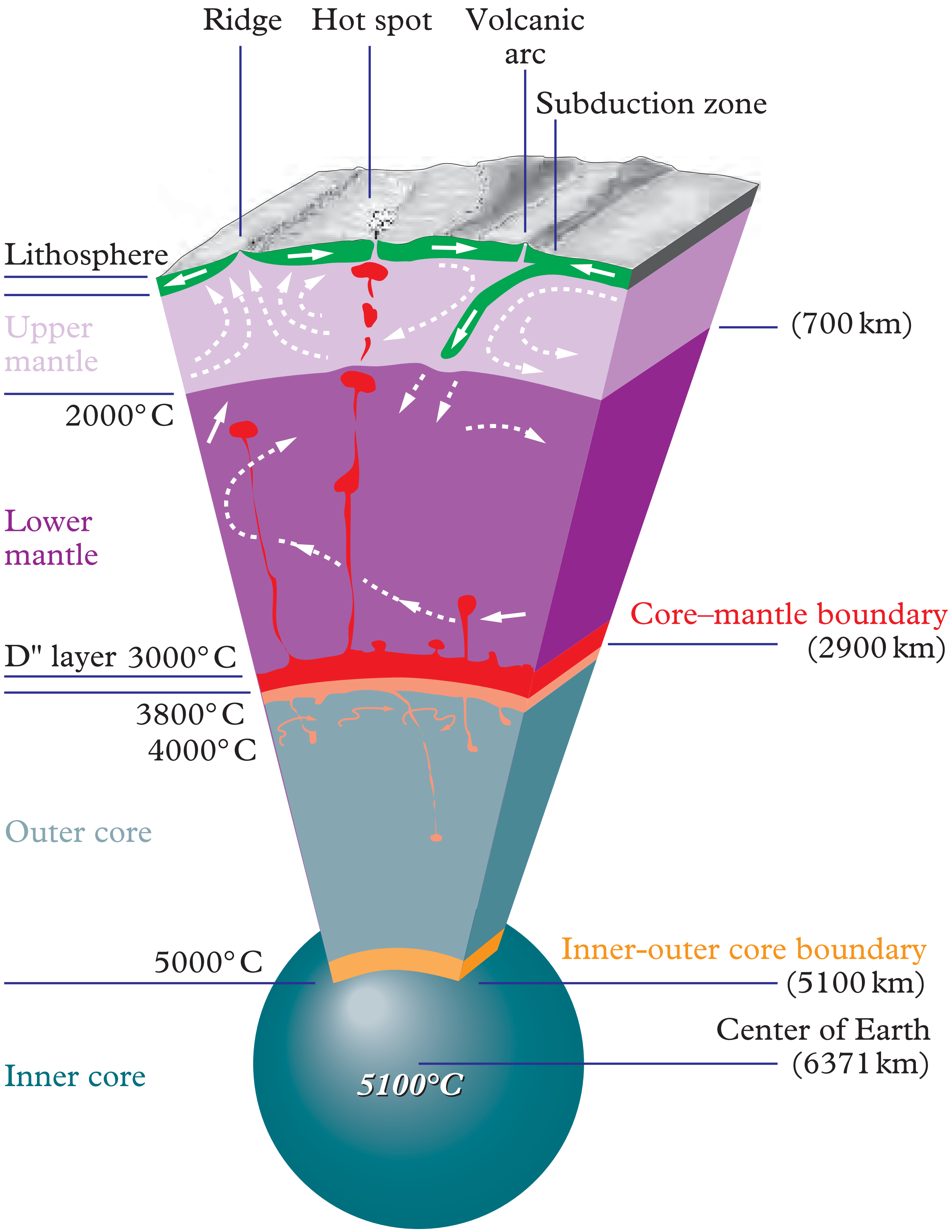

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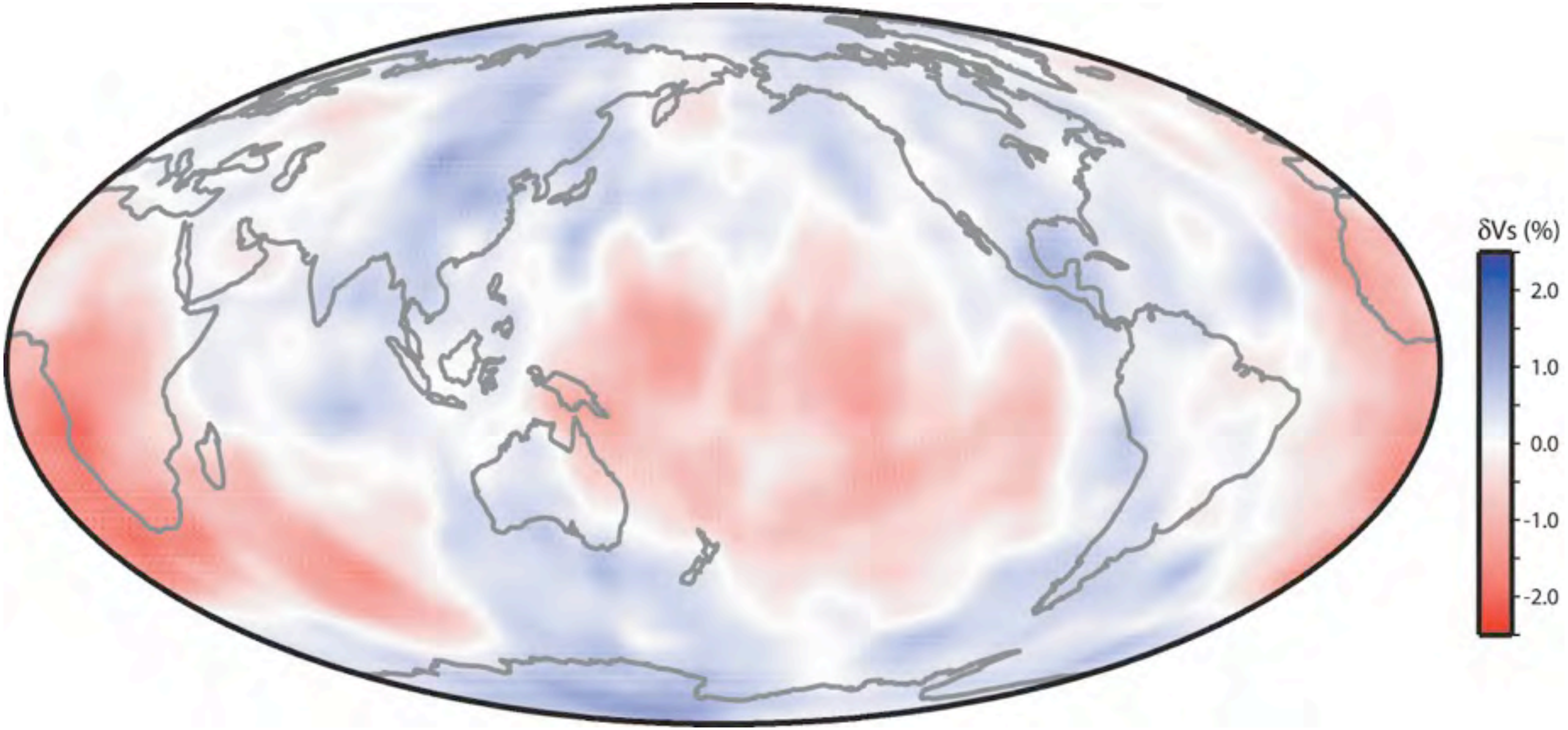
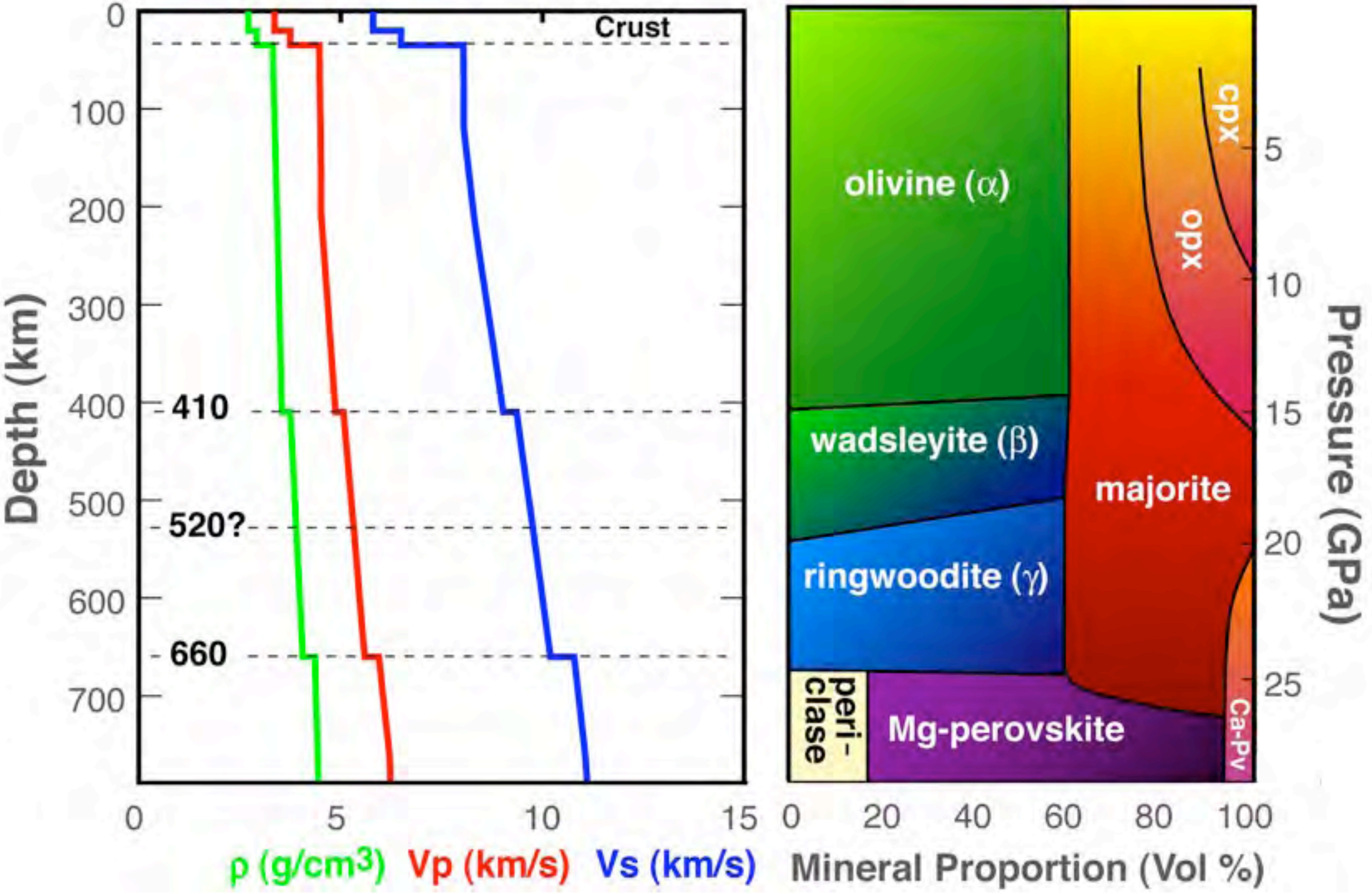
Global shear velocity heterogeneity in D"



Ritsema [Sci. Tech, 2000]

Upper mantle discontinuities: mineral phase boundaries

Upper mantle discontinuities: mineral phase boundaries



Upper mantle discontinuities: mineral phase boundaries

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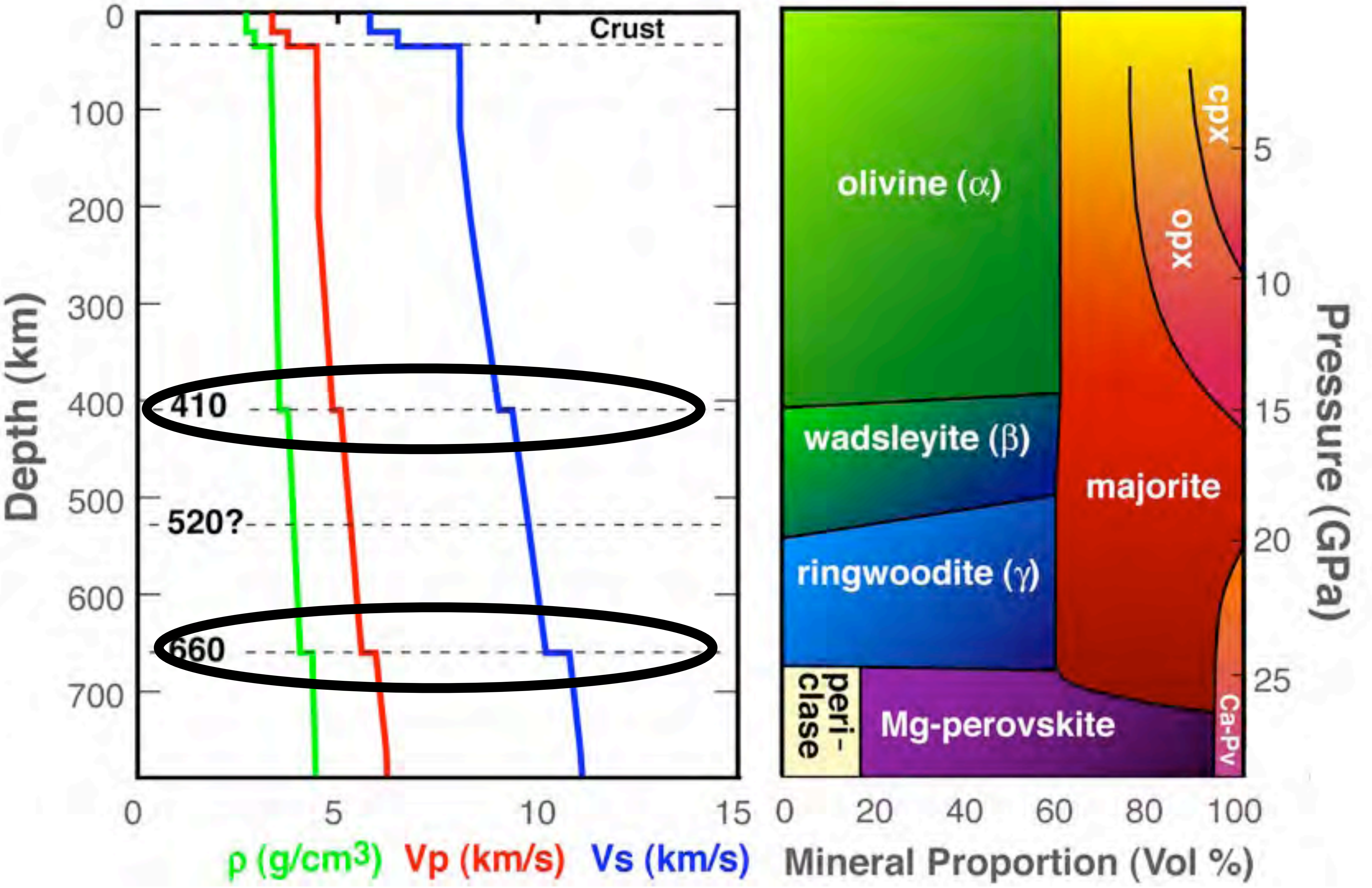
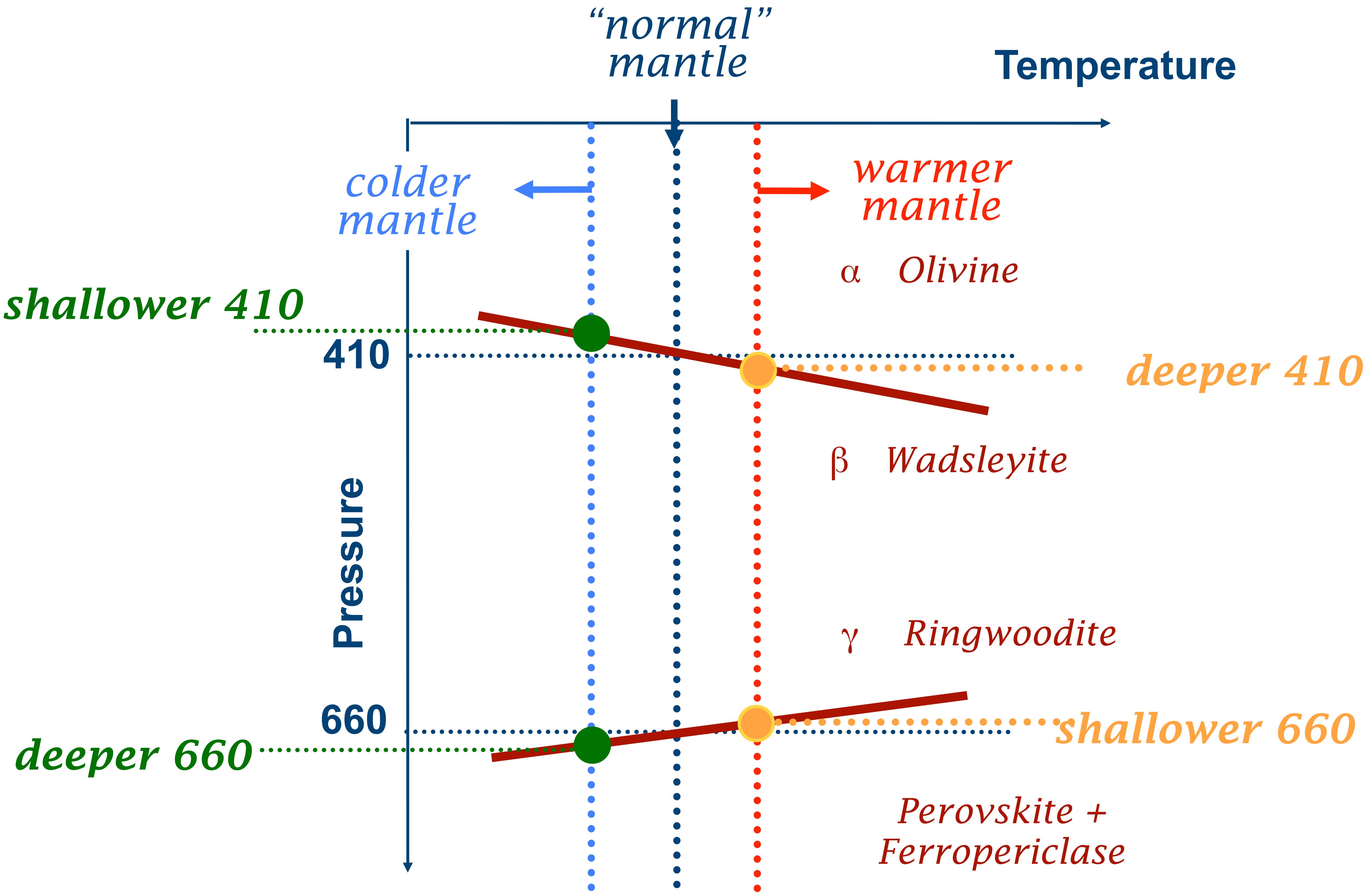
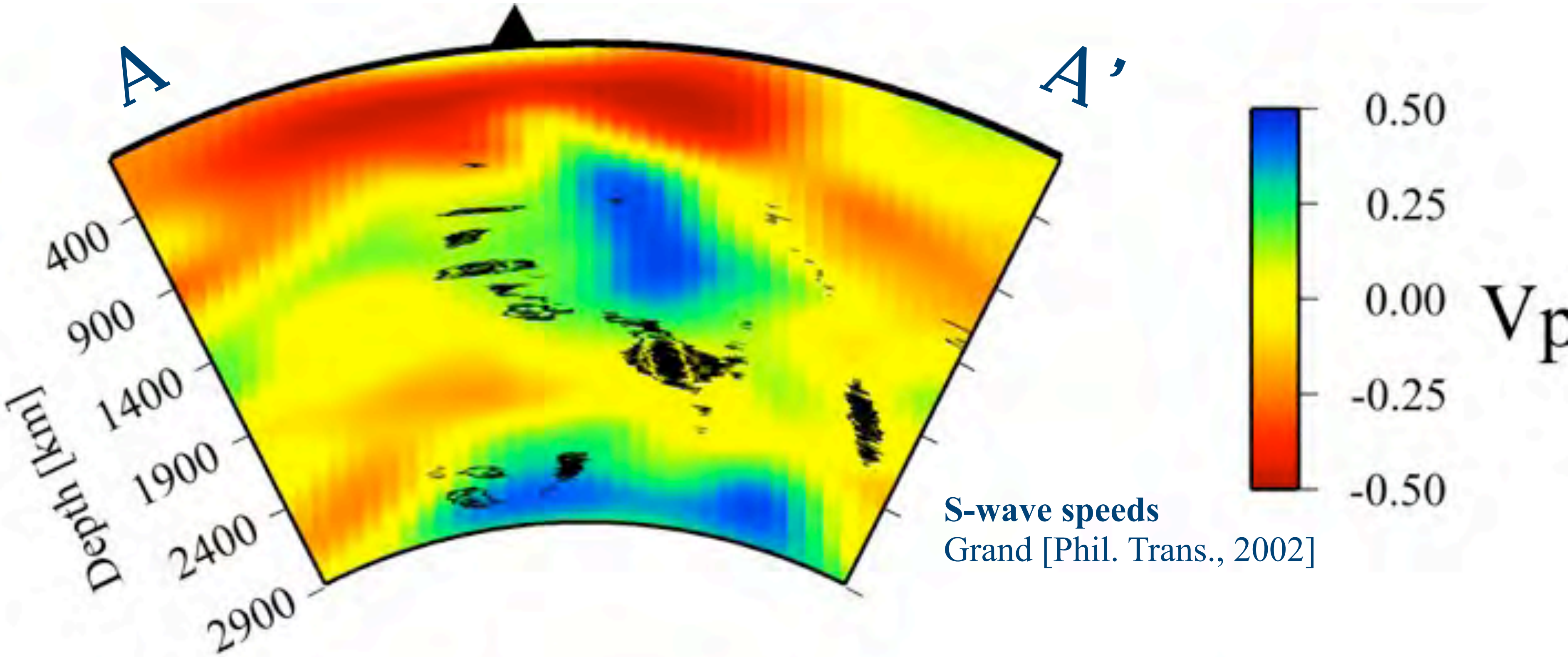


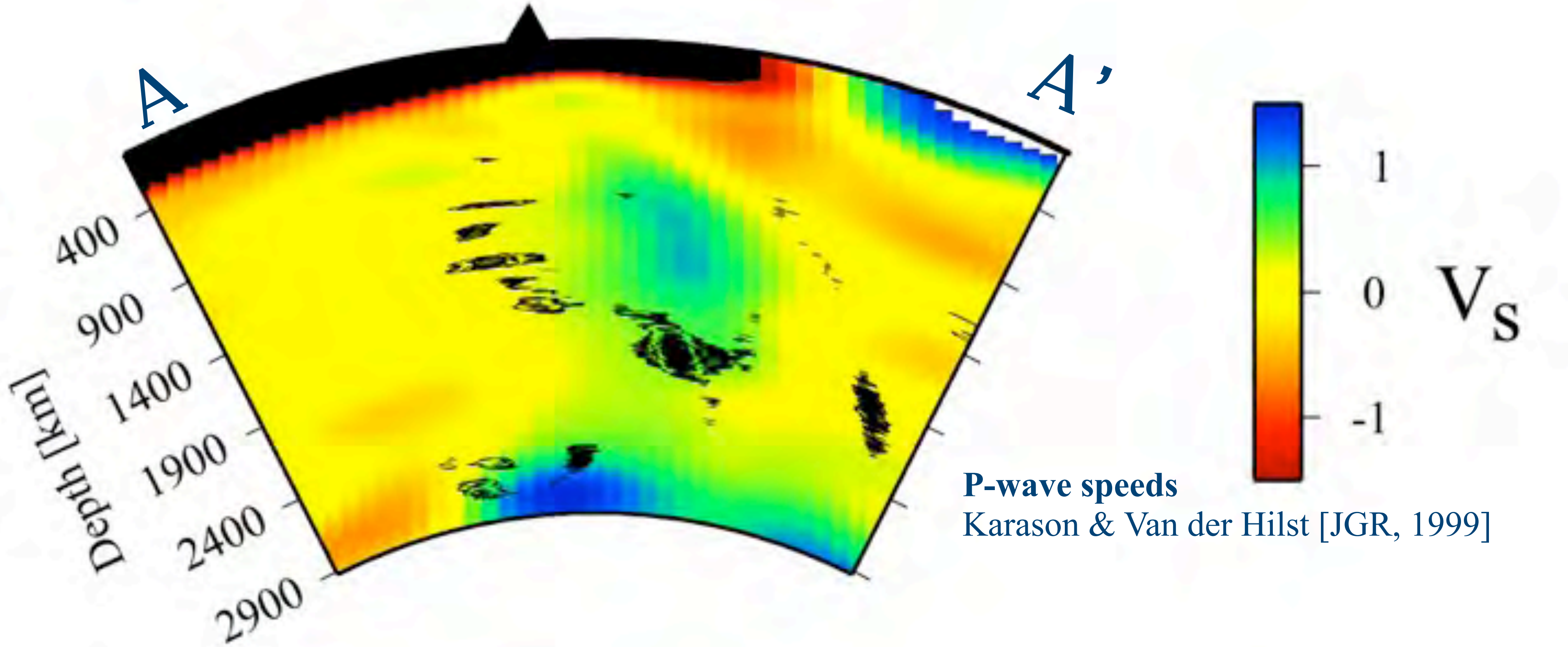
Olivine phase transitions and temperature



lower mantle beneath Caribbean

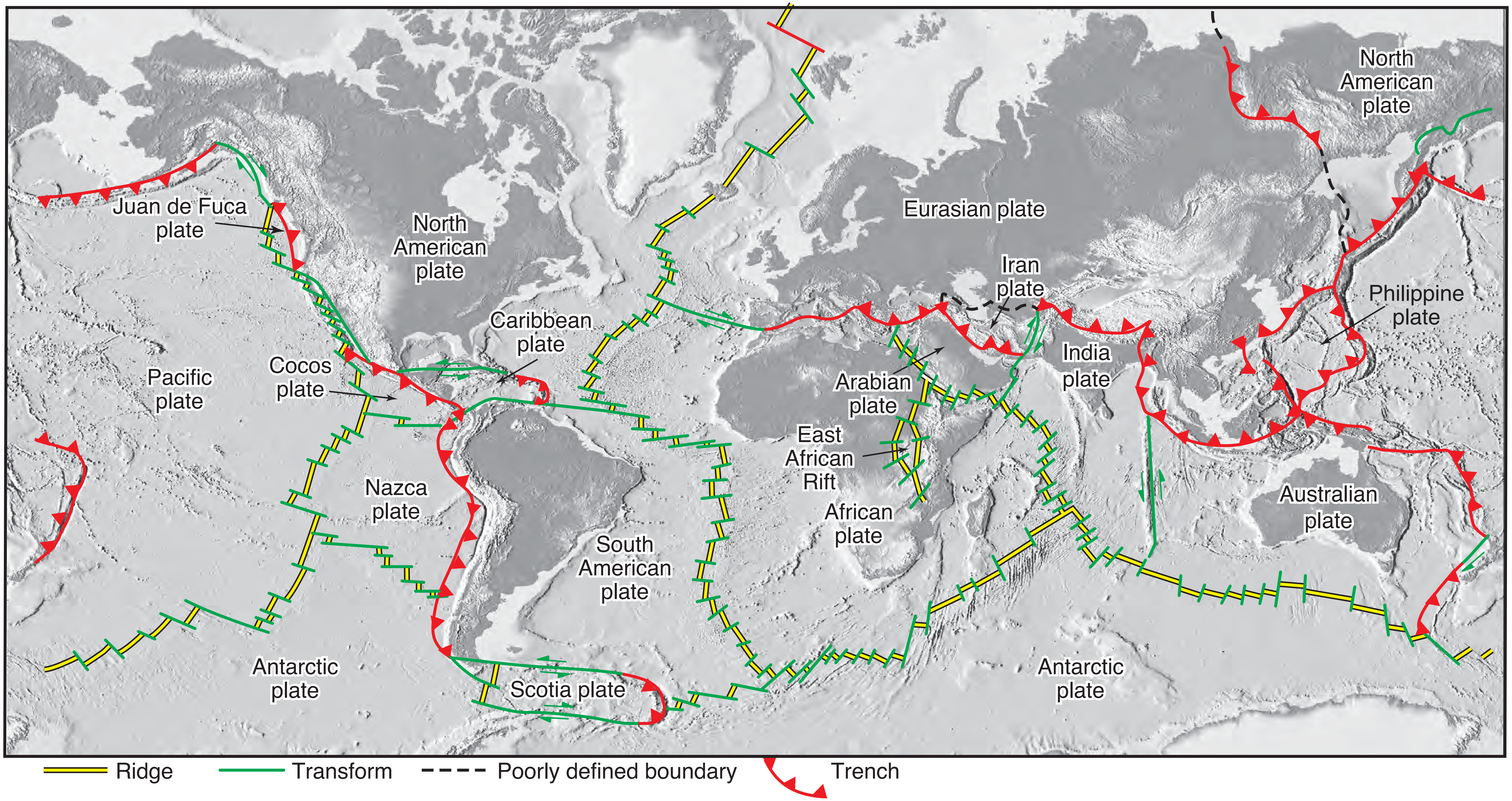


S-wave speeds
Grand [Phil. Trans., 2002]

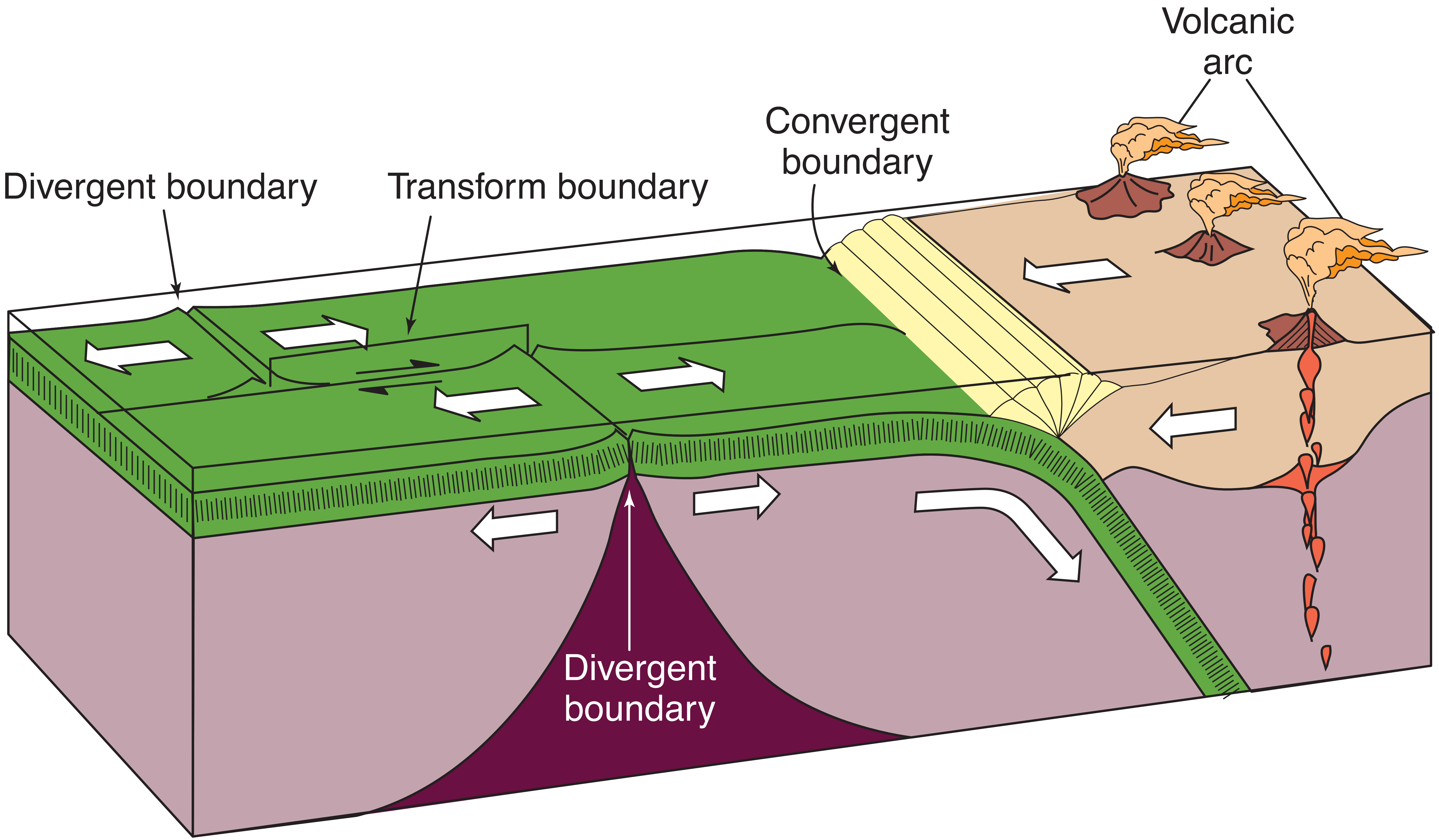


P-wave speeds
Karason & Van der Hilst [JGR, 1999]

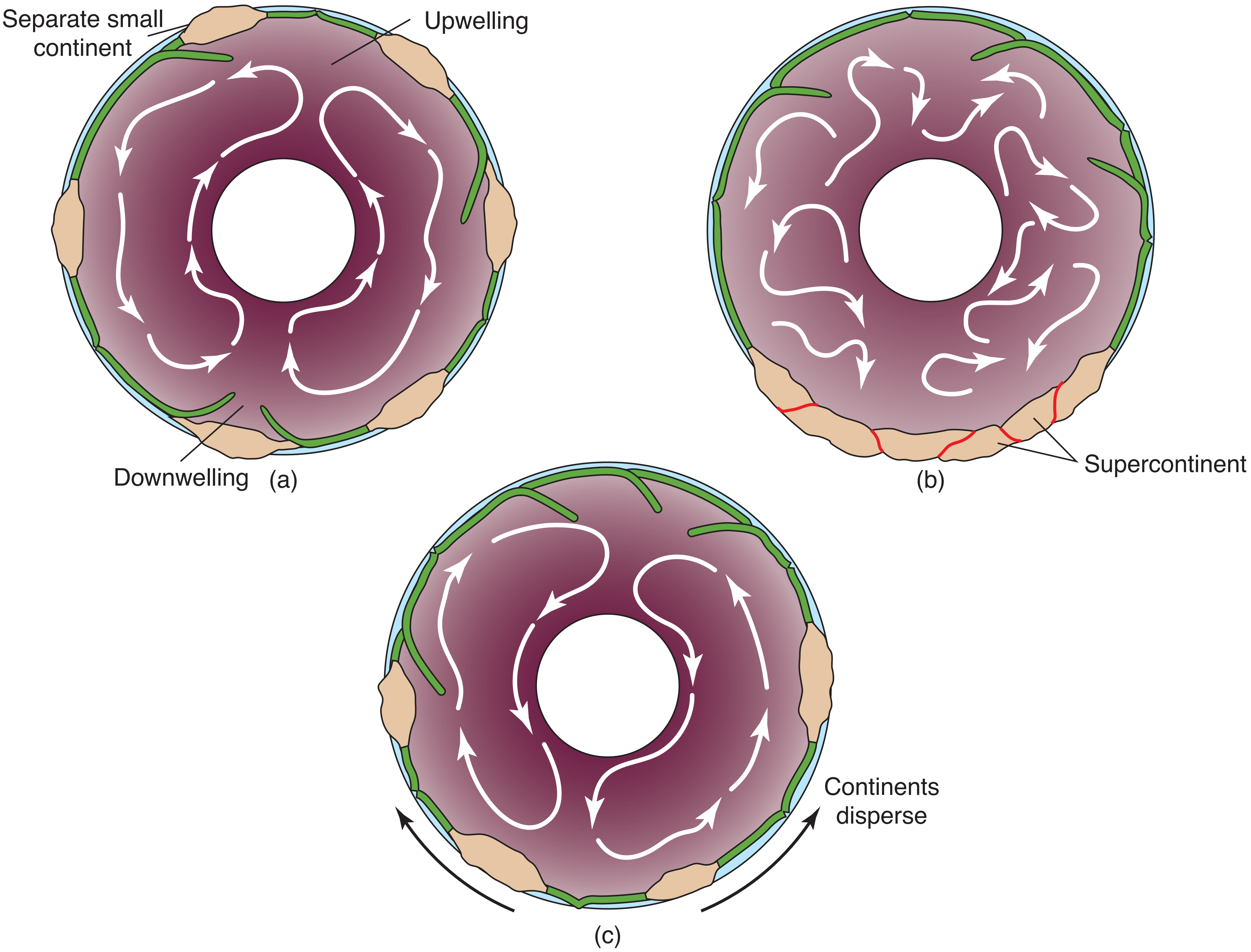
Kito et al. [GJI, 2008]


Juan de Fuca plate
North American plate
Caribbean plate
Cocos plate
Pacific plate
Nazca plate
South American plate
Scotia plate
Antarctic plate
Eurasian plate
Iran plate
Arabian plate
East African Rift
African plate
India plate
Philippine plate
North American plate
Australian plate
Antarctic plate
Ridge
Transform
Poorly defined boundary
Trench

Types of Plate boundaries



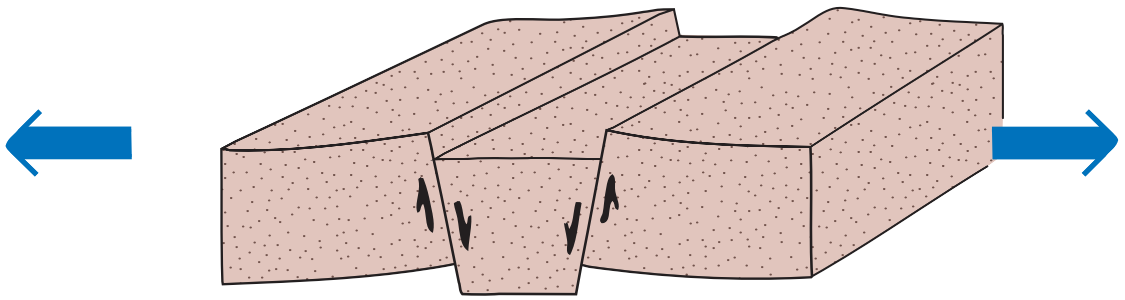
Wilson cycle: the concept



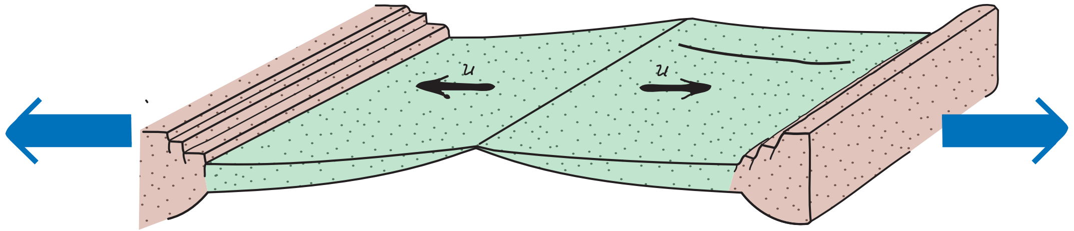
Wilson cycle: the stages

Module BP 11 - 07

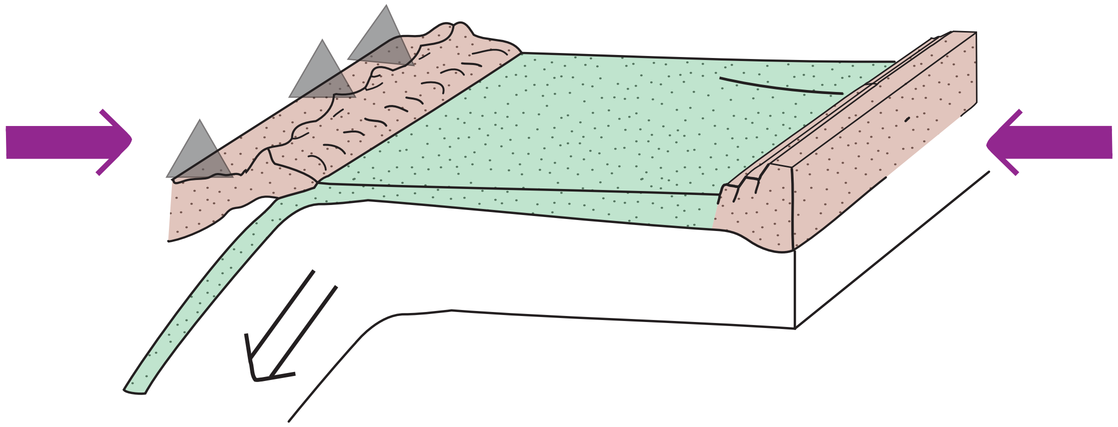
Rifting



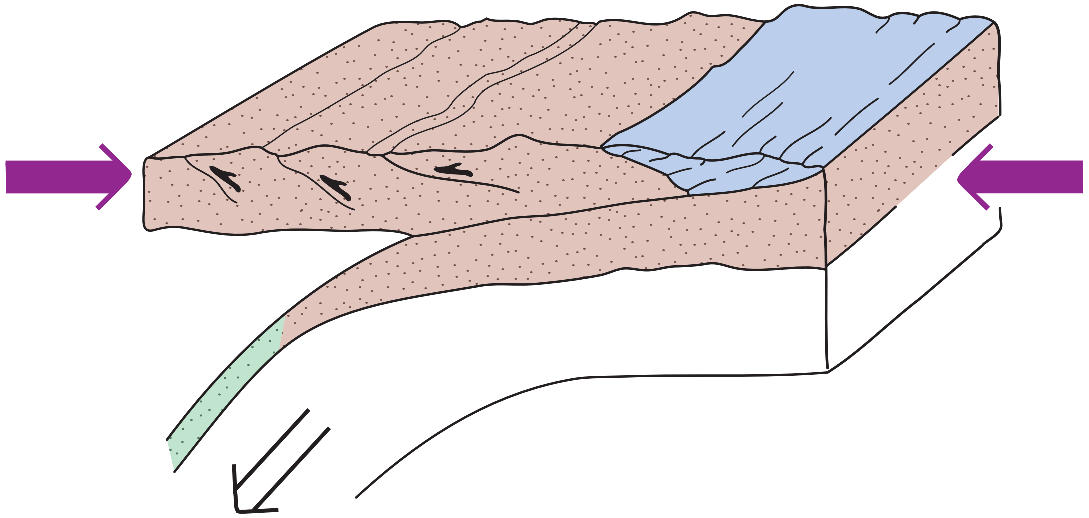
Ocean formation



Subduction



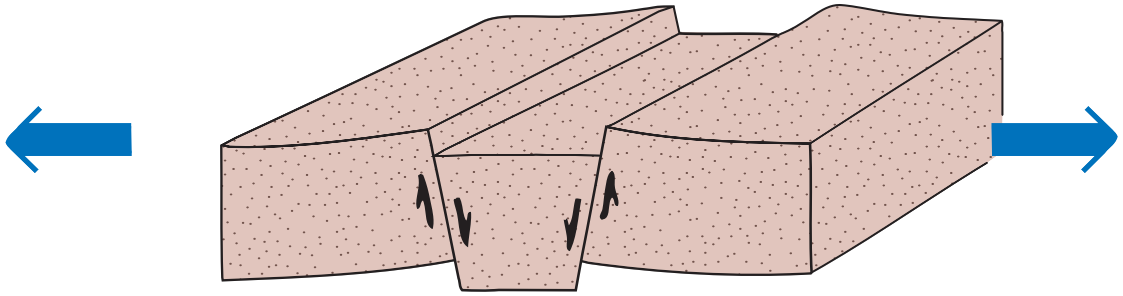
Collision



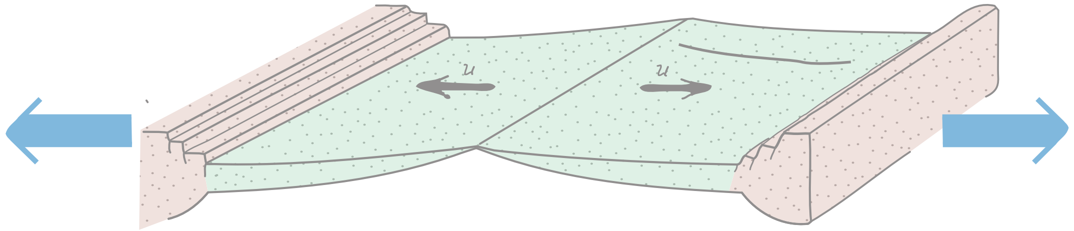
R. Bousquet 2009-2010

Wilson cycle: the stages

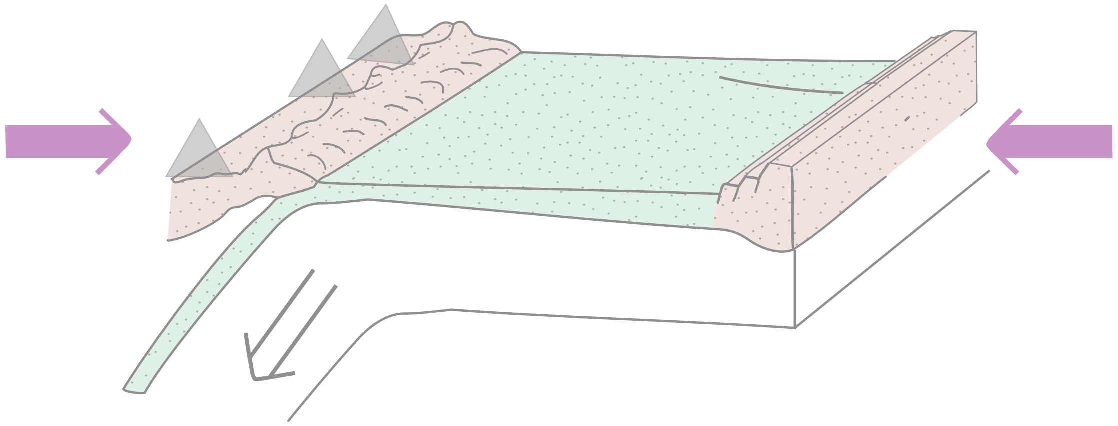
Rifting



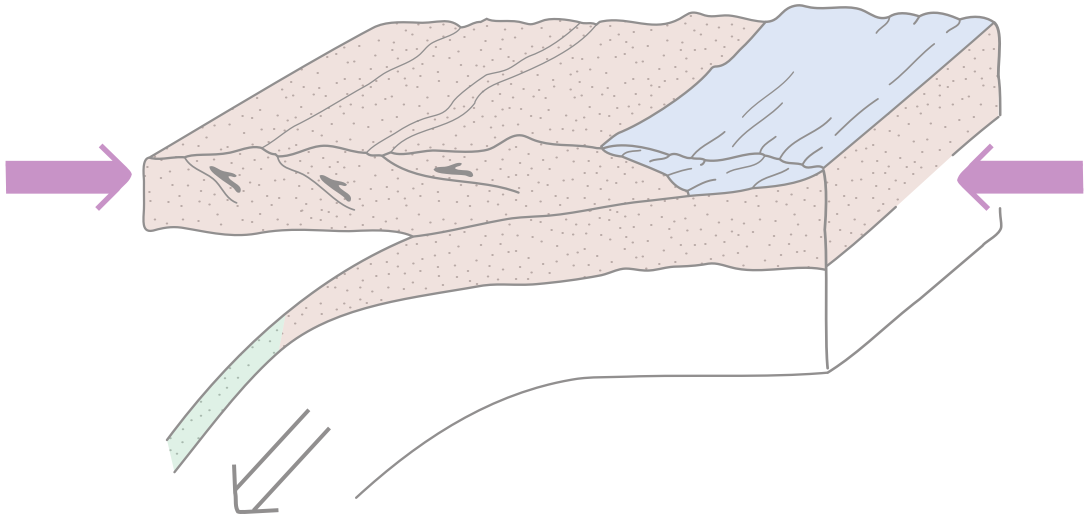
Ocean formation



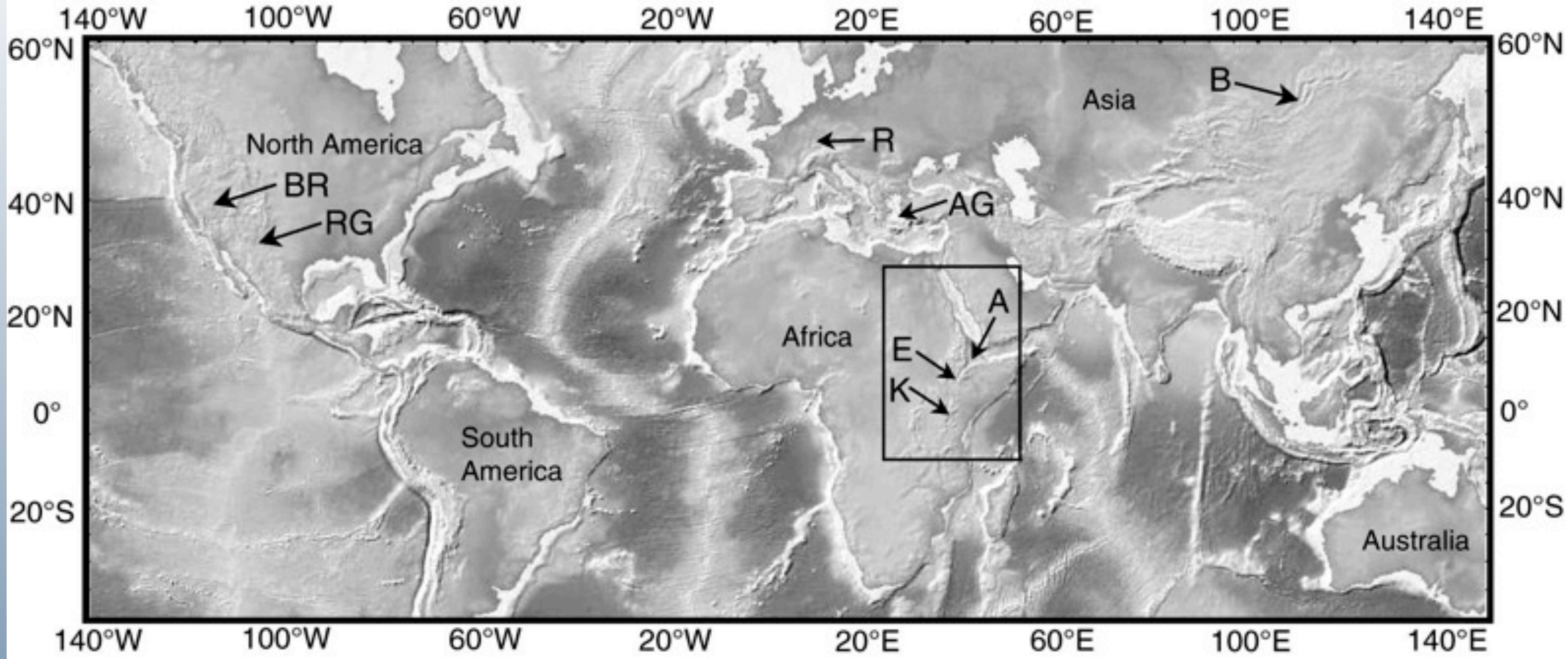
Subduction



Collision



Kontinentale Rift-Zonen



BR: Basin and Range
RG: Rio Grande Rift
R: Rheintalgraben
AG: Ägäis
B: Baikalrift
E: Äthiopien
A: Afar
K: Kenia-Rift

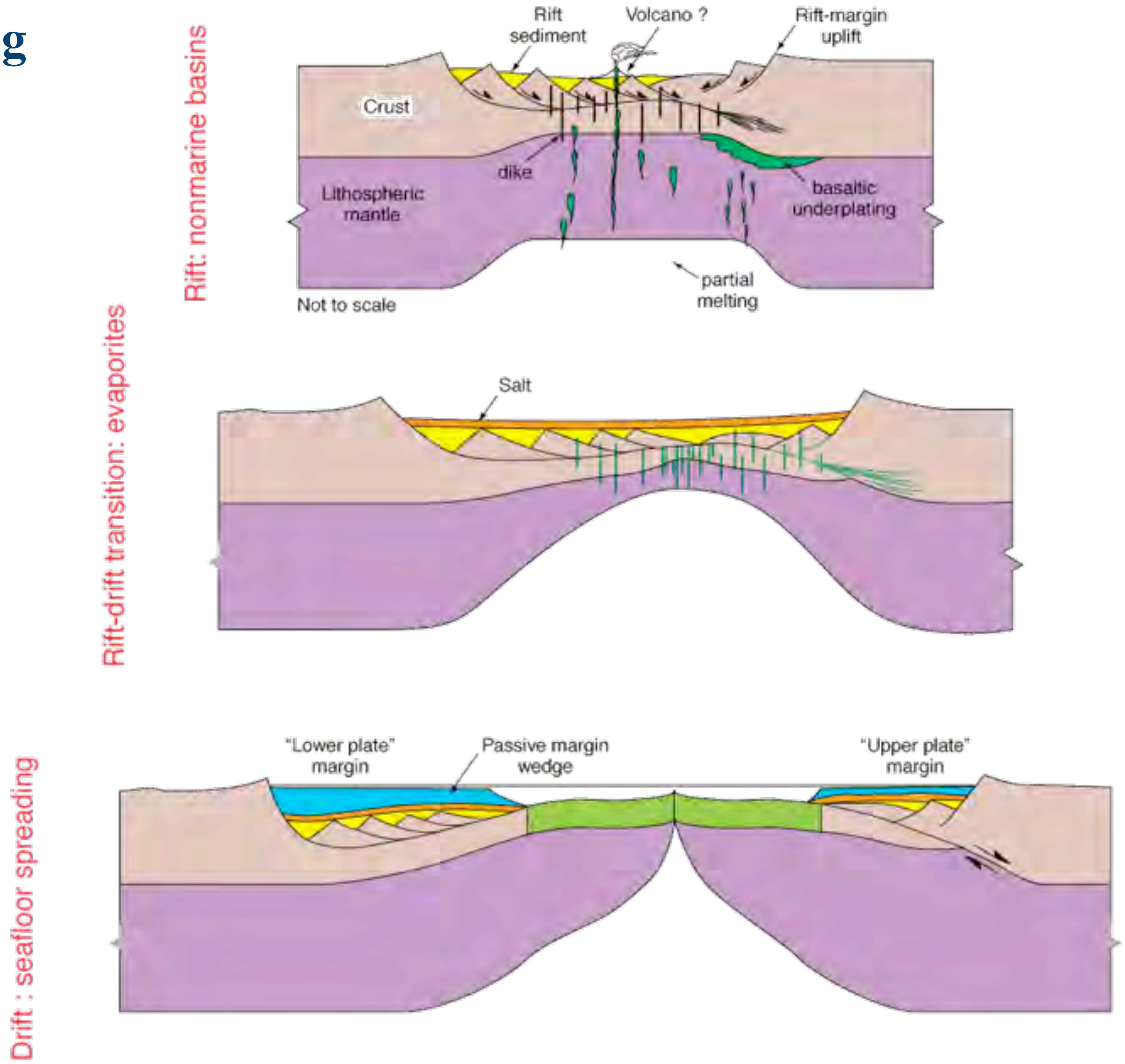
From Kearey, Klepeis, Vine

Kontinentale Riftzonen repräsentieren das Frühstadium des Aufbrechens der Kontinente durch Extension → Bildung neuer ozeanischer Becken

Kommt es zum Auseinanderbrechen der Lithosphäre, so wird das Rifting inaktiv und ein passiver Kontinentalrand entsteht (‚rifted continental margin‘).

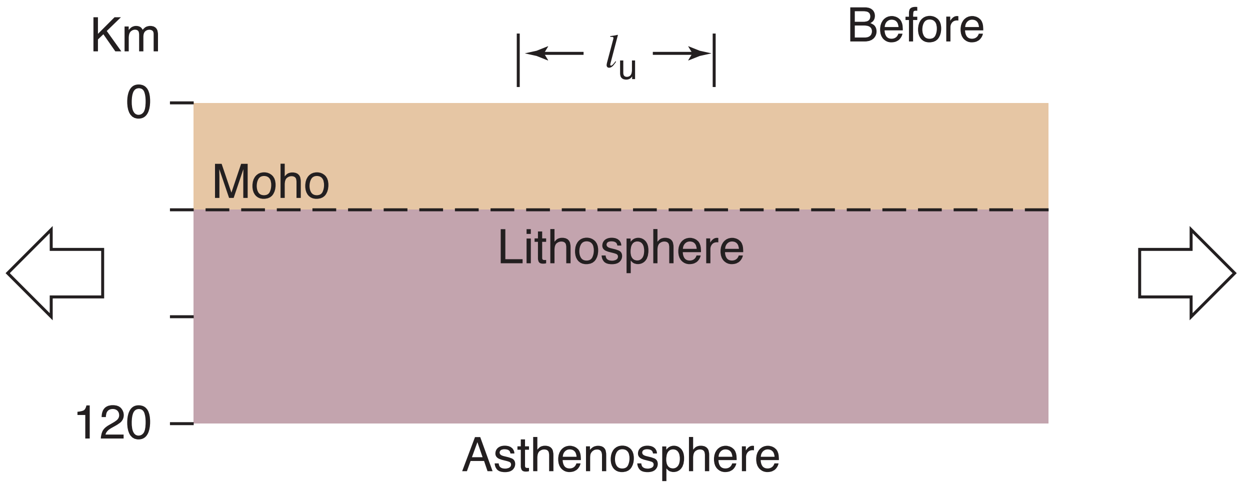
Stretching the continents

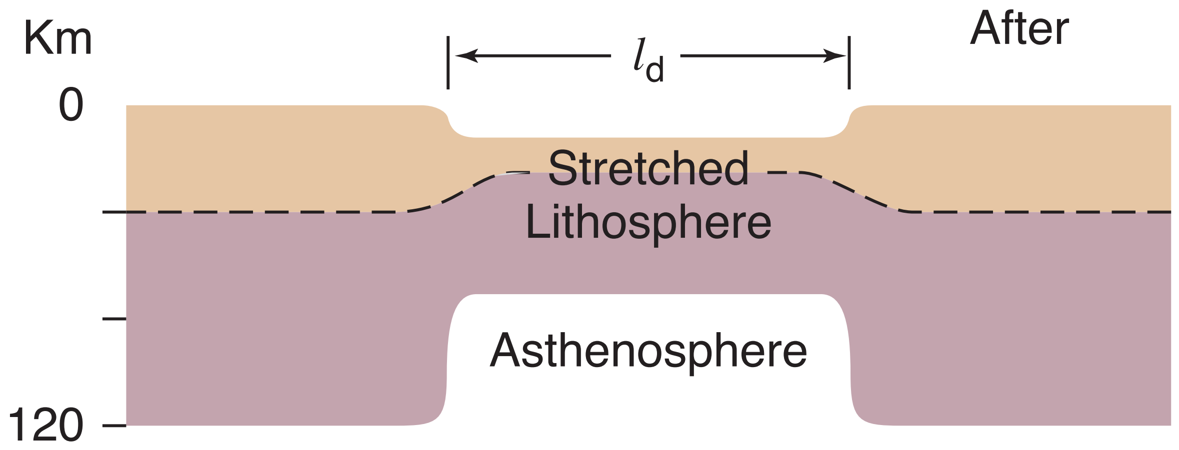
Step of rifting



Stretching the continents

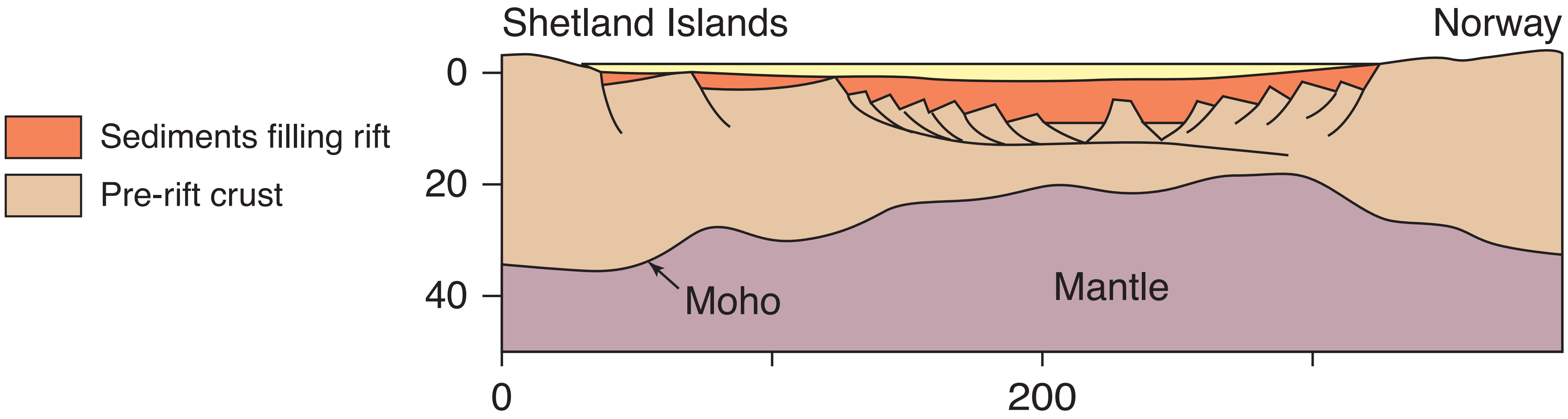
Principles





l_u = 80 km
l_d = 160 km

$\beta = 2$, where
$\beta = l_d / l_u$



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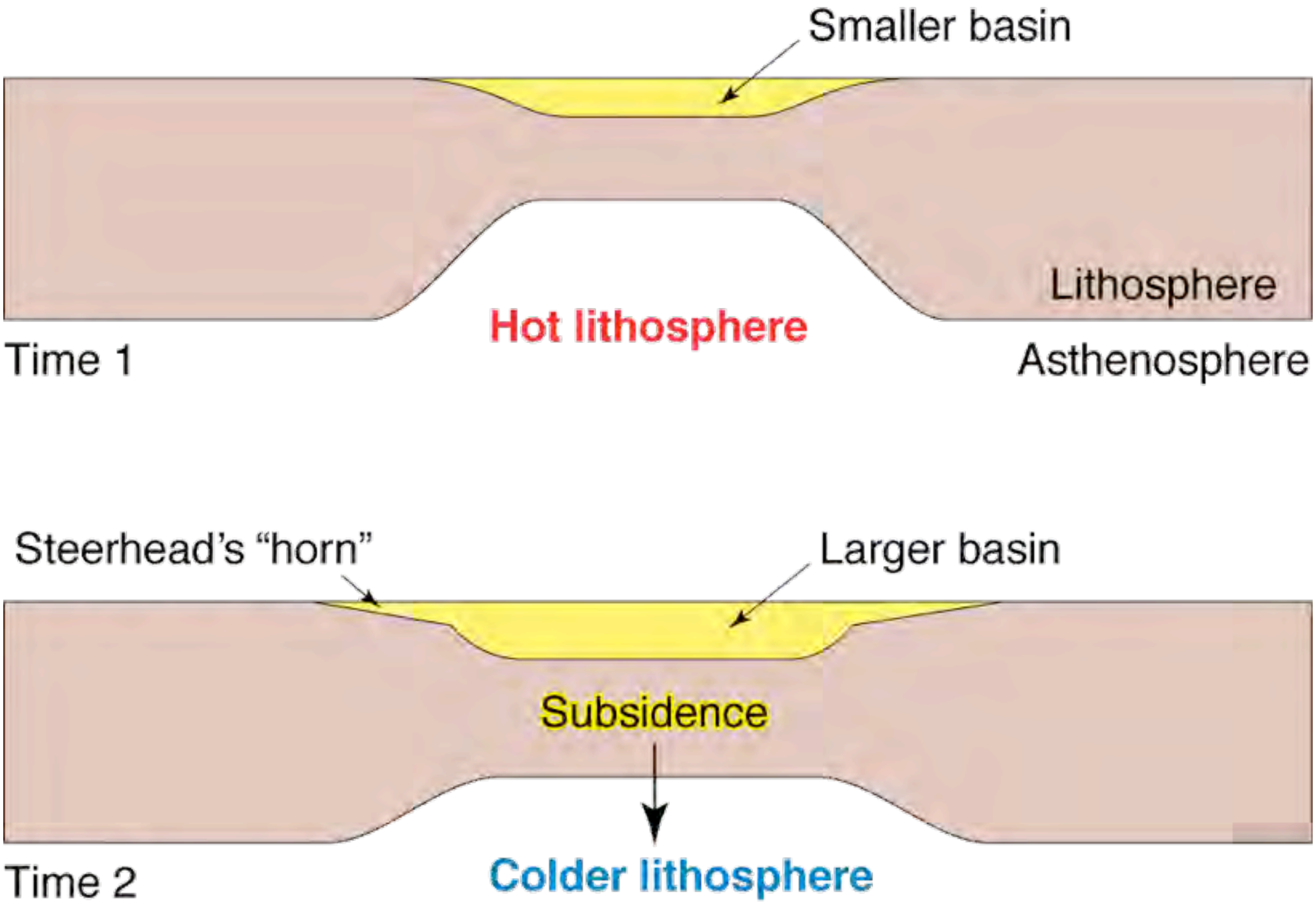
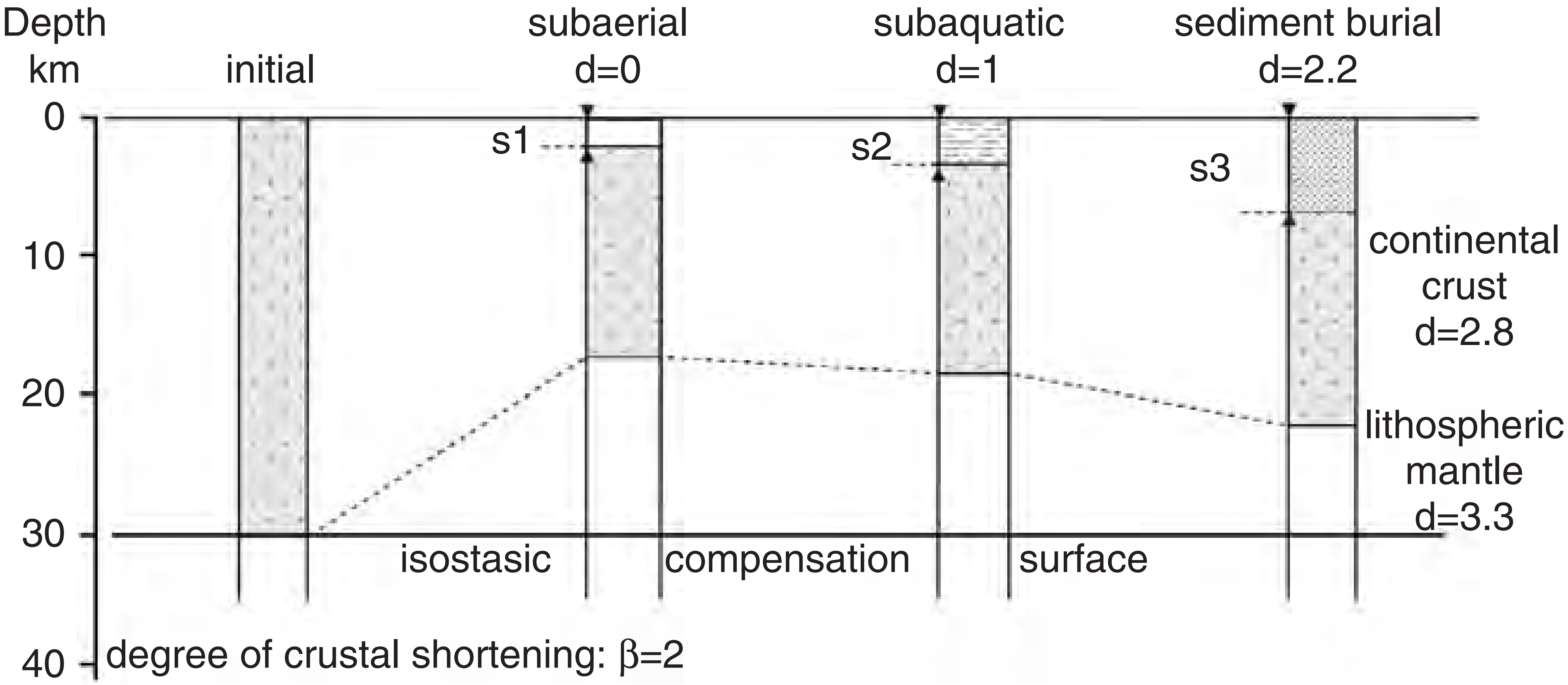
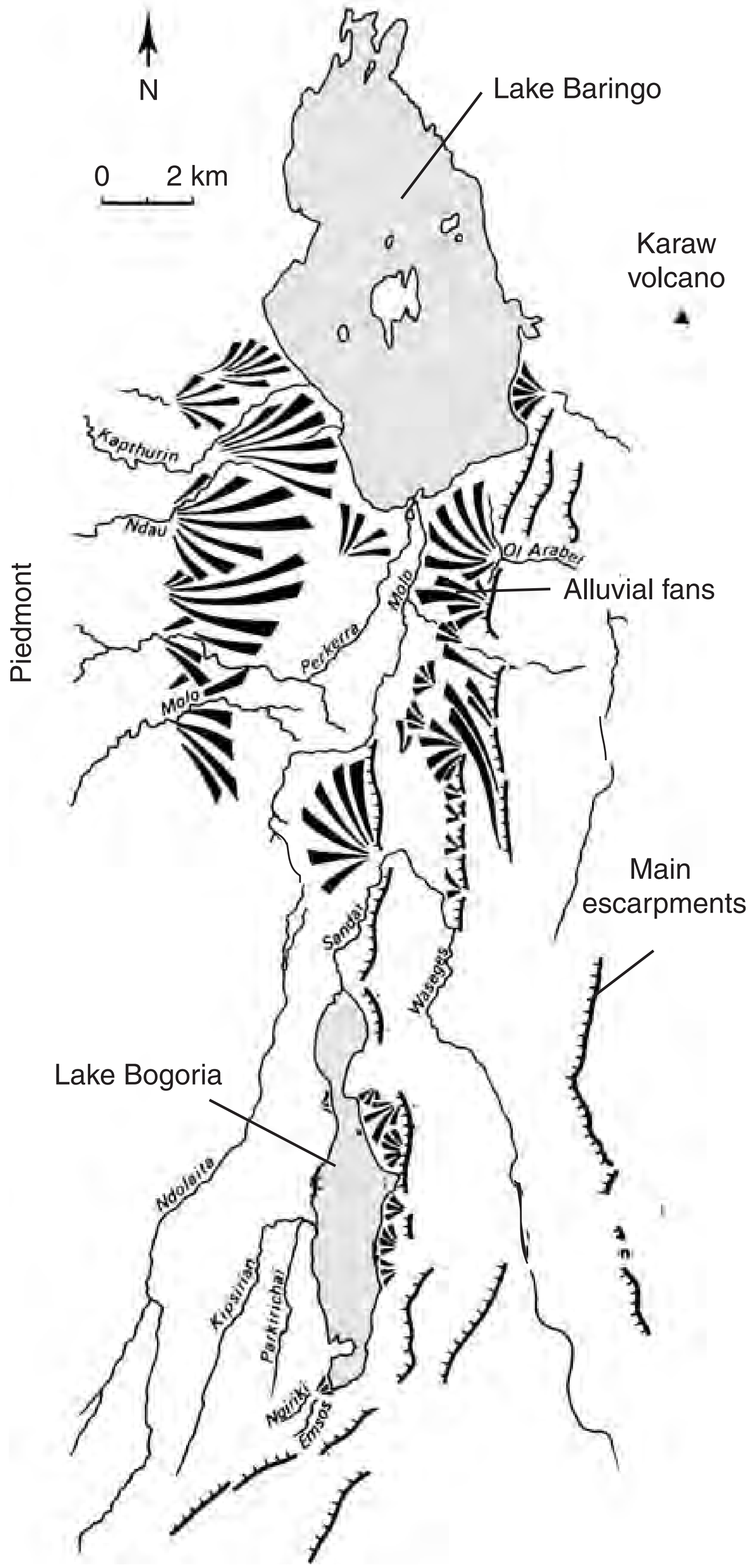
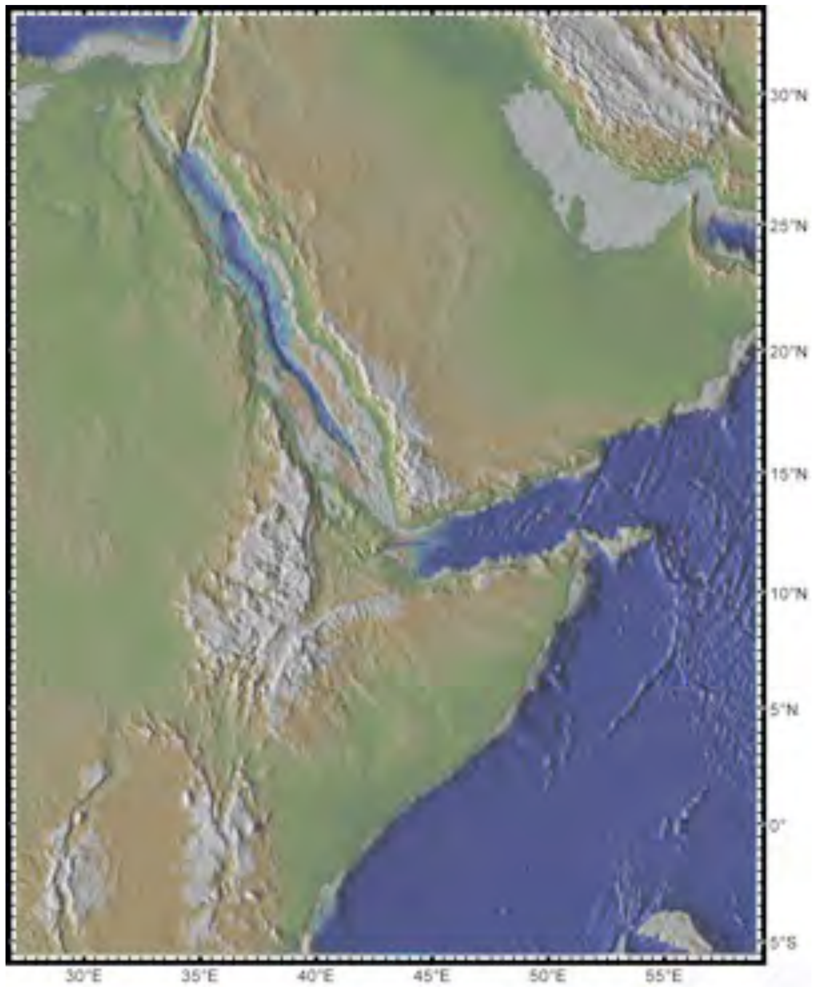


We can formulate the isostatic effects of active rifting in the following manner. Assuming an intial linear lithospheric geotherm, which amounts to ignoring the effects of any internal heat production, gives the temperature Tz at depth z

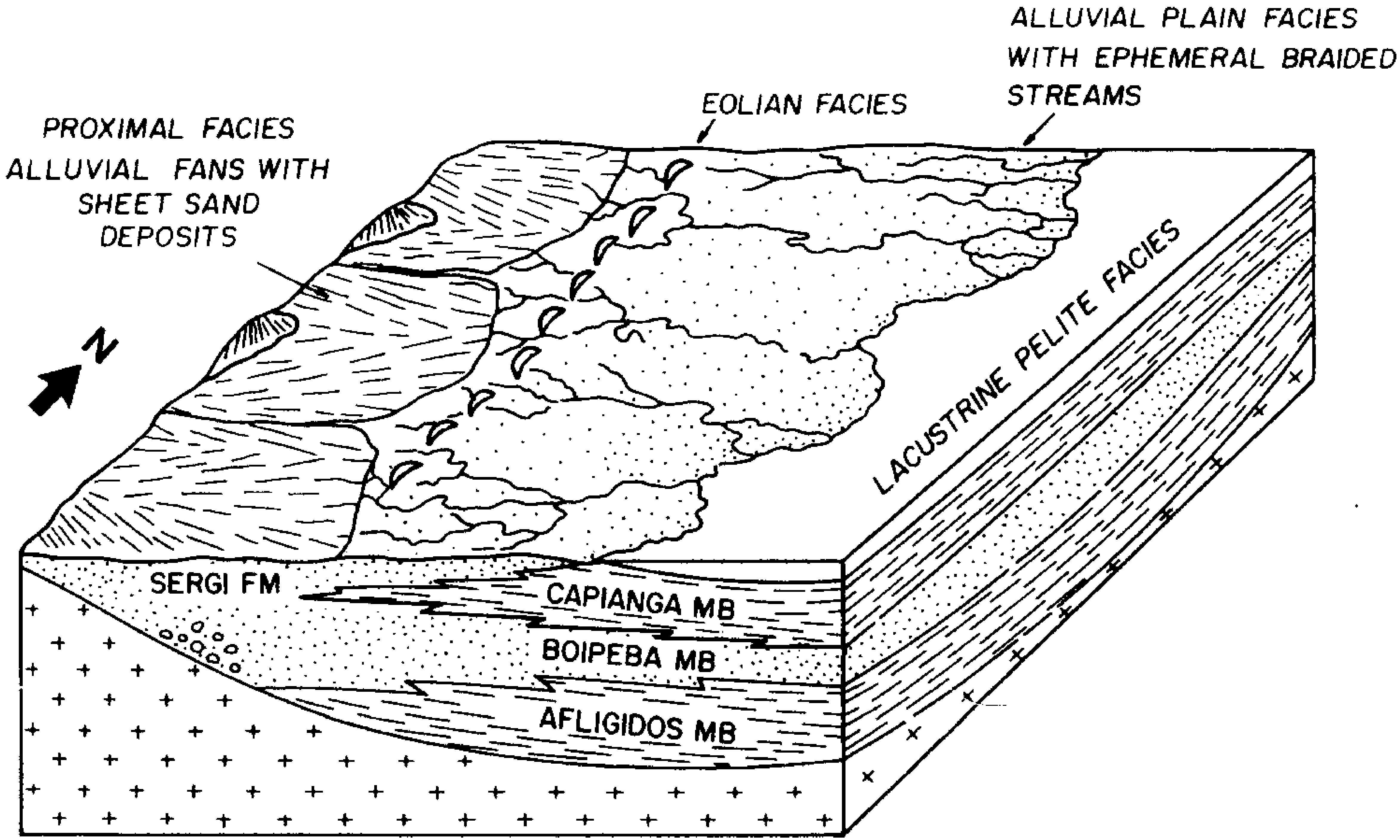


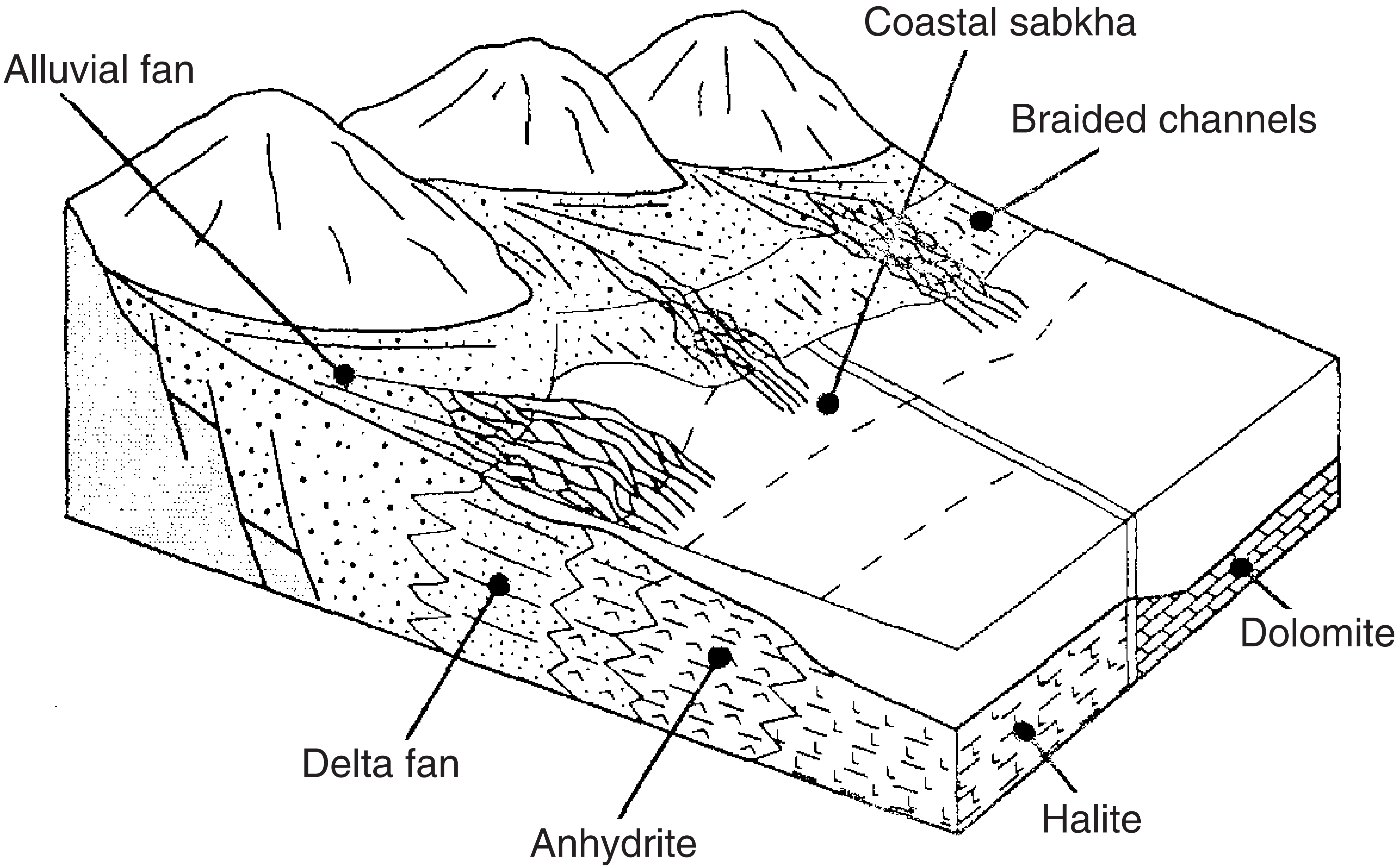
Comparative subsidence of a portion of thinned lithosphere (degree of crustal shortening of 2) for subaerial conditions, subaquatic conditions and sediment burial conditions. Note increased subsidence from s1 to s3.



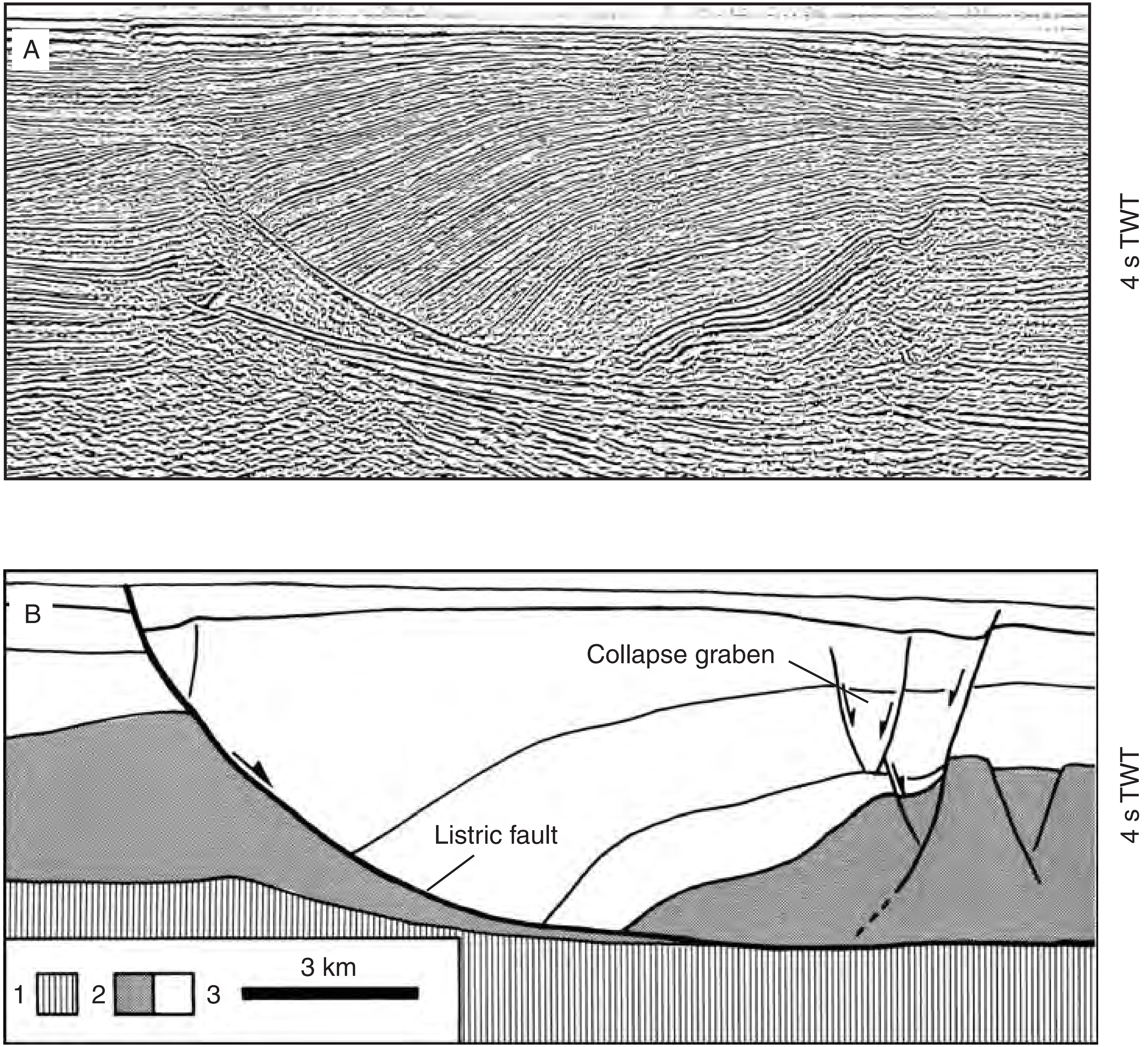


Distribution of alluvial fans in the Baringo-Bogoria rift area

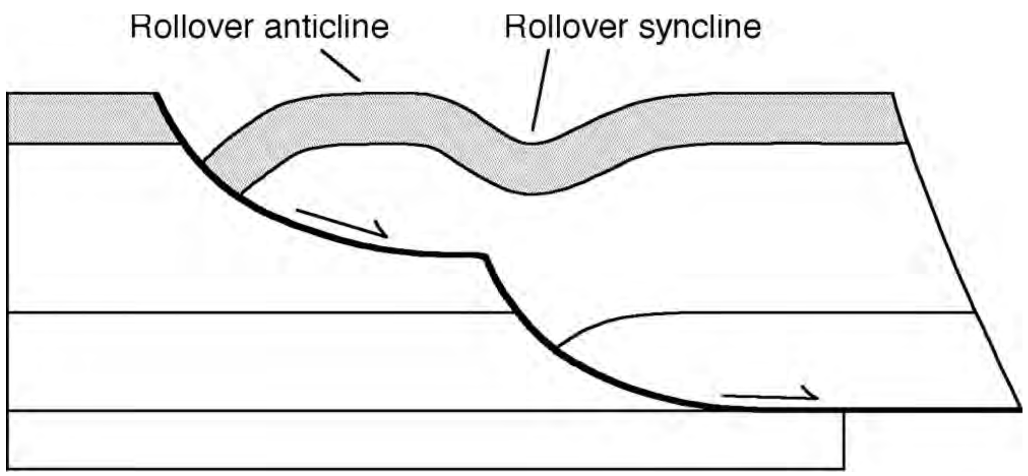

PROXIMAL FACIES
ALLUVIAL FANS WITH SHEET SAND DEPOSITS
EOLIAN FACIES
ALLUVIAL PLAIN FACIES WITH EPHEMERAL BRAIDED STREAMS
N
LACUSTRINE PELITE FACIES
SERGI FM
CAPIANGA MB
BOIPEBA MB
AFLIGIDOS MB


Coastal sabkha
Alluvial fan
Braided channels
Dolomite
Delta fan
Halite
Anhydrite

Example

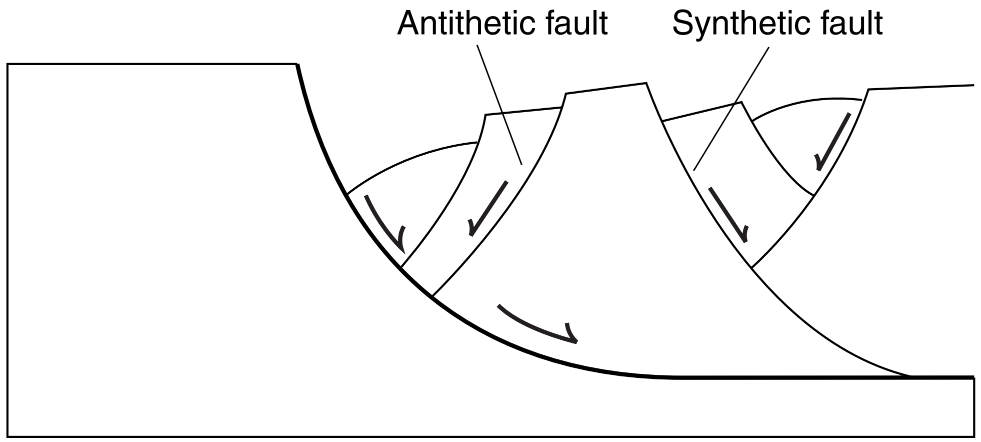


Complex fault systems and related folds found in rifts



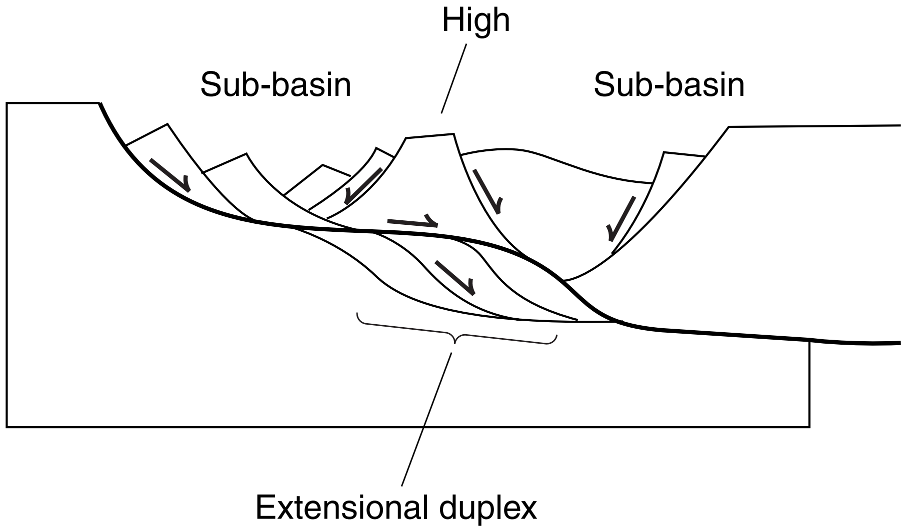
(a)

(a) Cross section showing a rollover anticline above a listric normal fault, and a rollover syncline forming at the intersection of a ramp and flat.



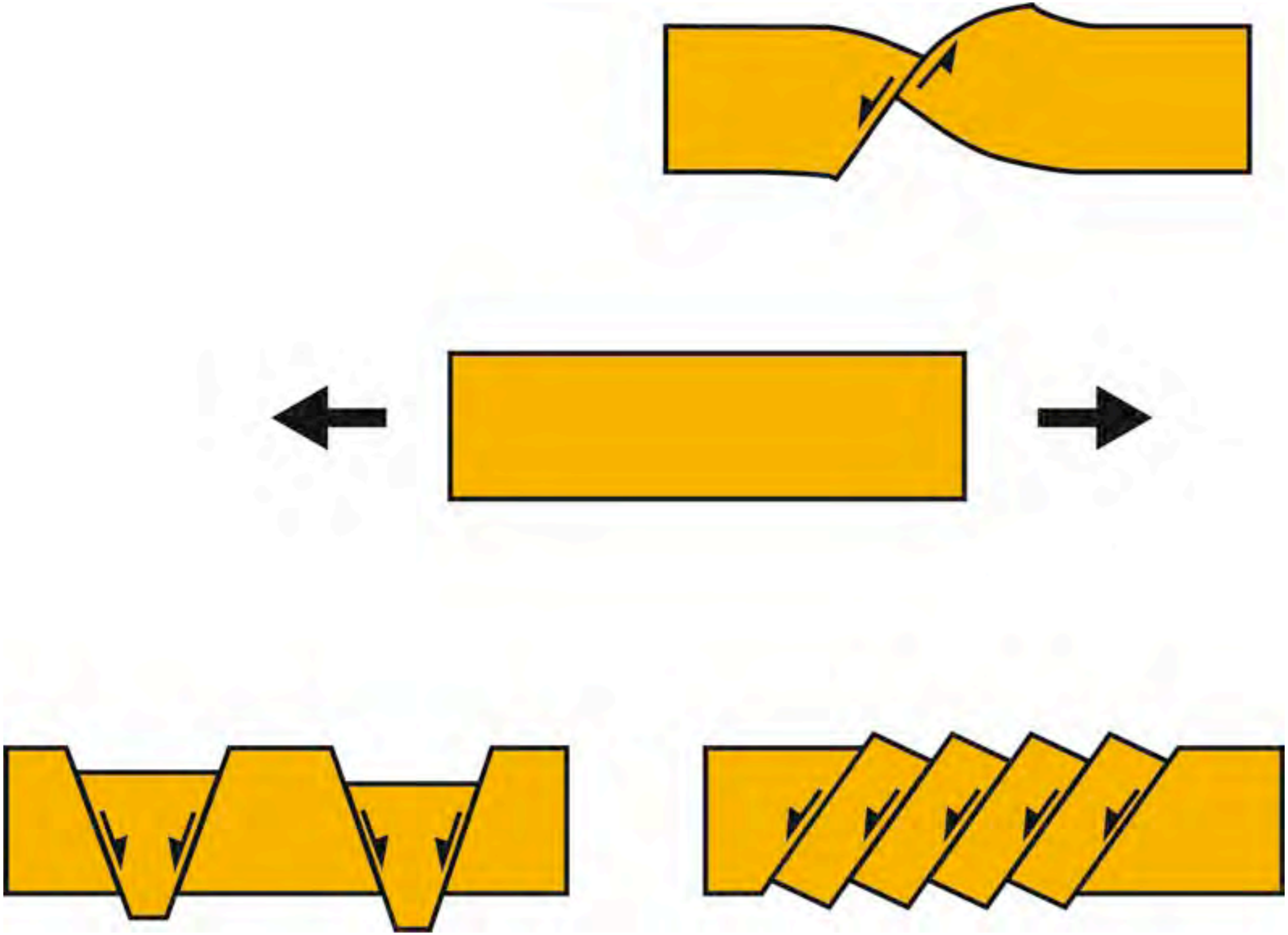
(b)

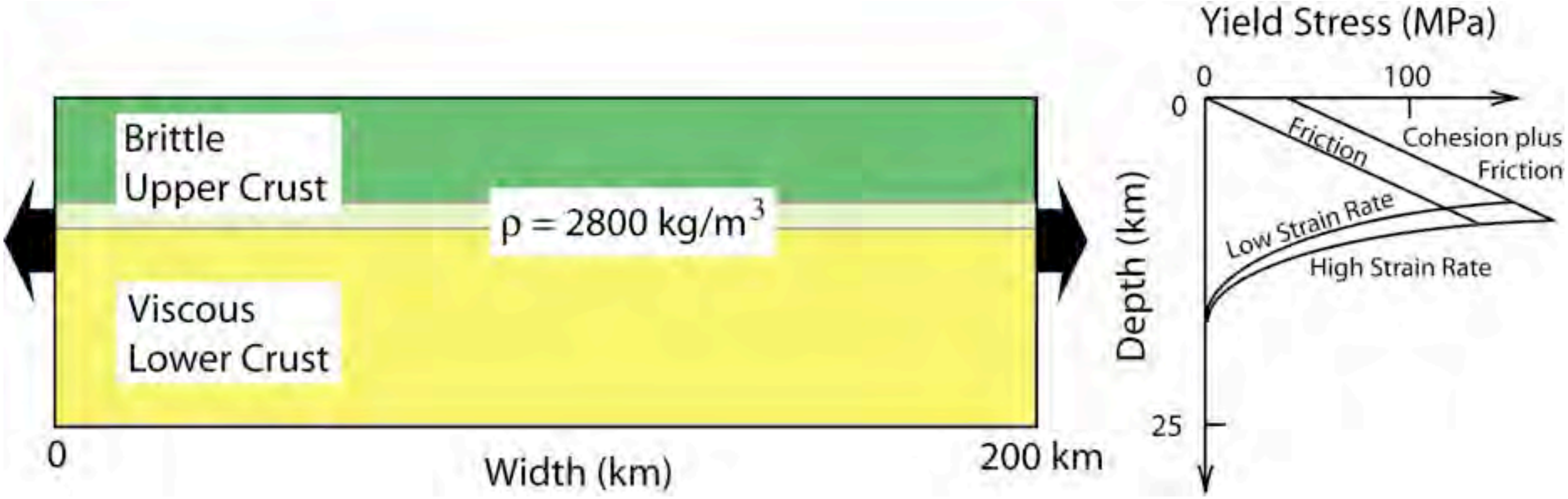
(b) Here, antithetic faults (dipping toward the main fault) and synthetic faults (dipping in the same direction as the main fault) break up the hanging-wall block.

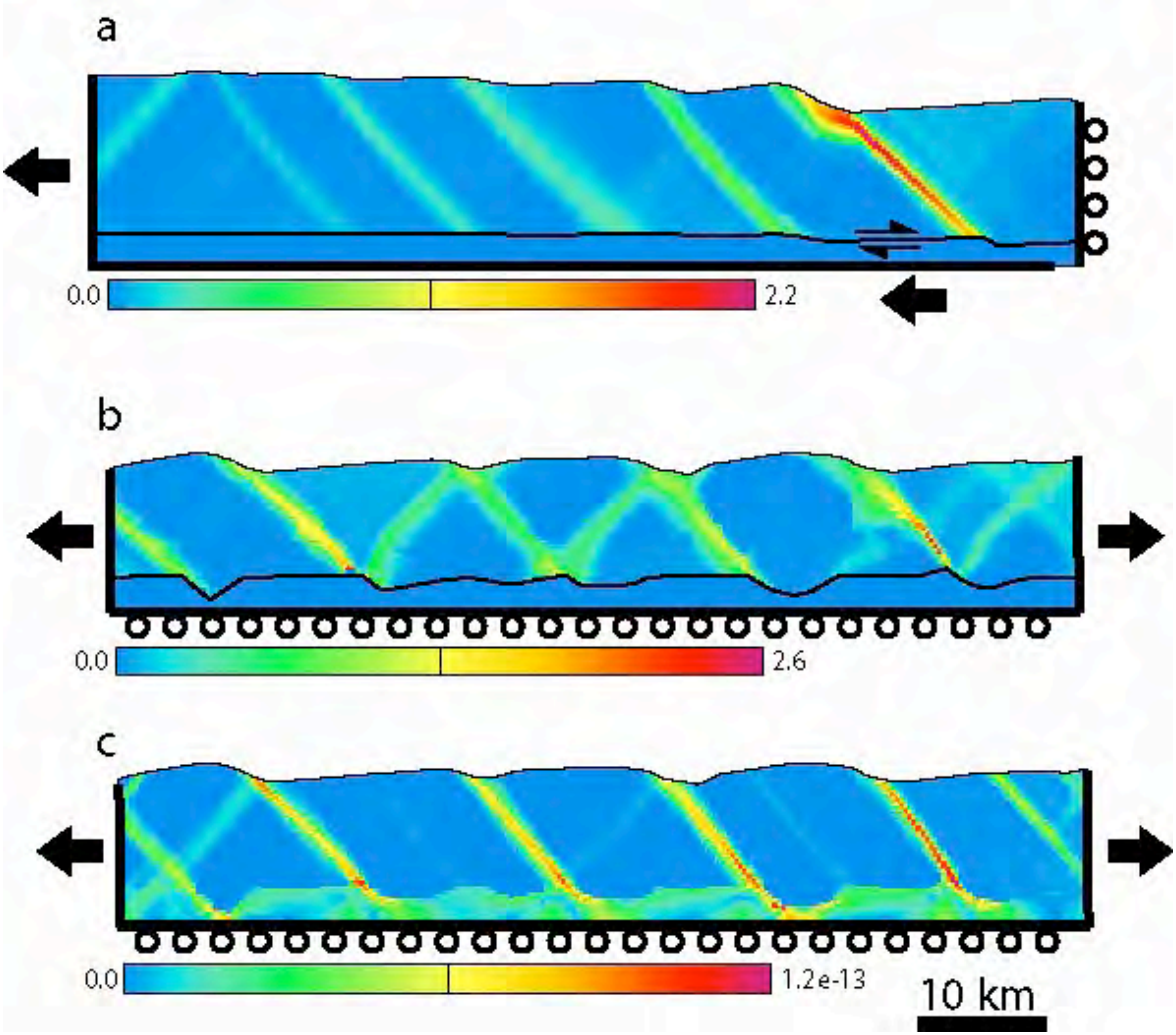


(c)

(c) Complex fault system underlain by an extensional duplex. Note the sub-basins and the high block between them.

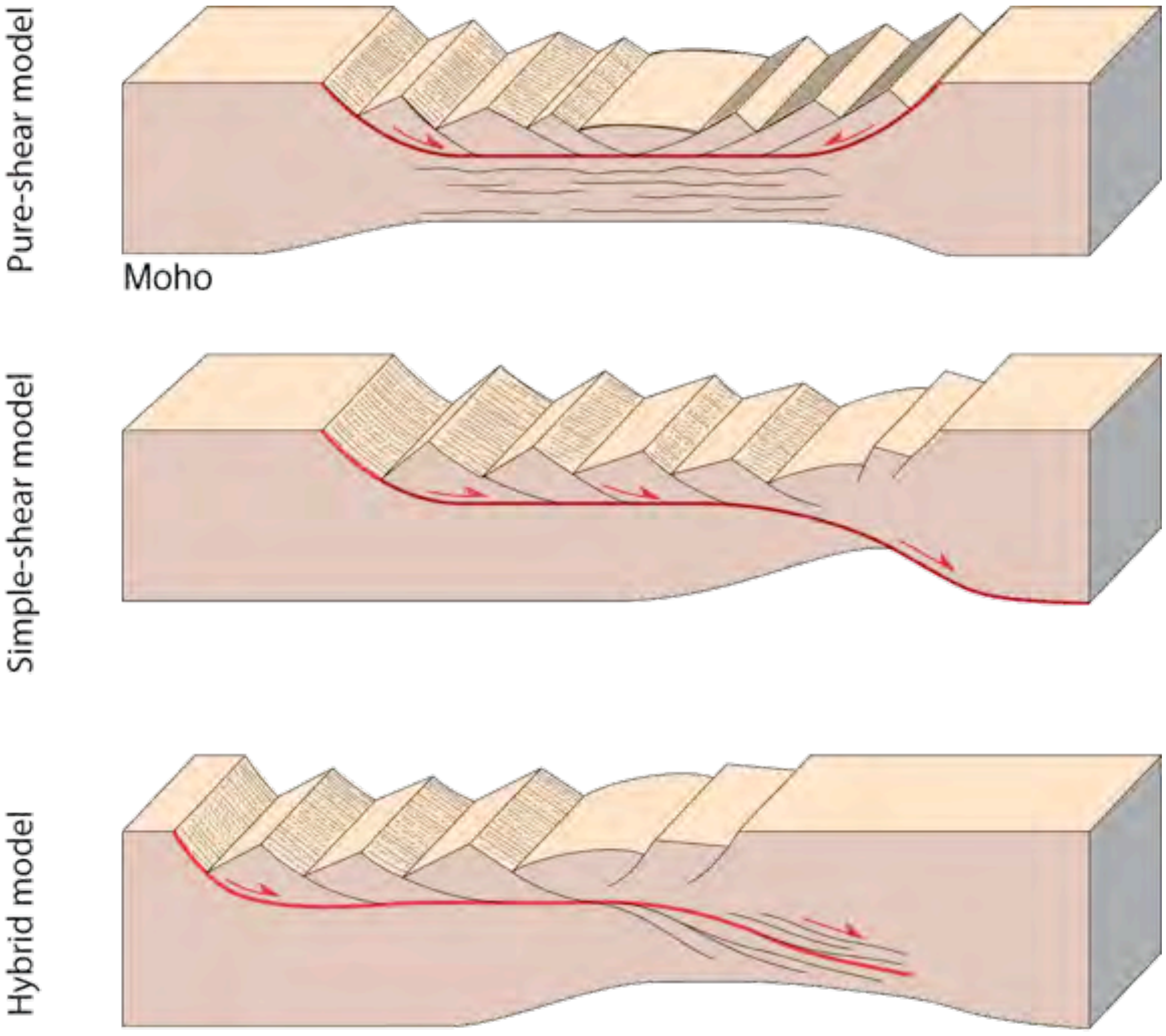



Brittle
Upper Crust
ρ = 2800 kg/m3
Viscous
Lower Crust
0
Width (km)
200 km
Yield Stress (MPa)
0
100
0
Friction
Cohesion plus
Friction
Low Strain Rate
High Strain Rate
Depth (km)
25

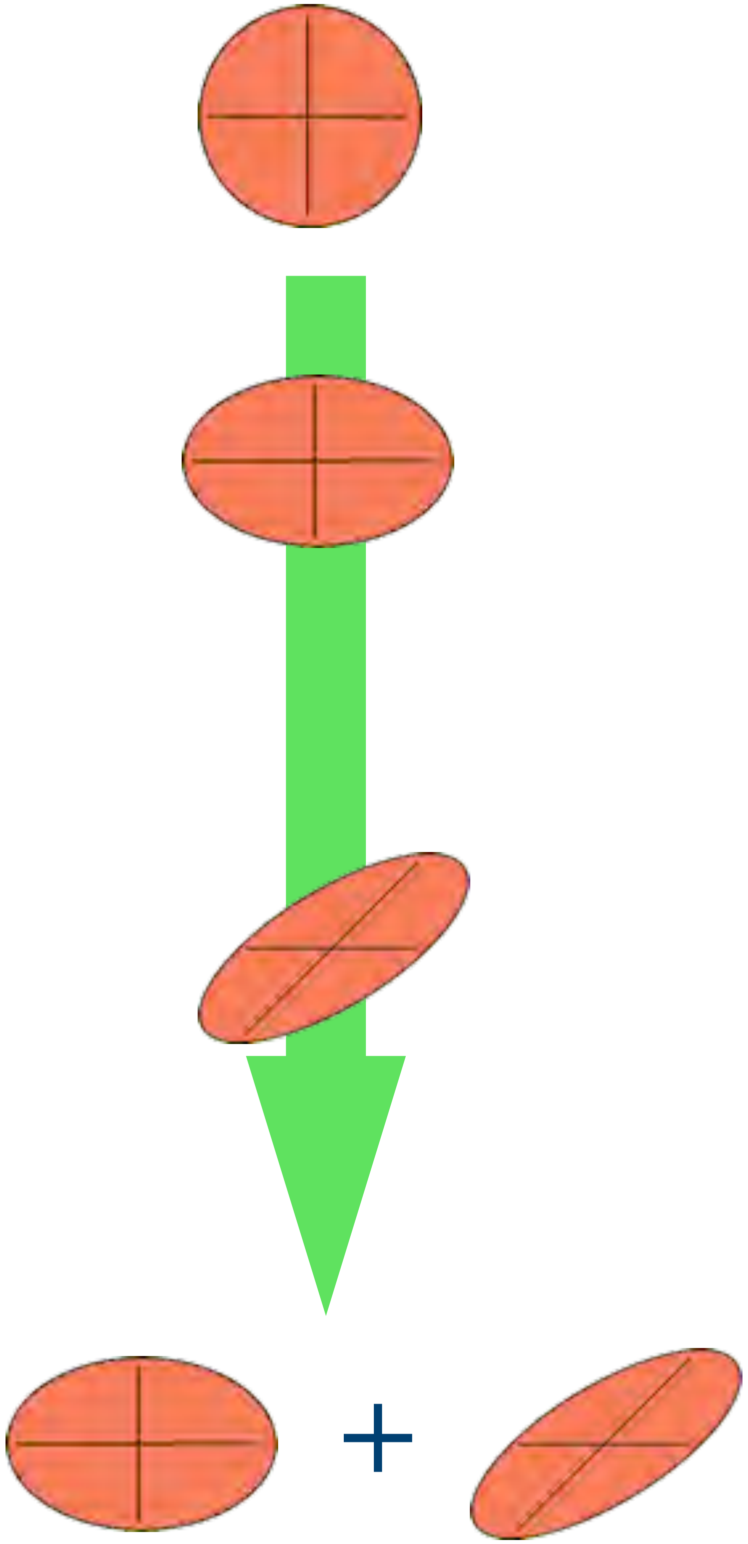

a
0.0
2.2
b
0.0
2.6
c
0.0
1.2e-13
10 km

Stretching the continents

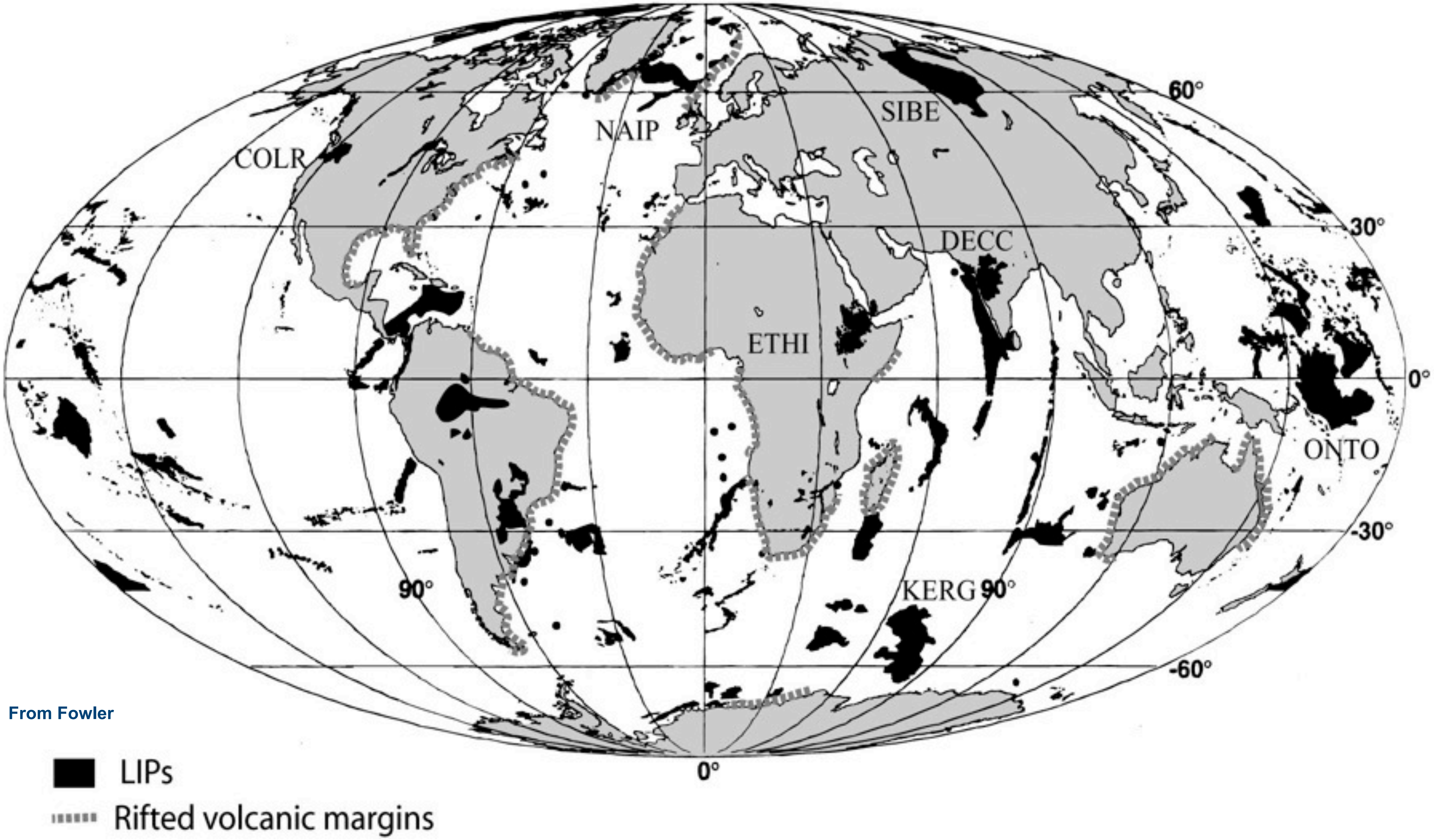
Different models of rifting



(simple shear plus broad zone of distributed shear at depth)



Large Igneous Provinces (LIPs)



From Fowler

Beispiele:
Ostafrikanischer Graben,
Rheingraben,
Rio Grande Rift,
Baikal Rift

Main LIPs associated with rifted zones

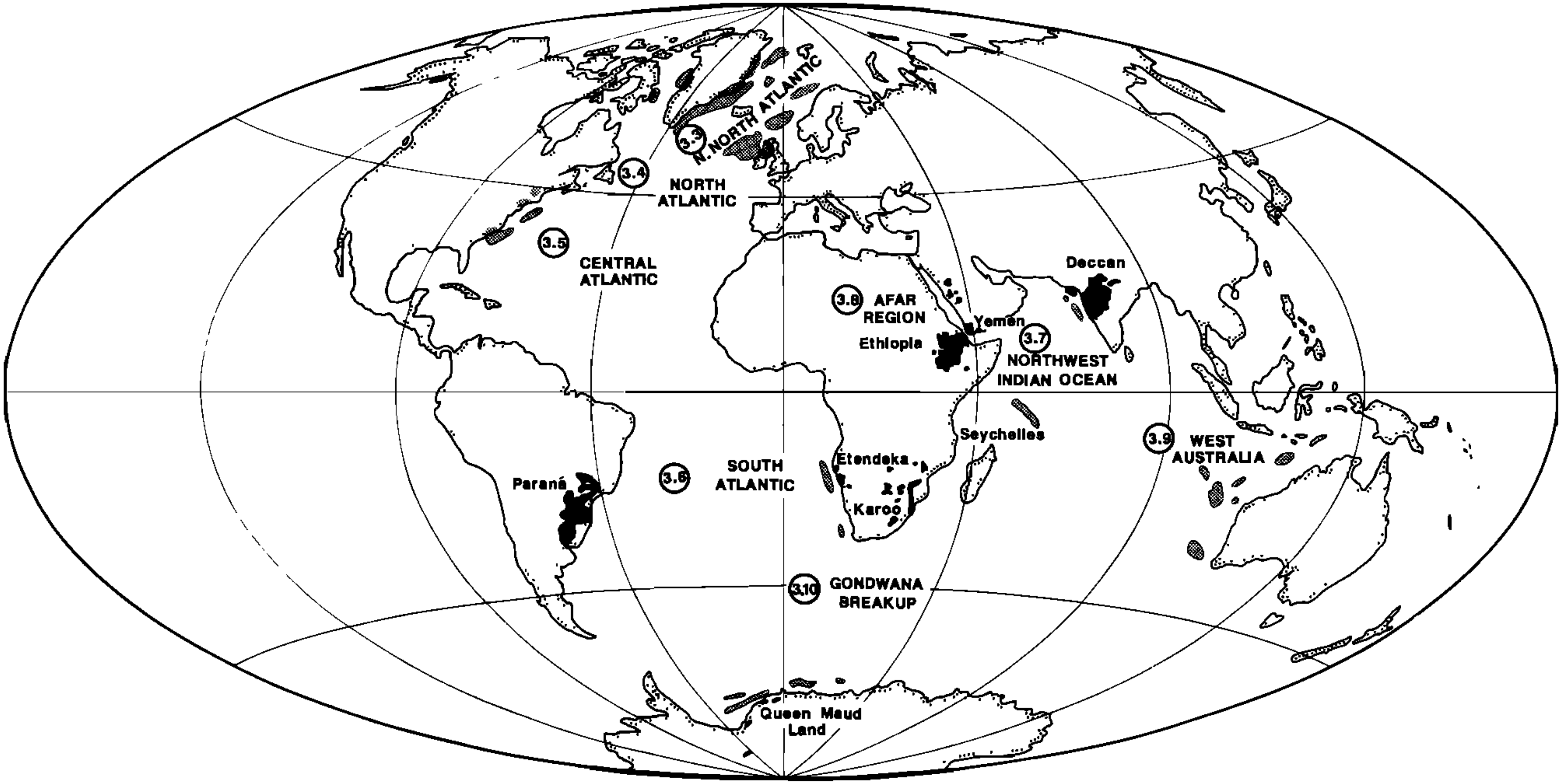


Fig. 1. Location of voluminous extrusive volcanic rocks on rifted continental margins (hatched), and extent of associated continental flood basalts (solid) with circled numbers showing section of this paper where each region is discussed. Projection is Aitoff equal area.

White & McKenzie, 1989

Example of LIPs associated with rifted zones

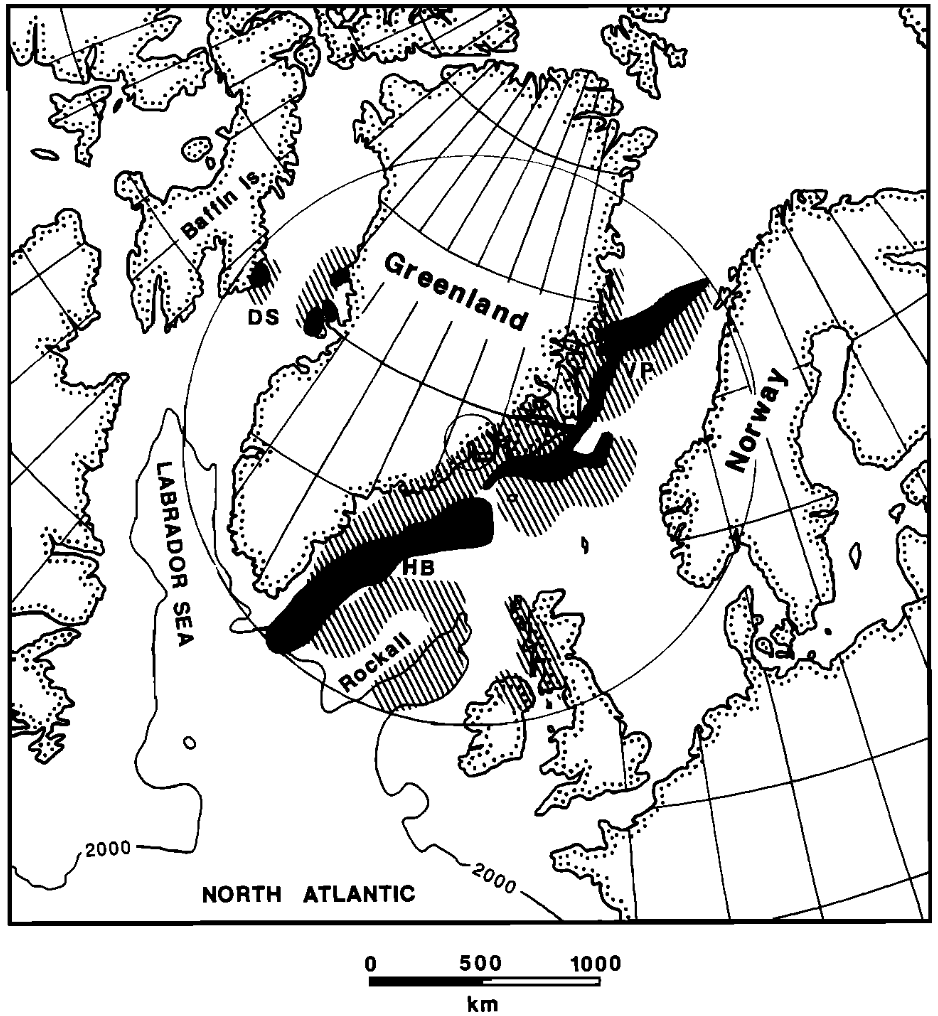


Fig. 8. Reconstruction of the northern North Atlantic region at magnetic anomaly 23 time, just after the on of oceanic spreading. Position of extrusive volcanic rocks is shown by solid shading, with hatching to show extent of early Tertiary igneous activity in the region. The inferred position of the mantle plume beneath e Greenland at the time of rifting and the extent of the mushroom-shaped head of abnormally hot asthenosph are superimposed. Projection is equal area centered on the mantle plume.

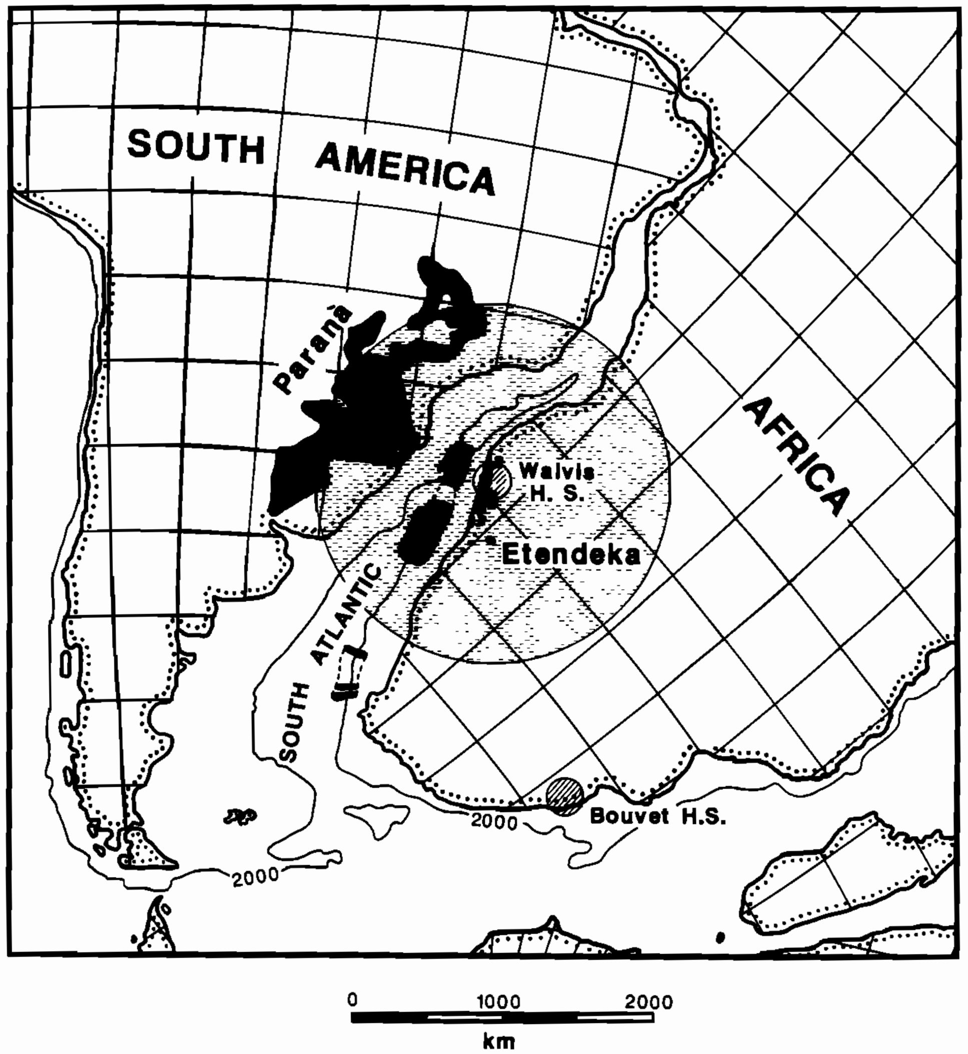
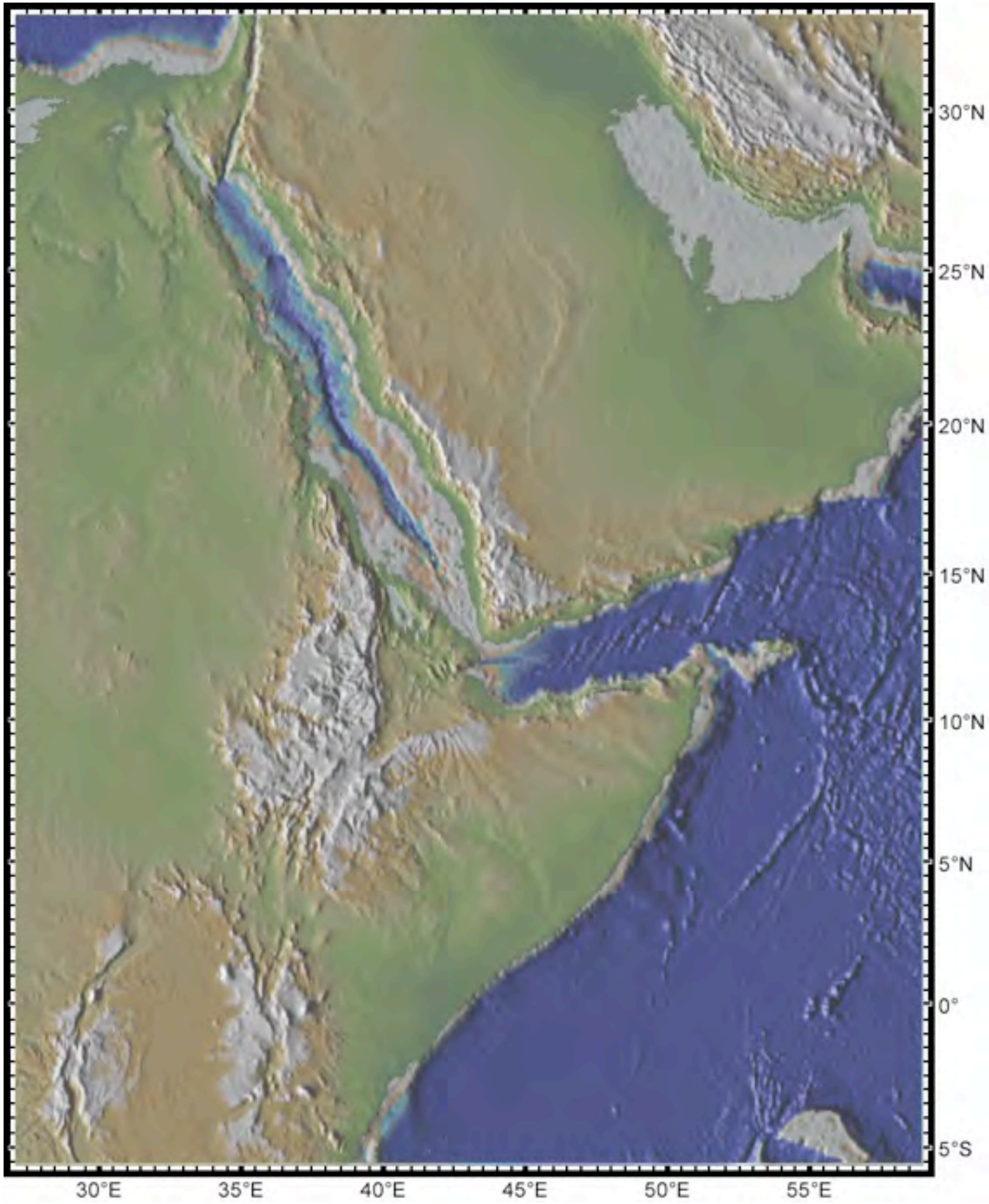
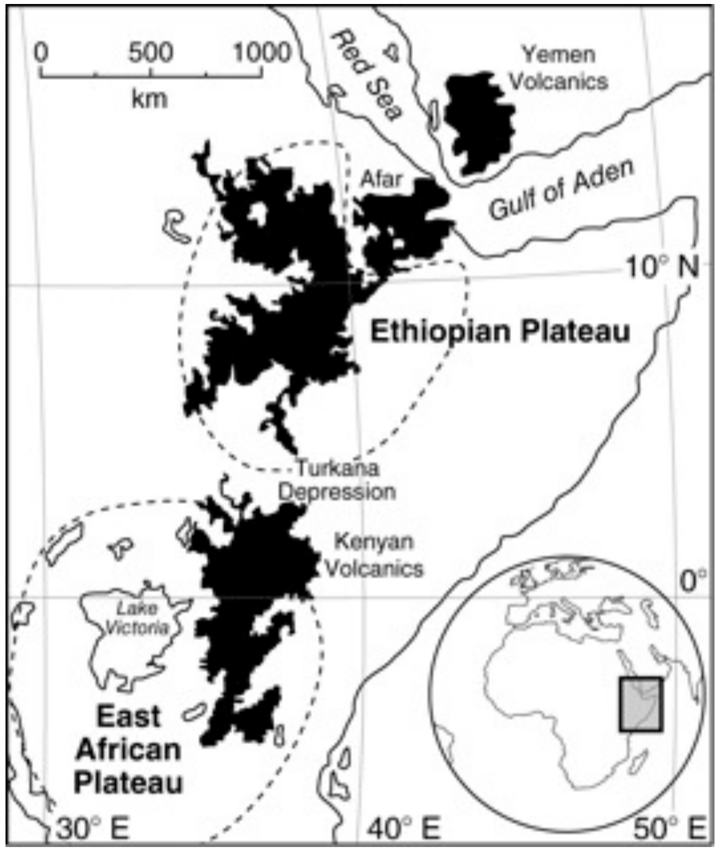


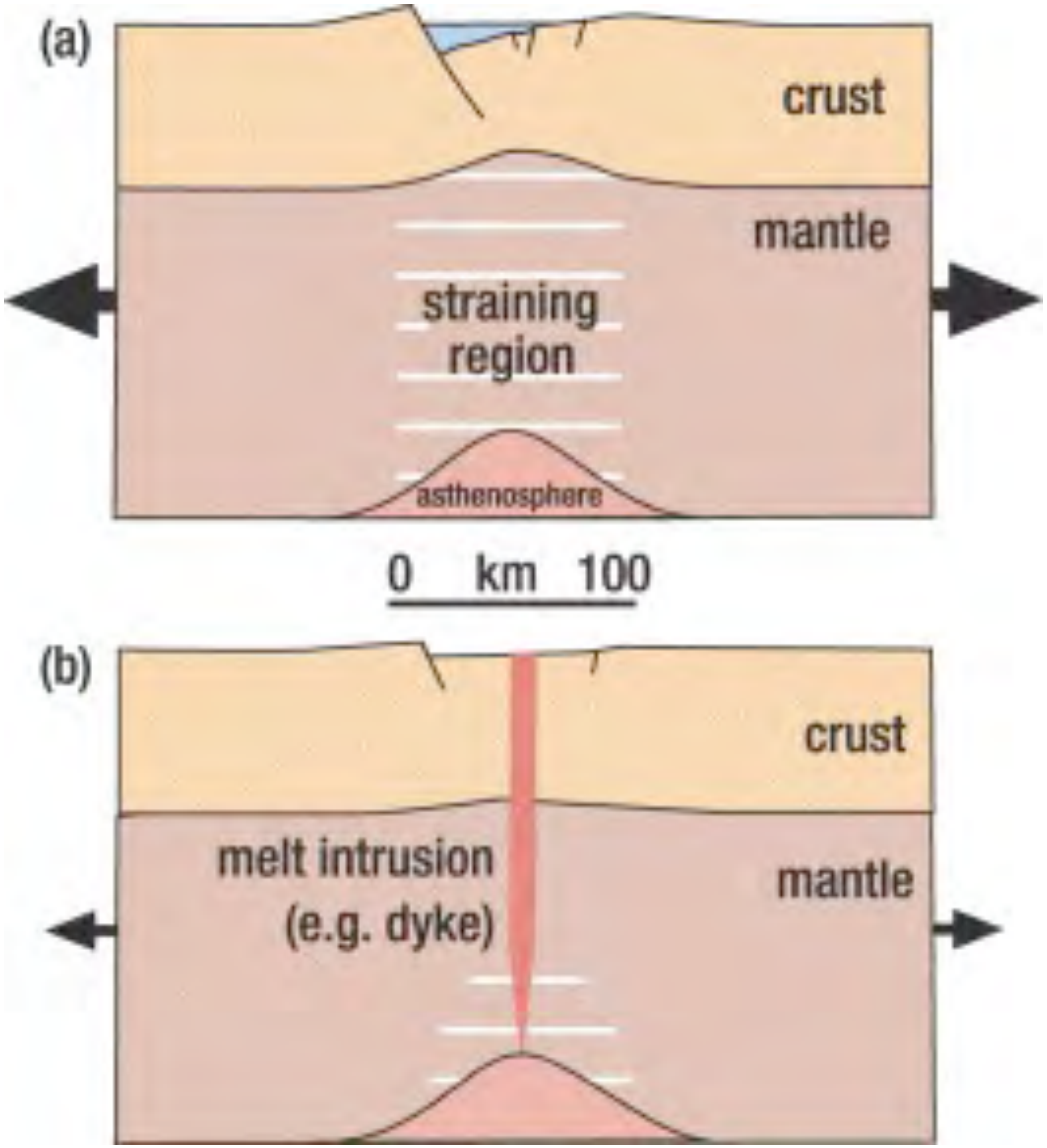
Fig. 15. Reconstruction of South Atlantic at anomaly M4 time (approximately 120 Ma) shortly after the onset of seafloor spreading. Solid shading shows areas of extrusive basalts. Extent of Paraná basalts from *Hawkesworth et al.* [1986], Etendeka basalts from *Eales et al.* [1984], offshore areas from seaward dipping reflectors reported by *Hinz* [1981], *Gerrard and Smith*, [1982] and *Austin and Uchupi* [1982]. Shaded area around Walvis hot spot shows extent of mushroom head of abnormally hot mantle. Equal area projection is centered on the hot-spot location.

Example of LIPs associated with rifted zones





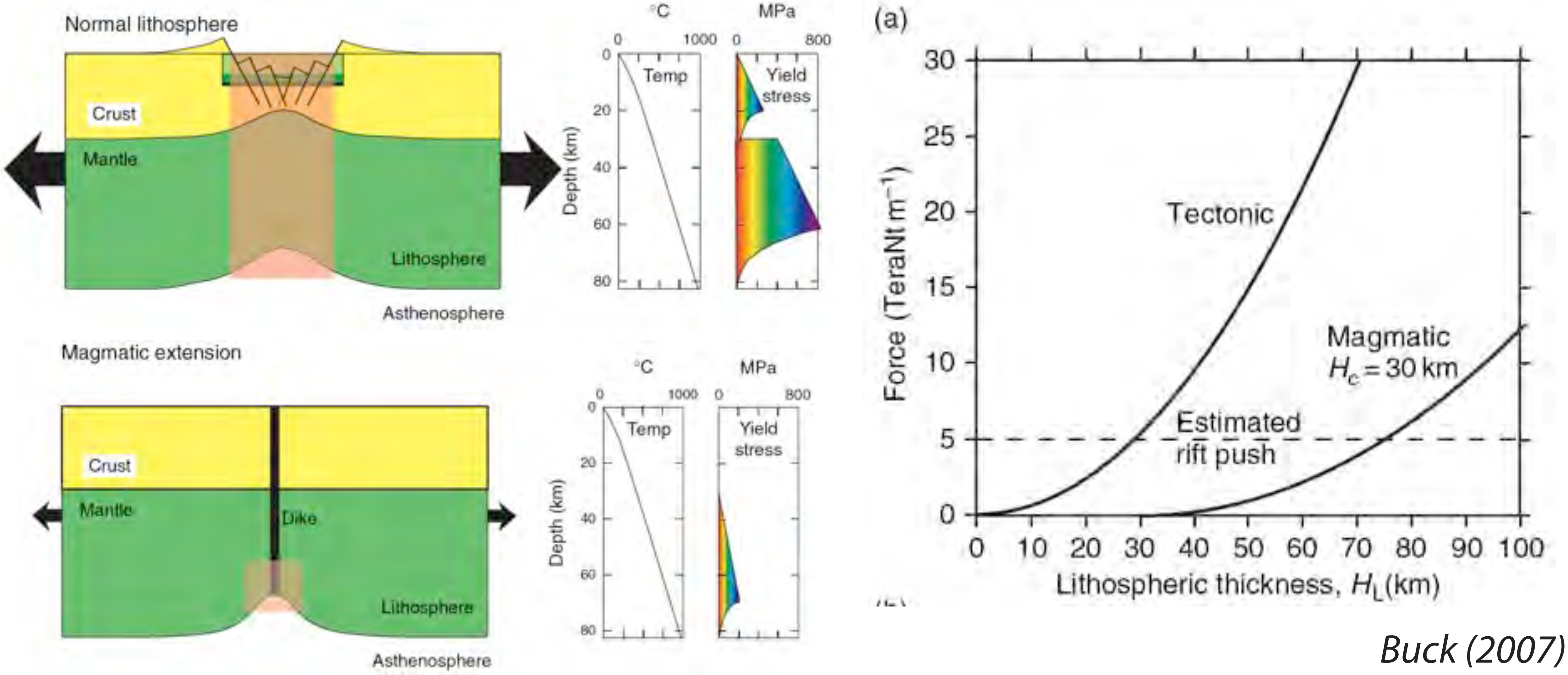
Extensional mechanisms & magmatism



Mechanical stretching

Magmatic extension

Extensional mechanisms & magmatism



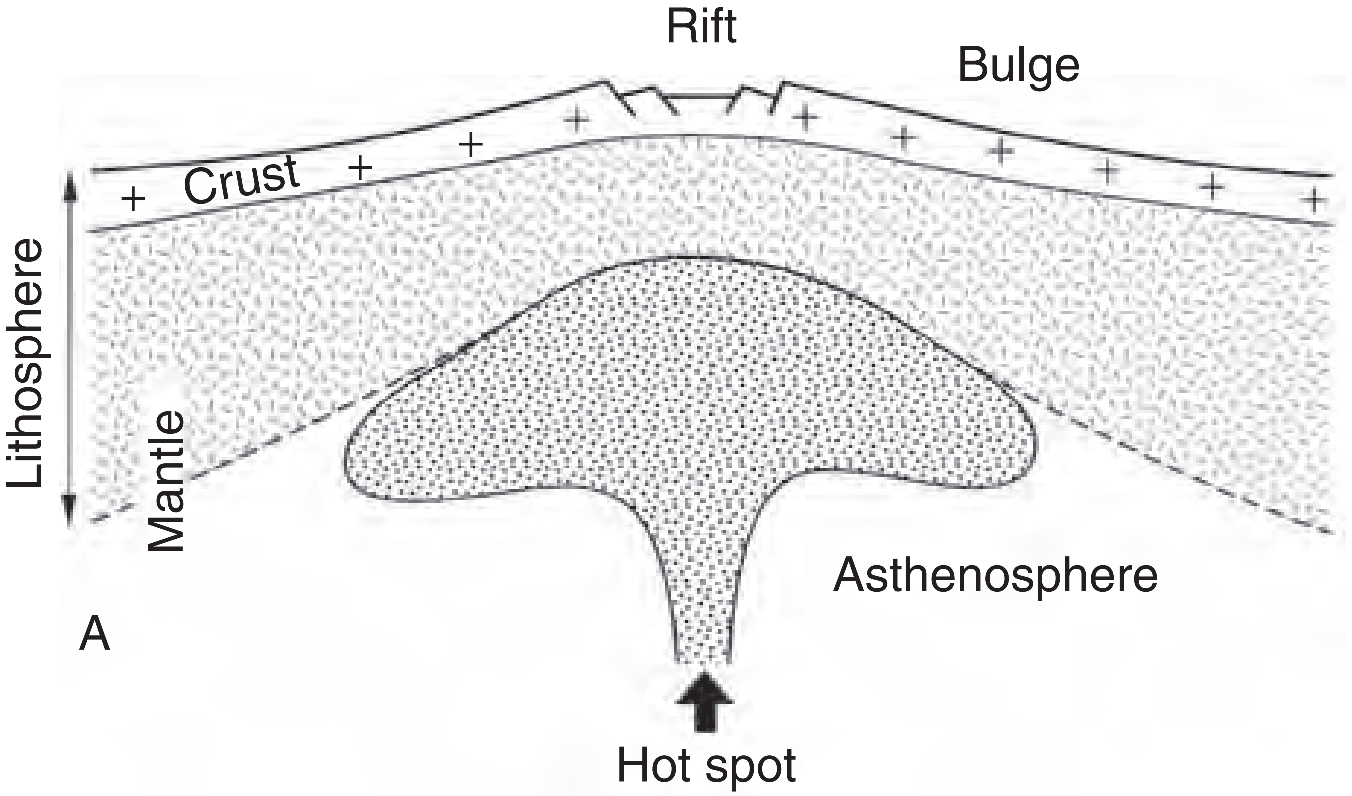
Buck (2007)

Magmatic rifting requires significantly less tectonic force than does amagmatic rifting.

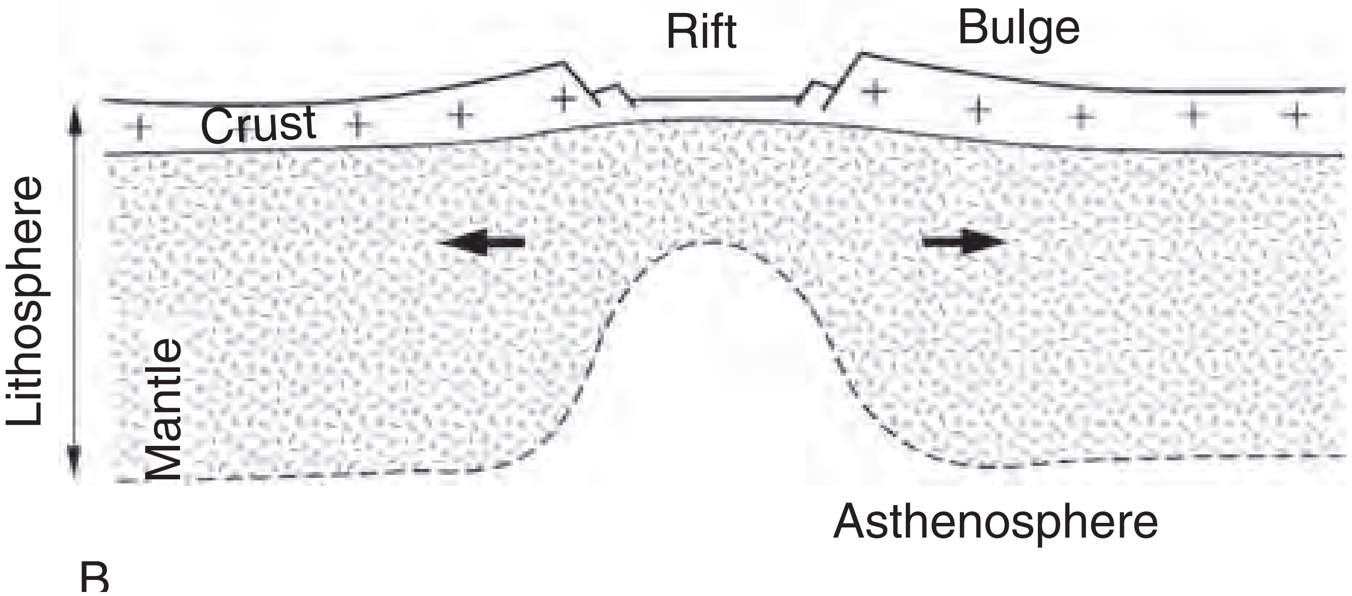
Thus, early magmatism associated with active rifting provides a plausible solution to the "tectonic force" paradox. But how is this magma distributed with depth and how much magma is required for rupture?

Two types of rifted zones

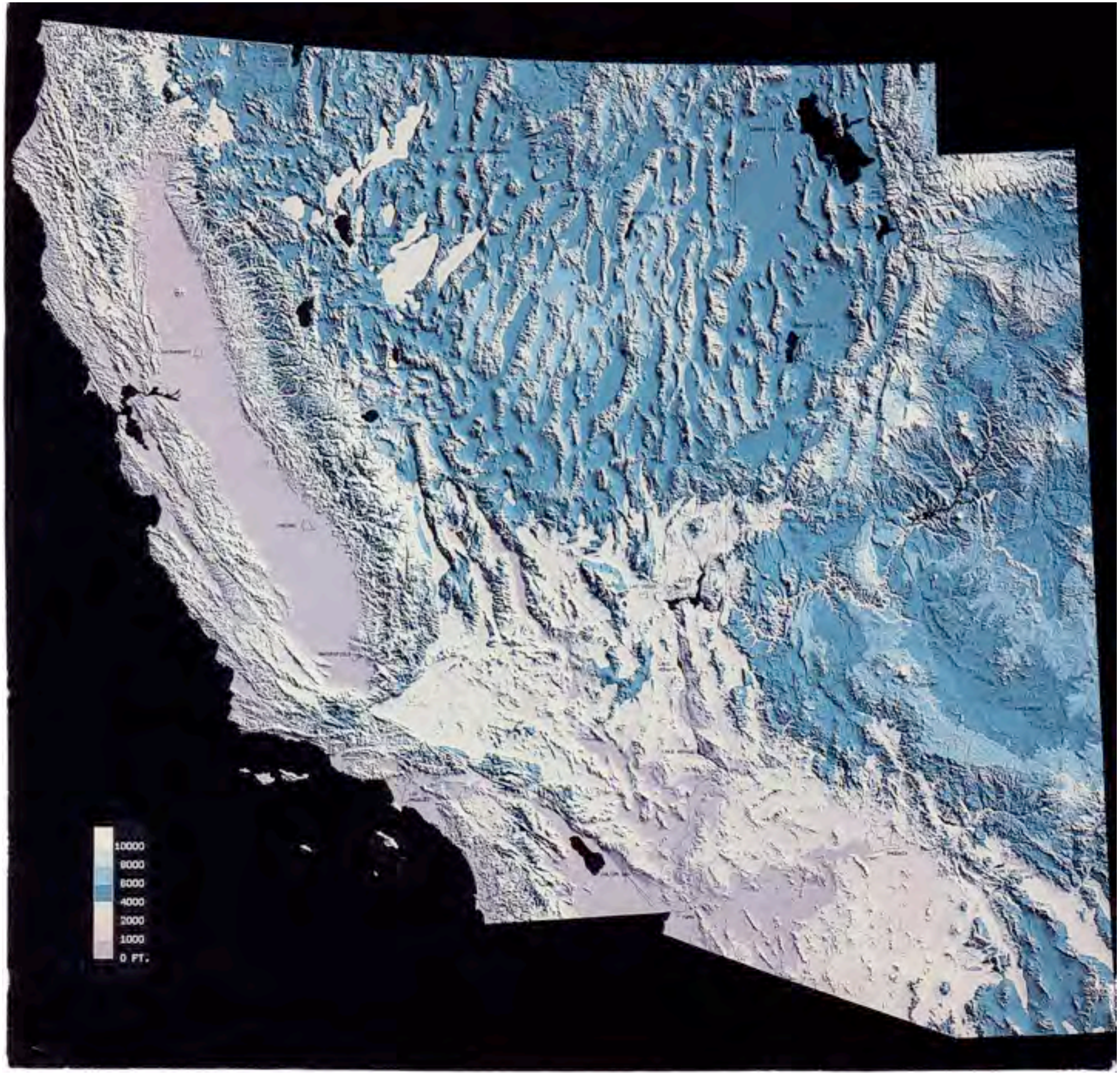
Associated with volcanism: plume related?



Without volcanism: tectonic?

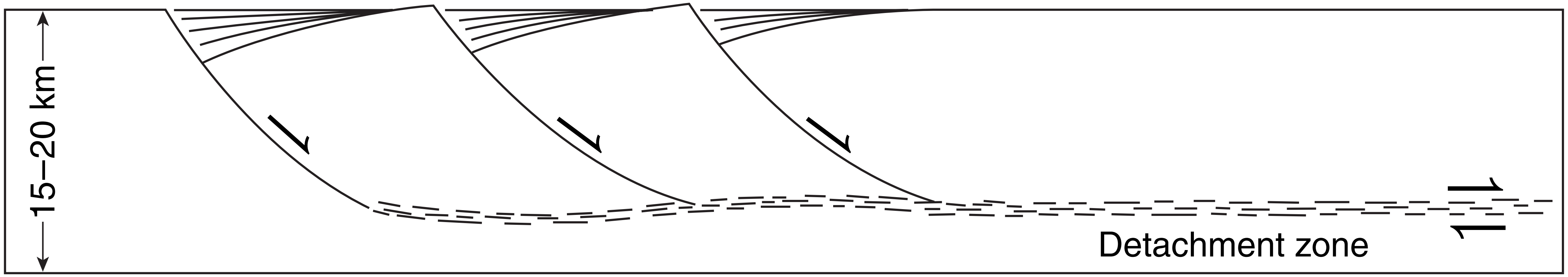


Intracontinental extension: Basin & Ranges



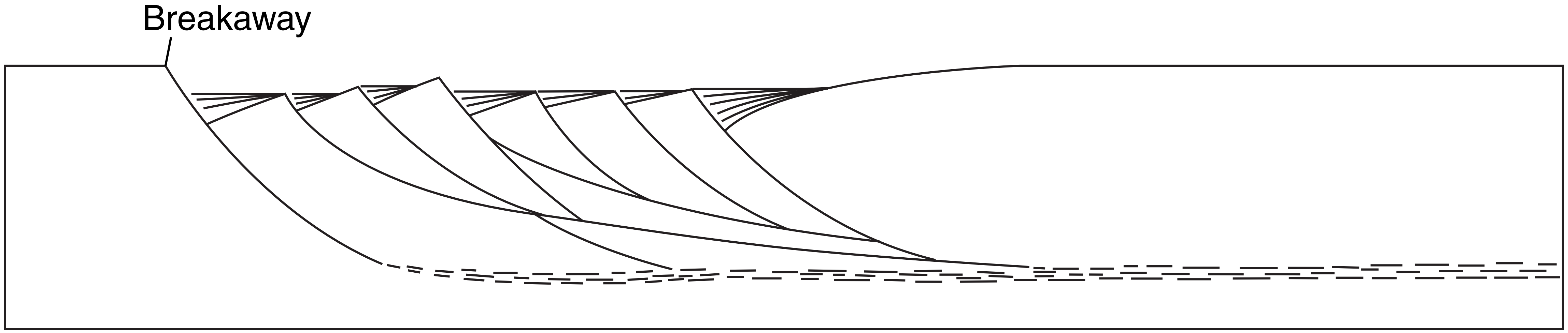
Intracontinental extension: Basin & Ranges

Core-complex development



(a)

An initially subhorizontal, midcrustal ductile detachment zone is formed beneath an array of steeply dipping normal faults in the upper plate

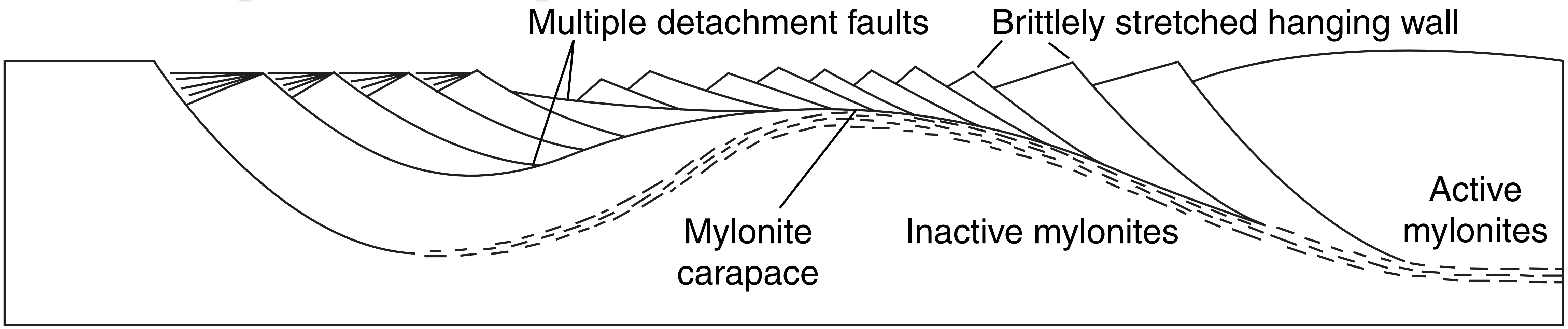


(b)

(b) additional normal faults have formed, increasing the geometric complexity;

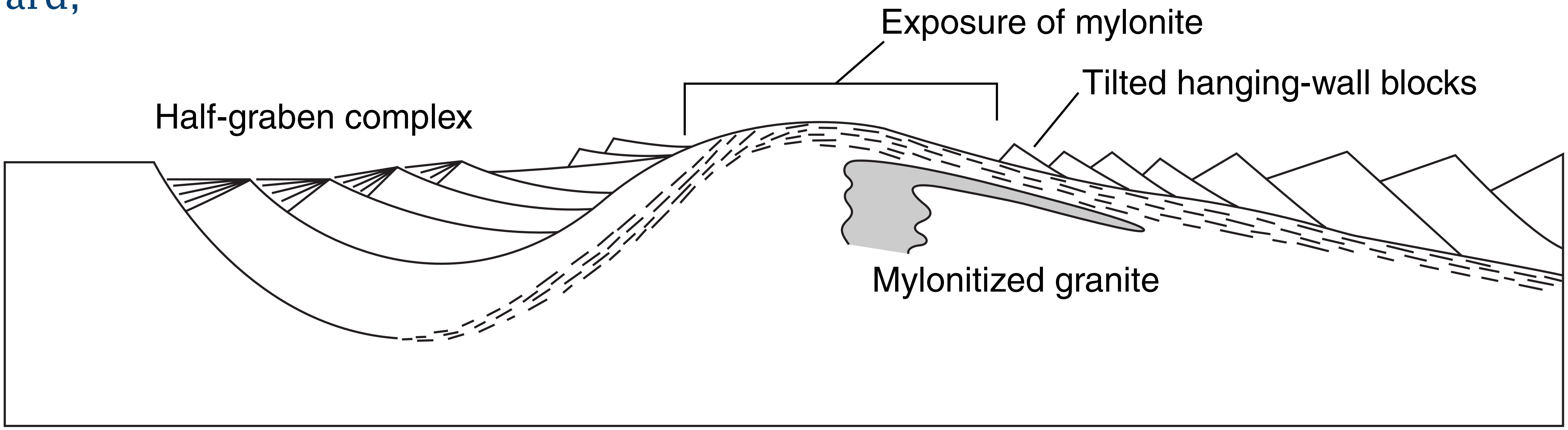
Intracontinental extension: Basin & Ranges

Core-complex development



(c)

(c) as a result of unloading and isostatic compensation, the lower plate bows upward;



(d)

(d) extreme thinning of the hanging wall exposes the “metamorphic core” (an exposure of the mylonitic shear zone of the detachment). Some of the hanging-wall blocks have rotated by 90°.