Beyond Plate Tectonics:
Plumes, Hotspots, Supervolcanoes and Diamonds

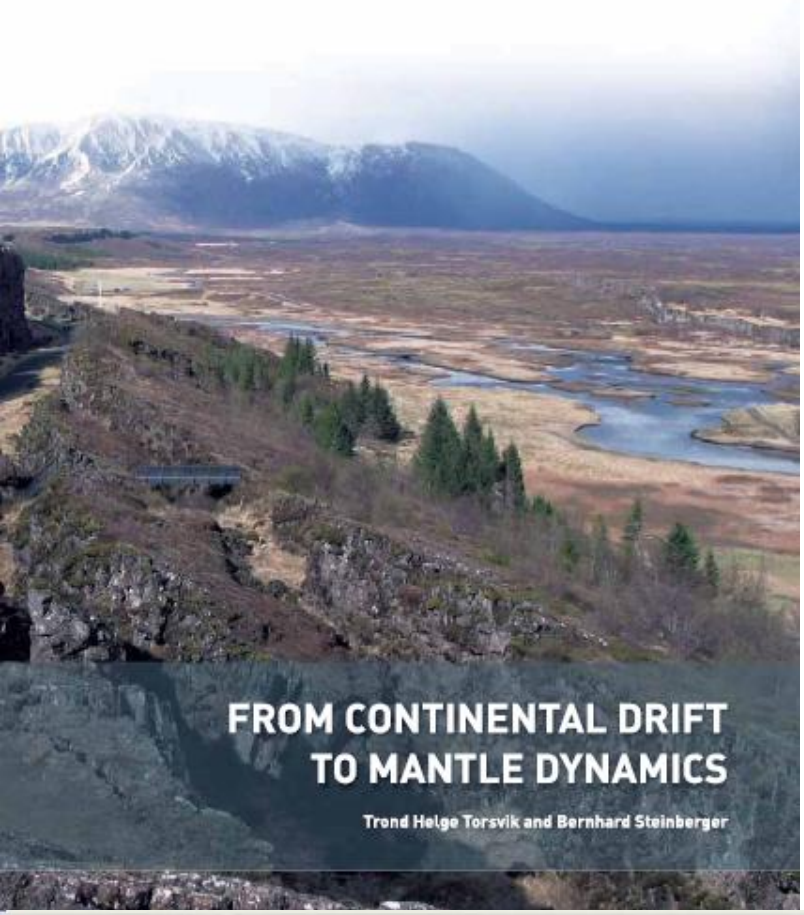
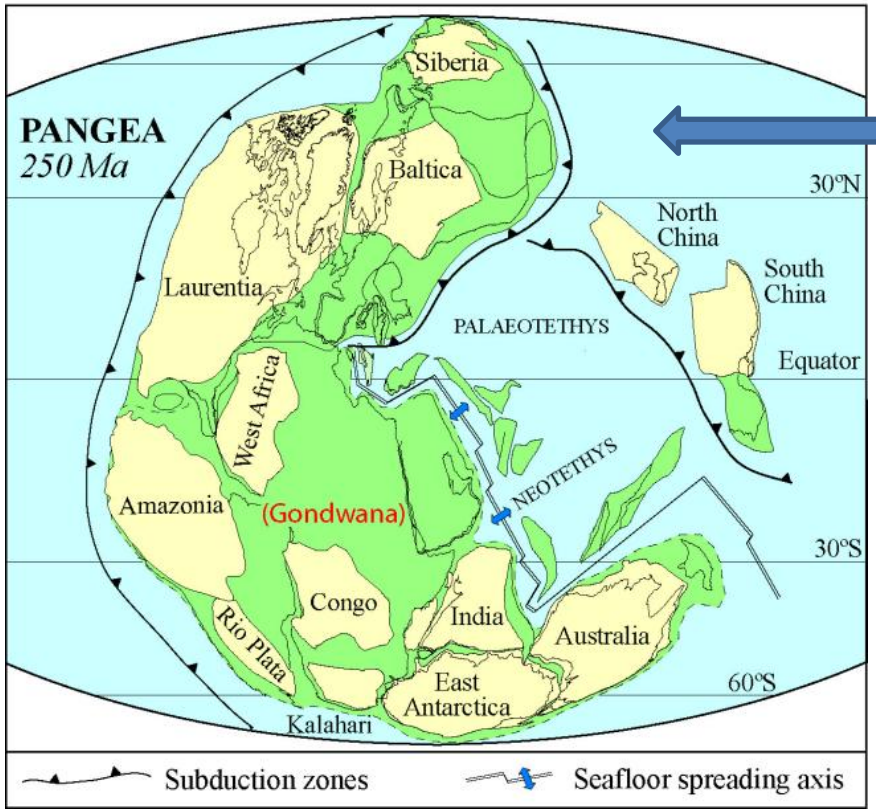


Plate tectonics is as fundamentally unifying to the Earth Sciences as Darwin's Evolution Theory is to Life Sciences.....but there is no generally accepted mechanism that explains Plate Tectonics in the framework of mantle convection nor explain plumes, hotspots & supervolcanoes unrelated to plate boundaries.

Our prime aim is to integrate Plate Tectonics into a new unifying theory of Mantle Dynamics (4th revolution in Earth Sciences).

Mantle Dynamics - The 4th Revolution

Integrating Plate Tectonics with processes in the underlying mantle



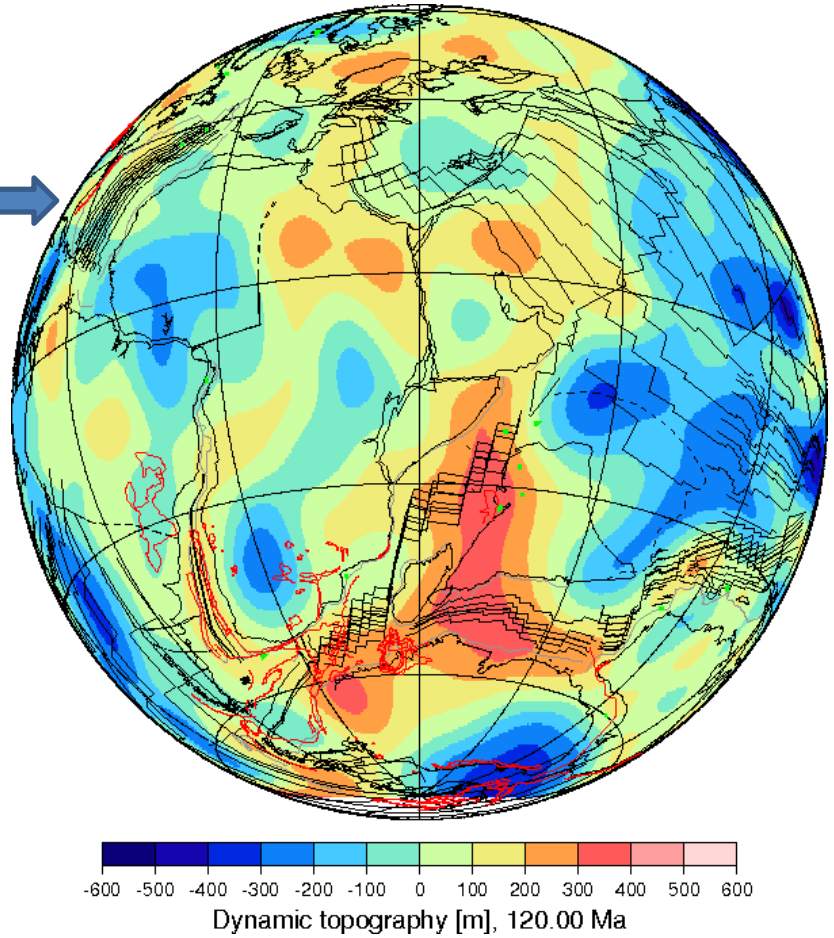
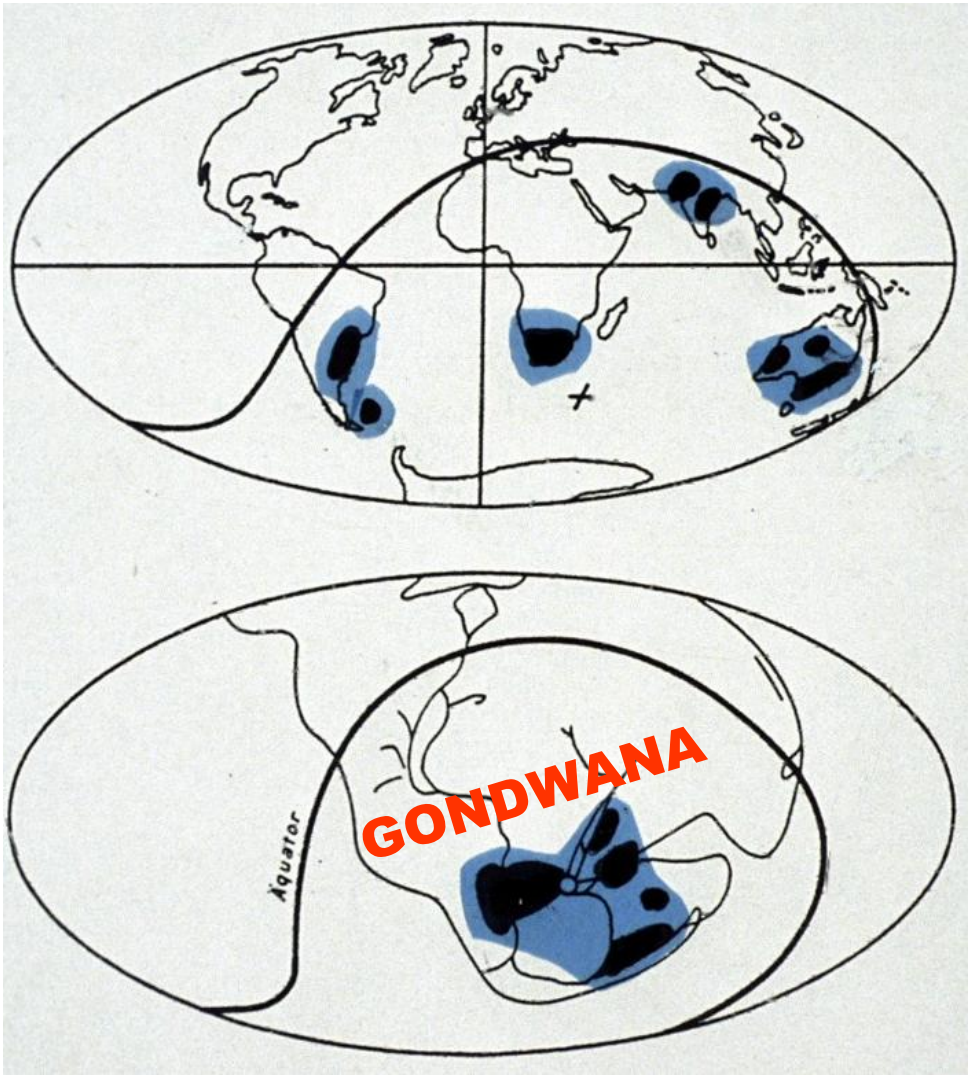


PLATE TECTONICS

What is it & a brief historical account

Alfred Wegener (1915)

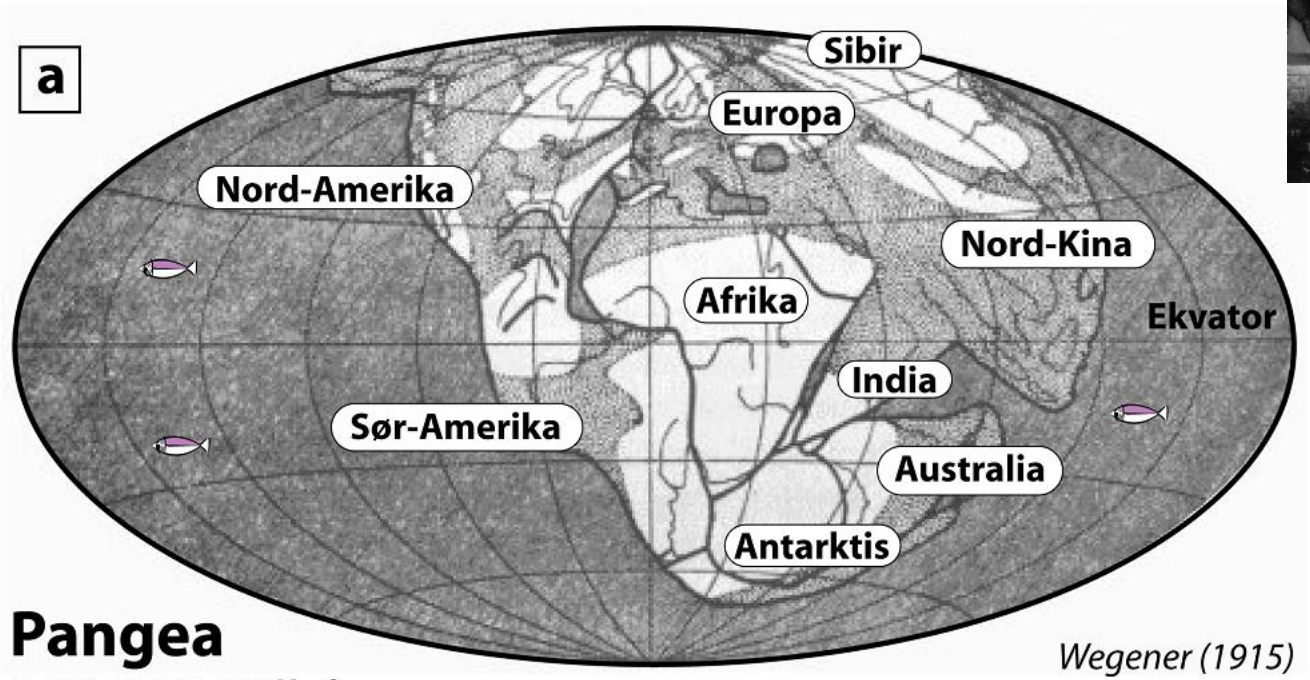
He used glacial relicts, c. 300 Myr (blue), to group the continents around a reconstructed icecap at the south pole (bottom diagram).



The first revolution... Continental Drift

The Debate Begins

Wegener Drifts Into Gear



Pangea
300-310 Mill. år

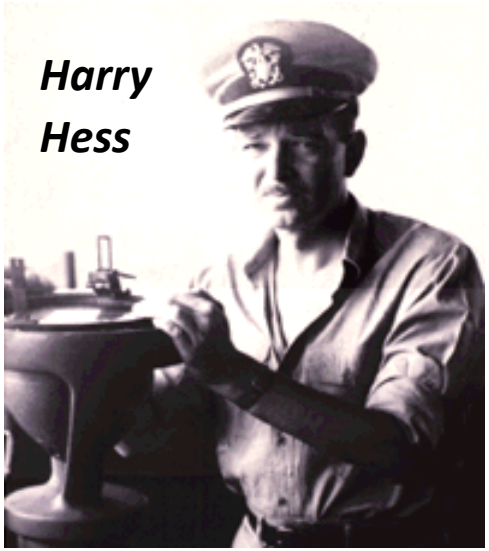
Wegener (1915)

Revolutions in modern science

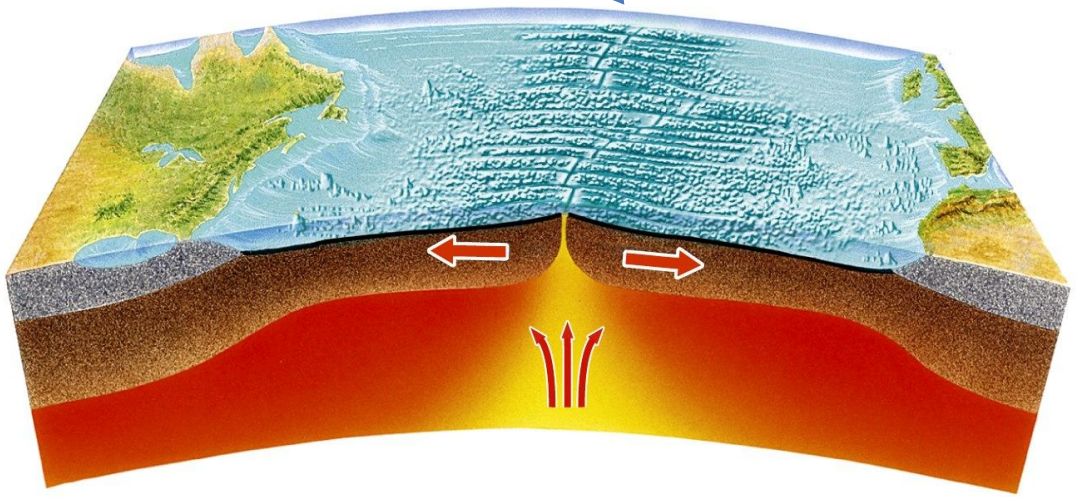
The second revolution...Seafloor Spreading

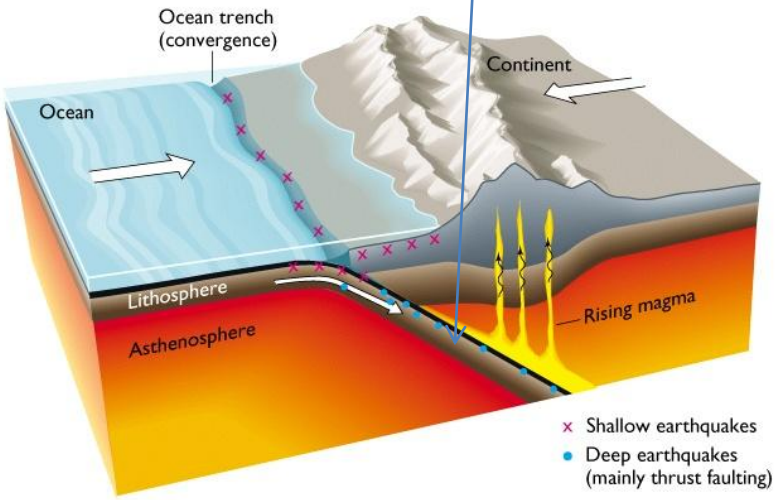
✓**1962**

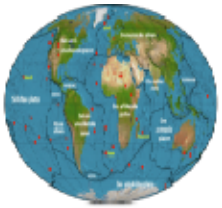
Hess's historic article, "**History of the Ocean Basins**," was published, suggesting that upwelling of mantle material along the mid-ocean ridge system created new sea floor.



The convective motion of mantle material carries the sea floor in a conveyor belt fashion to the deep-ocean trenches, where the sea floor descends into the mantle.

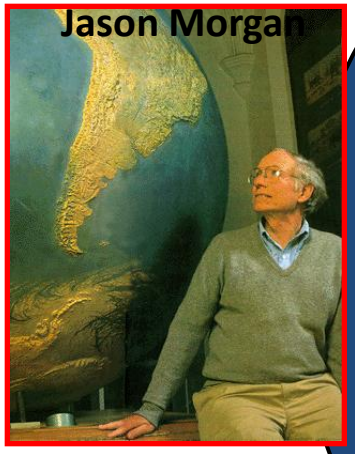


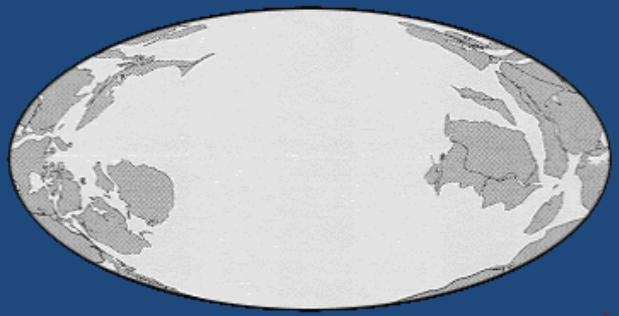




The third revolution...Plate Tectonics

With Robert Parker published in **1967** the quantative principles for plate tectonics.





In **1968** published a primal paper that, taken together, constituted the plate-tectonics revolution.

Ground-breaking proposal in **1968** of how plate tectonics could explain orogeny

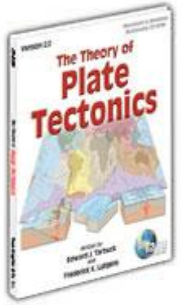
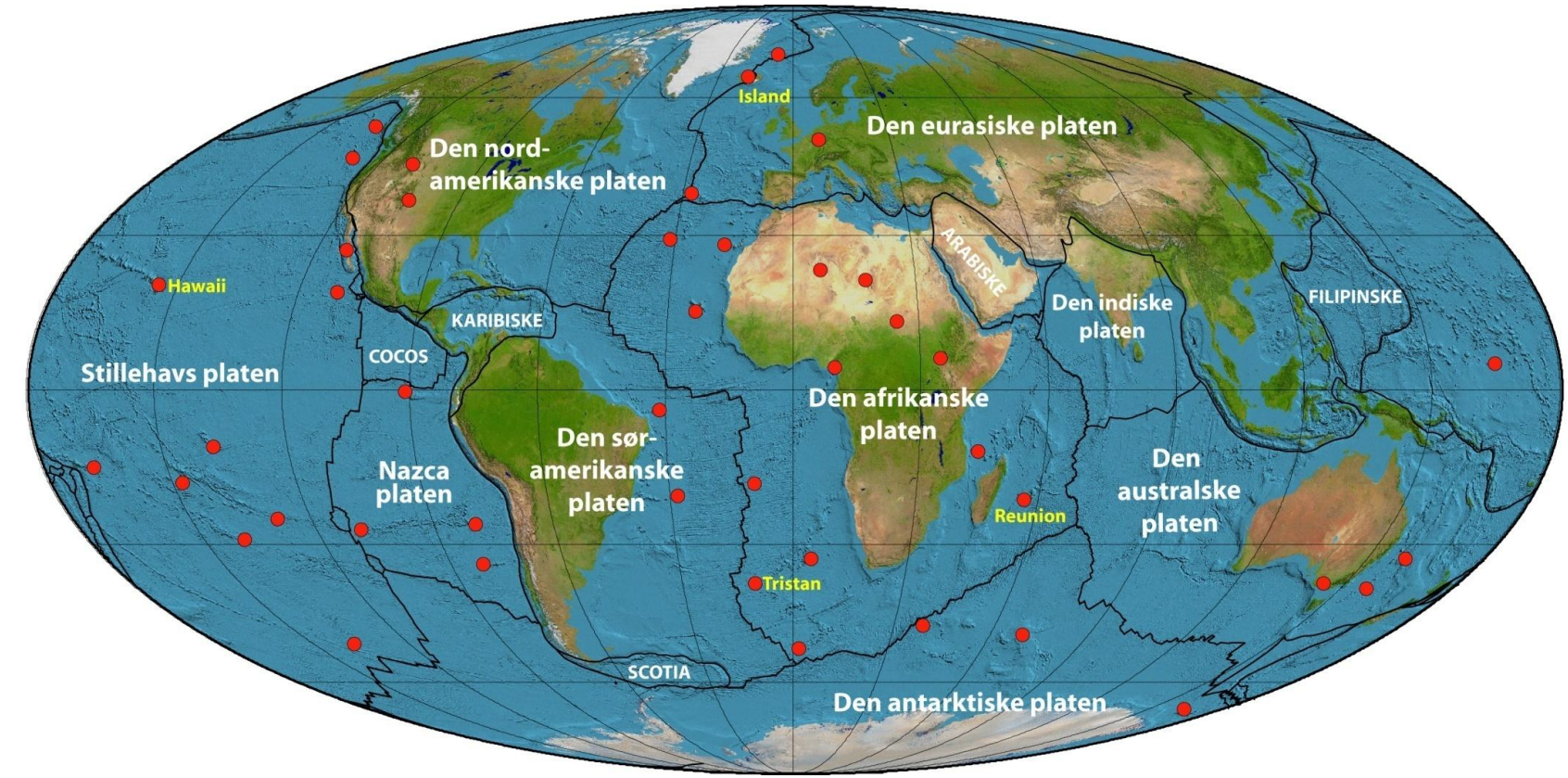
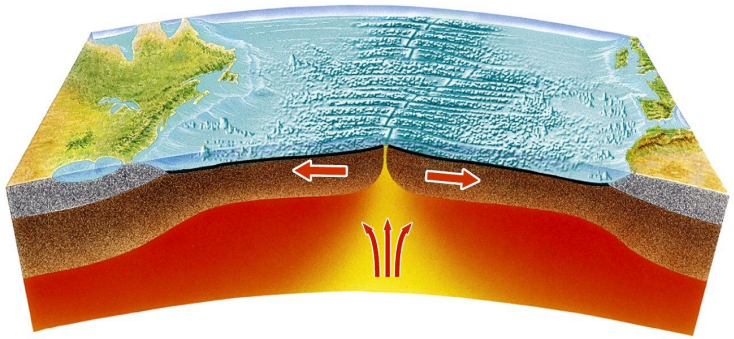
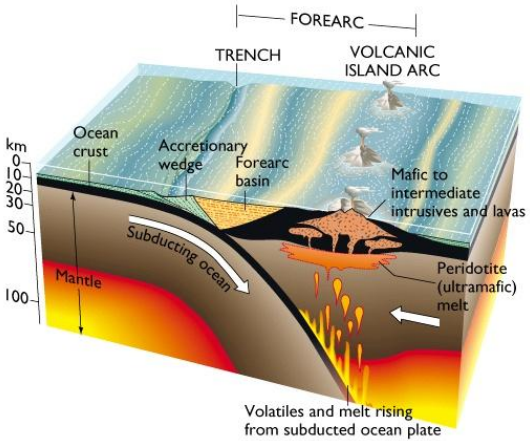
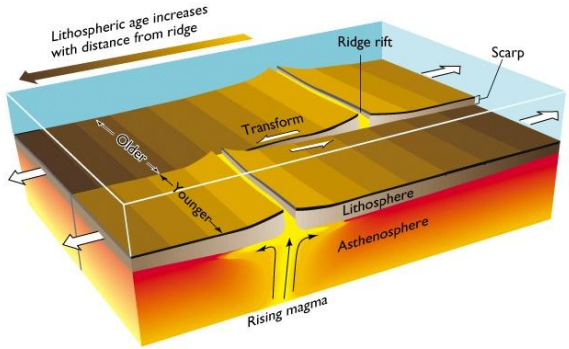


Plate Tectonics: A dozen plates, 70-350 km thick, and three different types of boundaries where most of the action occurs, i.e. volcanism and earthquakes









Evidence for Plate Tectonics (GPS)

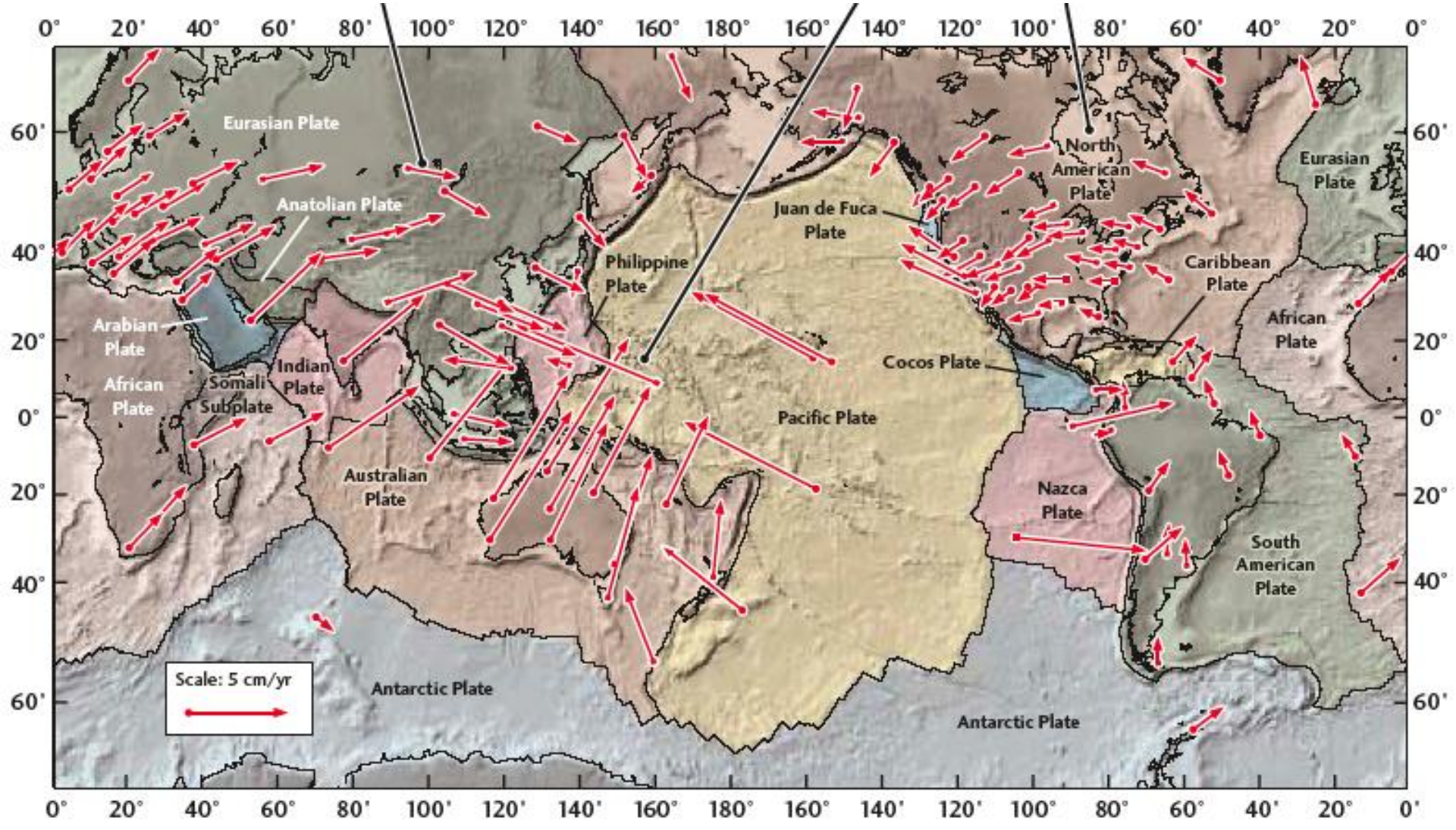
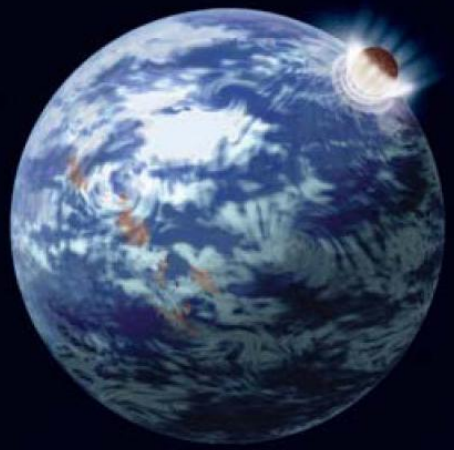
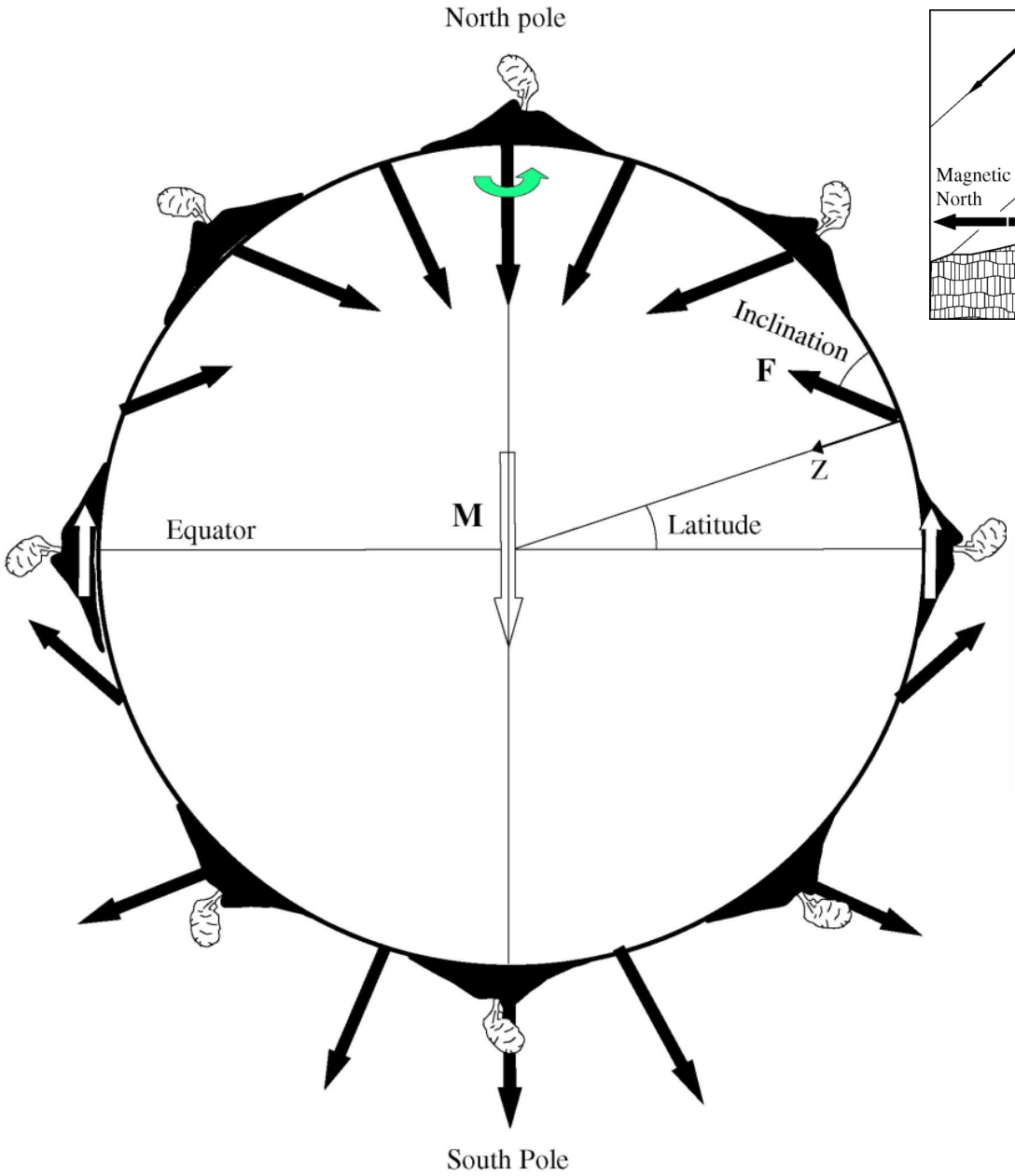


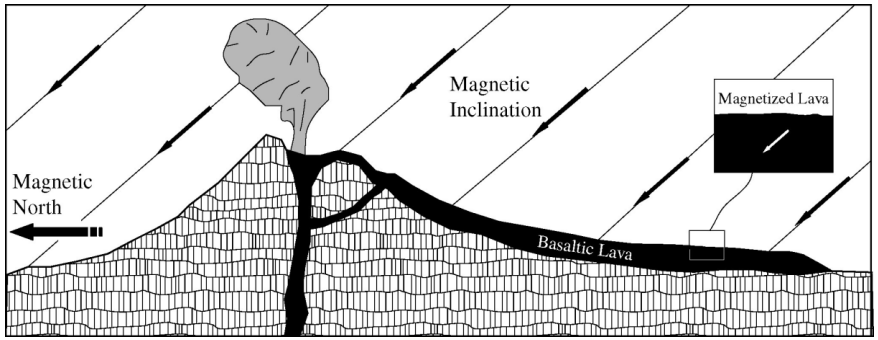
Plate tectonics is not a dogma, but a confirmed theory whose strength lies in its simplicity, its generality, and its consistency with many types of observations.



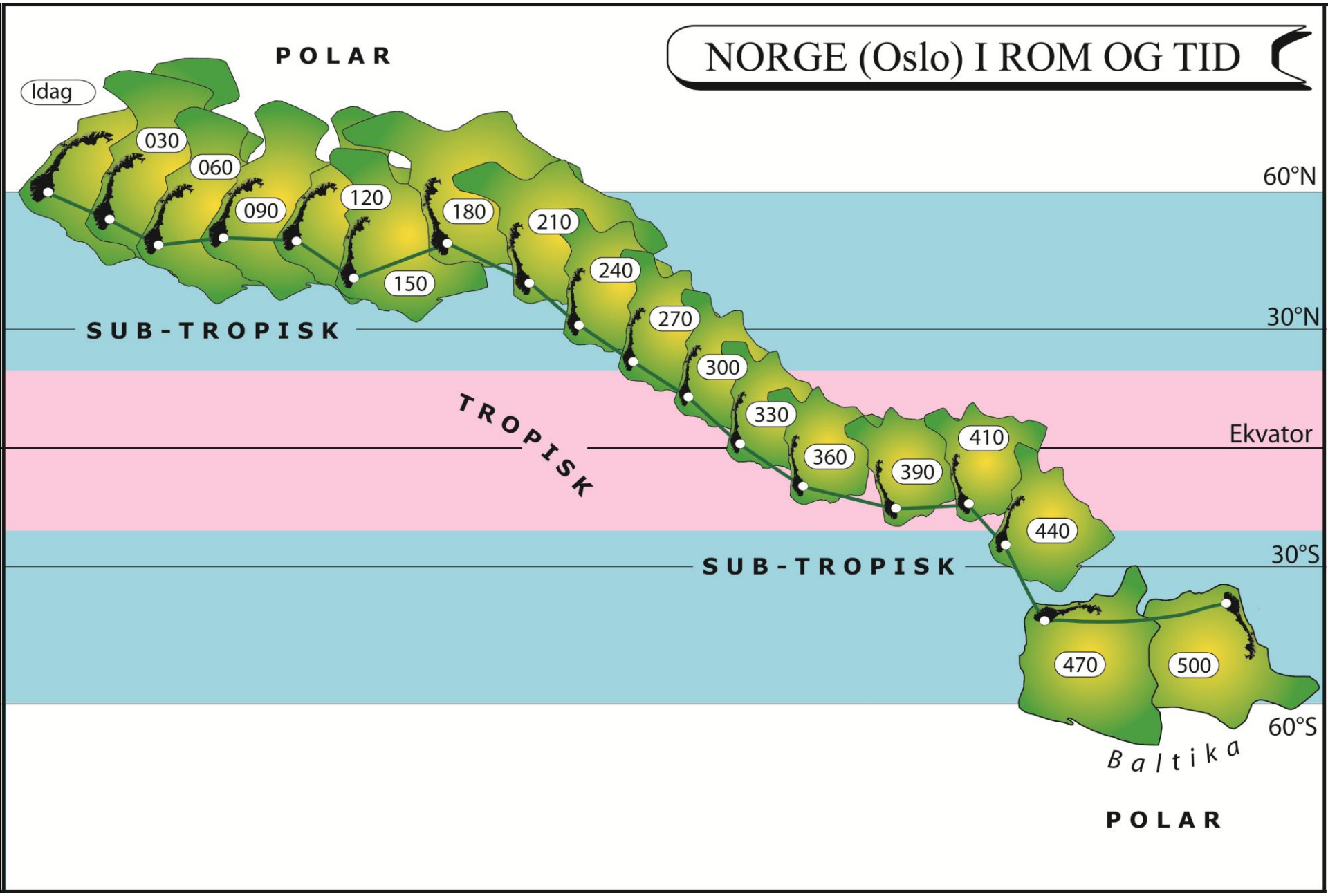
The Evolution of Earth

Examples





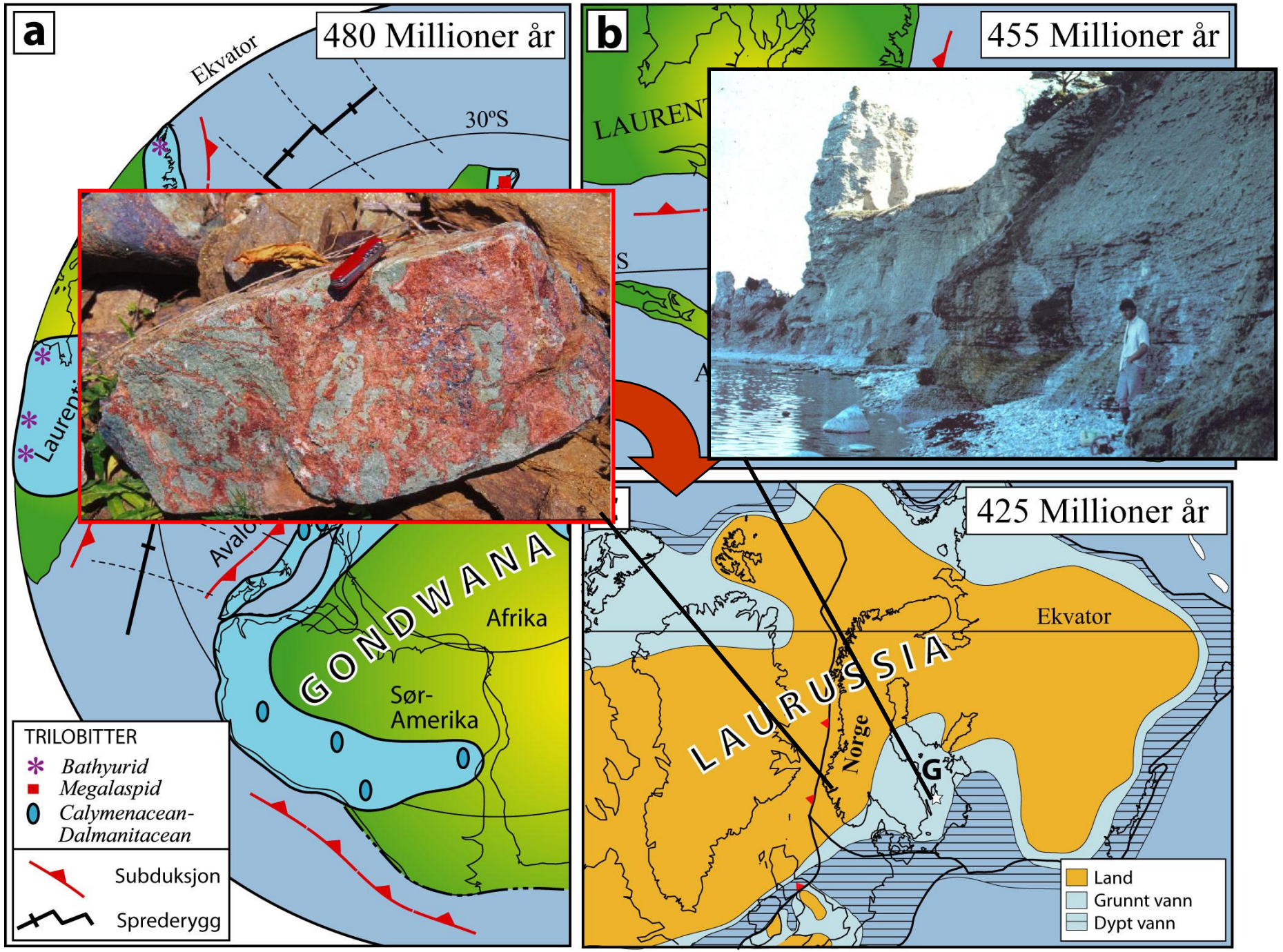
Palaeomagnetism: Fundamental method to reconstruct the continents

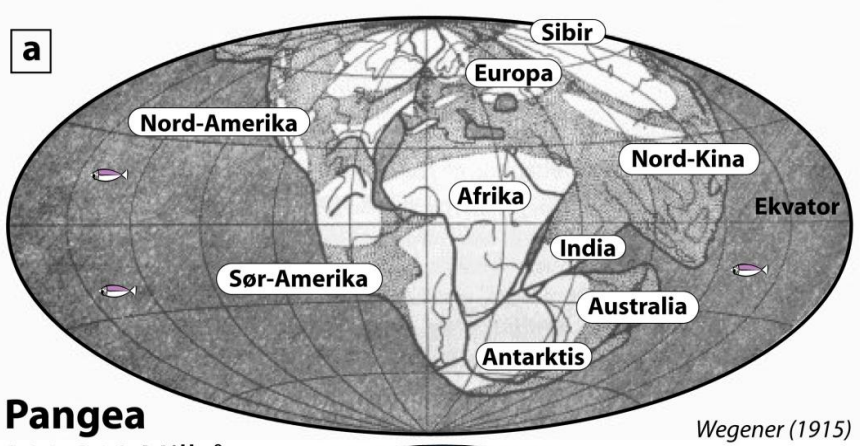

NORGE (Oslo) I ROM OG TID
POLAR
Idag
030
060
090
120
150
180
210
240
270
300
330
360
390
410
440
470
500
60°N
30°N
Ekvator
30°S
60°S
SUB-TROPISK
TROPISK
SUB-TROPISK
Baltika
POLAR

490 Ma

Europe located to many plates: very different trilobites

1.8	Phanerozoikum	Kvartær
23		Nytiden
		Tertiær
65		Kritt
145		Mellomtiden
		Jura
199		Trias
251		Perm
299		Karbon
359		Devon
		Oldtiden
416		Silur
443		Ordovicium
488		Kambrium
542	Urtiden	

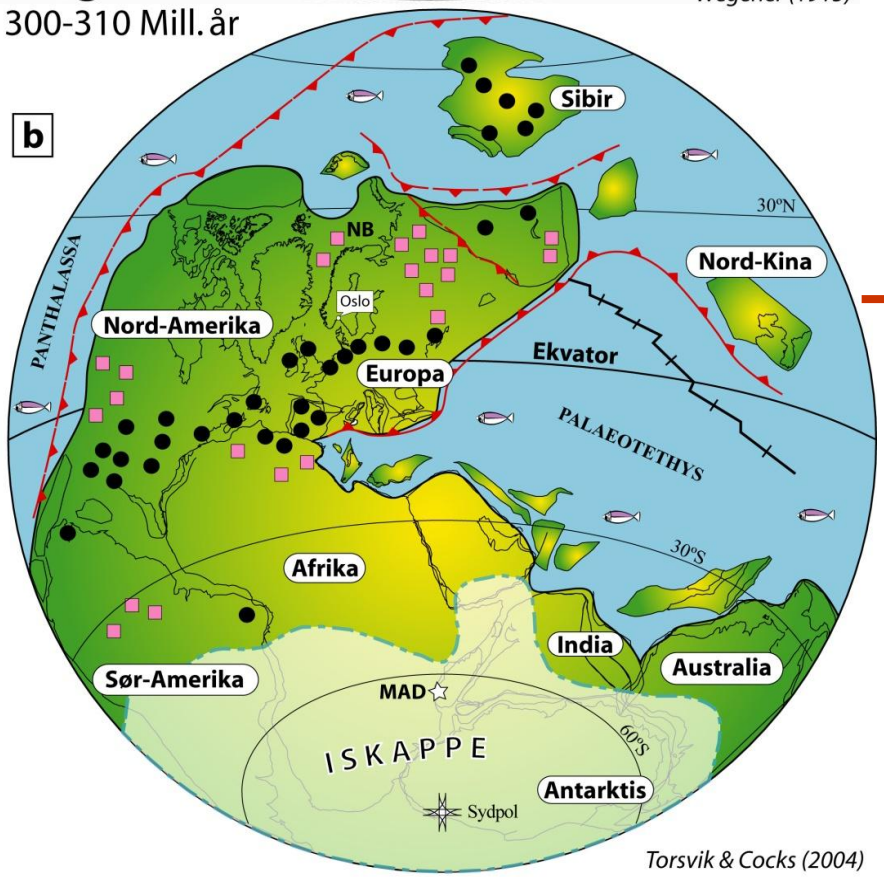

a
480 Millioner år
Ekvator
30°S
Laurentia
Avalonia
GONDWANA
Afrika
Sør-
Amerika
TRILOBITTER
Bathyurid
Megalaspid
Calymenacean-
Dalmanitacean
Subduksjon
Spredерygg
b
455 Millioner år
LAURENTIA
425 Millioner år
Ekvator
LAURUSSIA
Norge
Land
Grunnt vann
Dypt vann



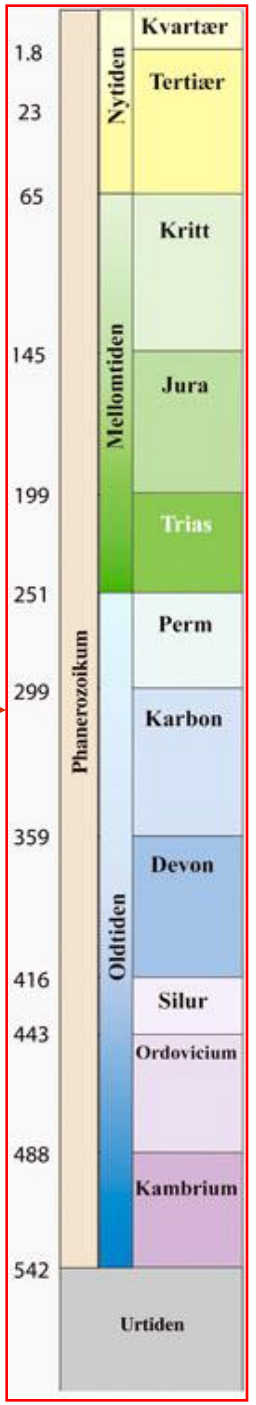
Pangea

300-310 Mill. år

Wegener (1915)



Torsvik & Cocks (2004)



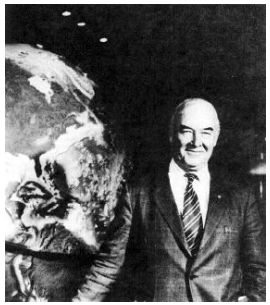

Perhaps it looked like this
Permian Dimetrodon

BEYOND PLATE TECTONICS

Why, it explains so much, or?

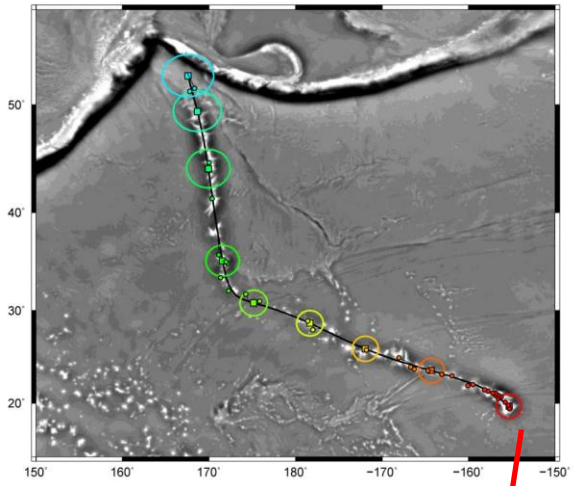
Driving Forces & why only Plate Tectonics on Earth?

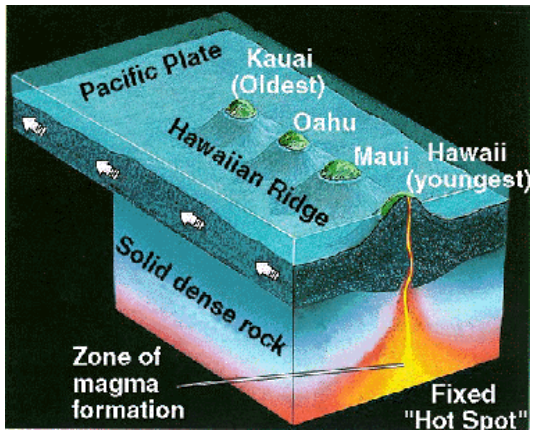
1964

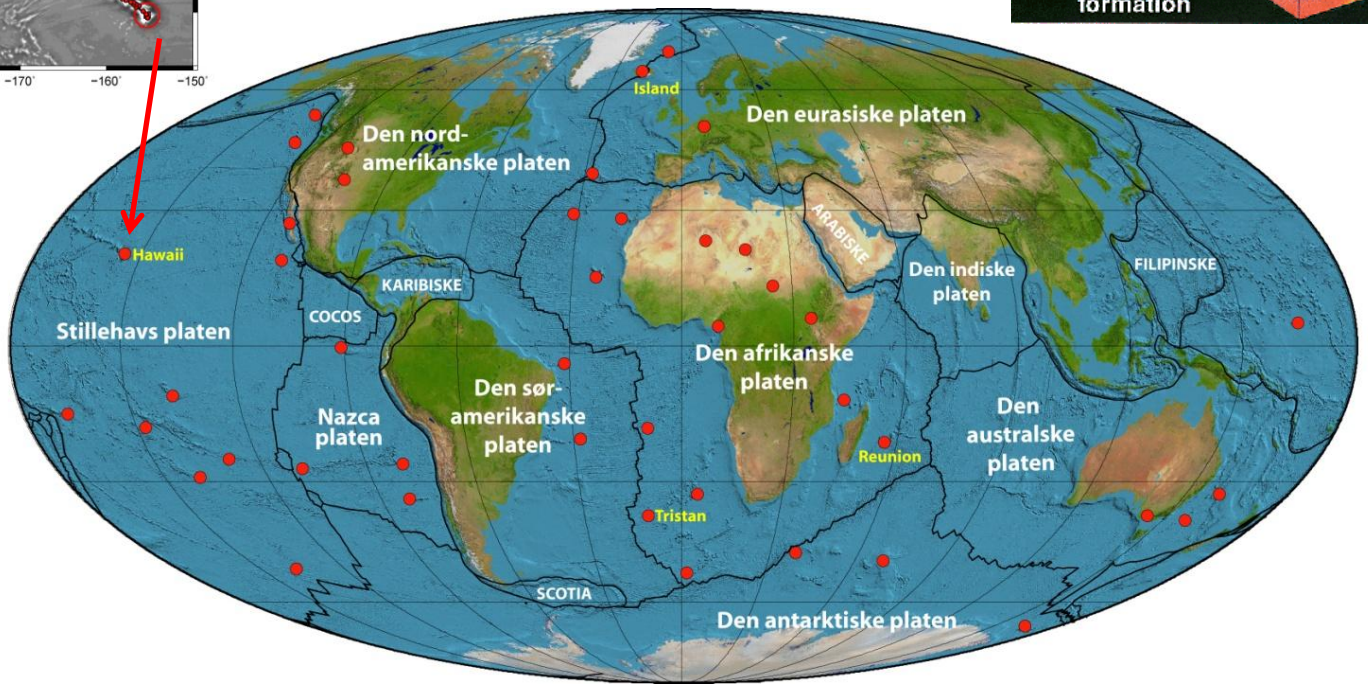


J. Tuzo Wilson, University of Toronto, postulated that oceanic islands such as the Hawaiian Islands were formed by the movement of a plate over a hotspot deep in the mantle.

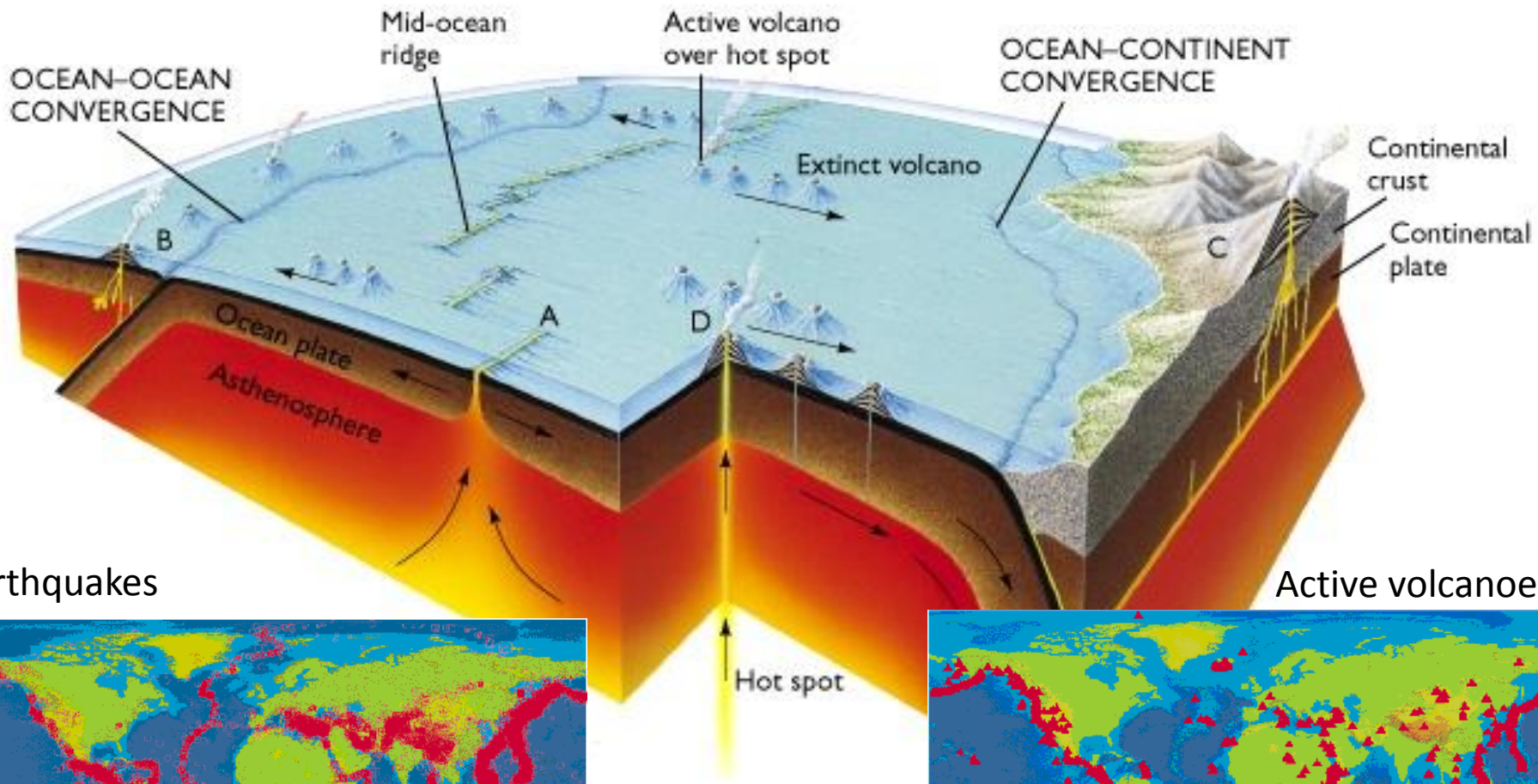
This does not fit with Plate Tectonic theory: Why?



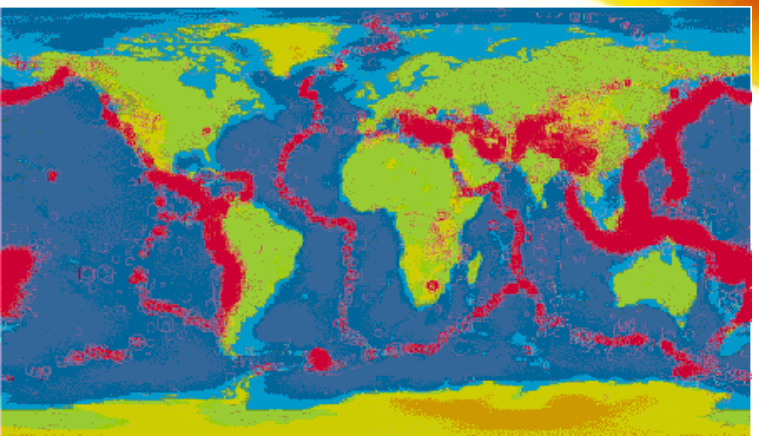




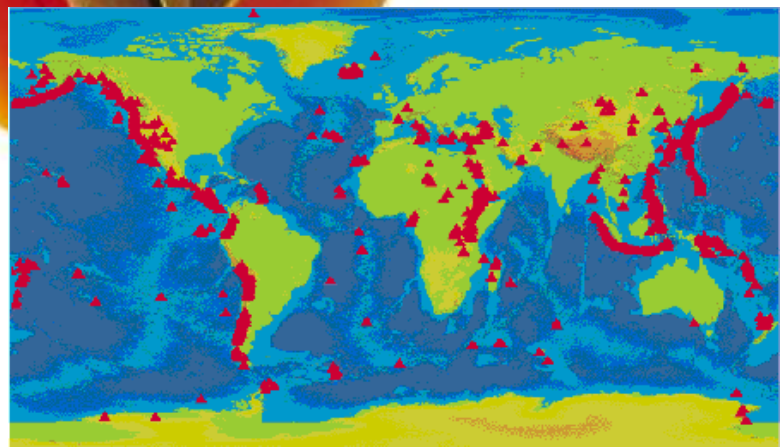
Hotspots not formed at plate boundaries are odd and cannot be explained by plate tectonics

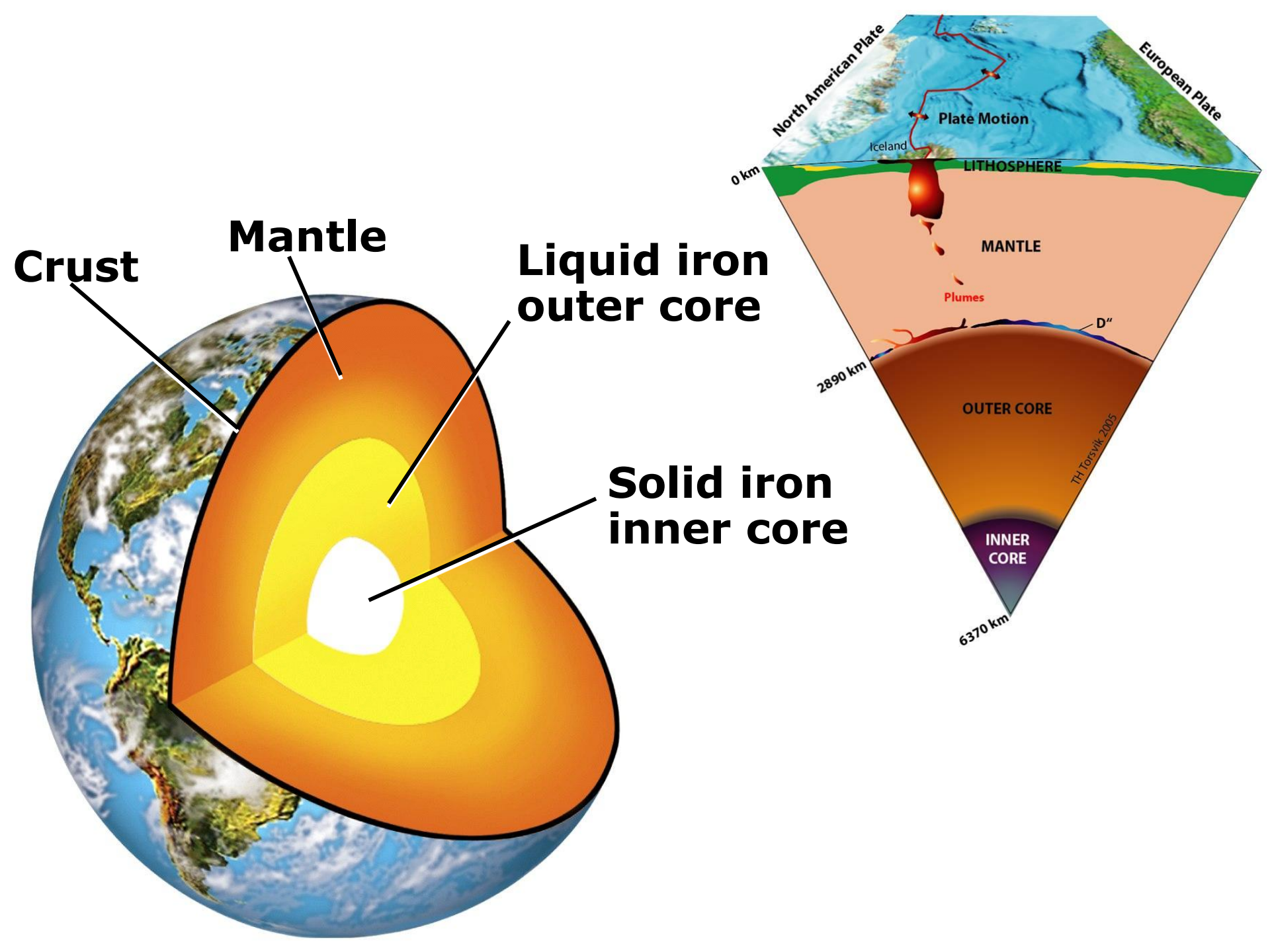


Earthquakes

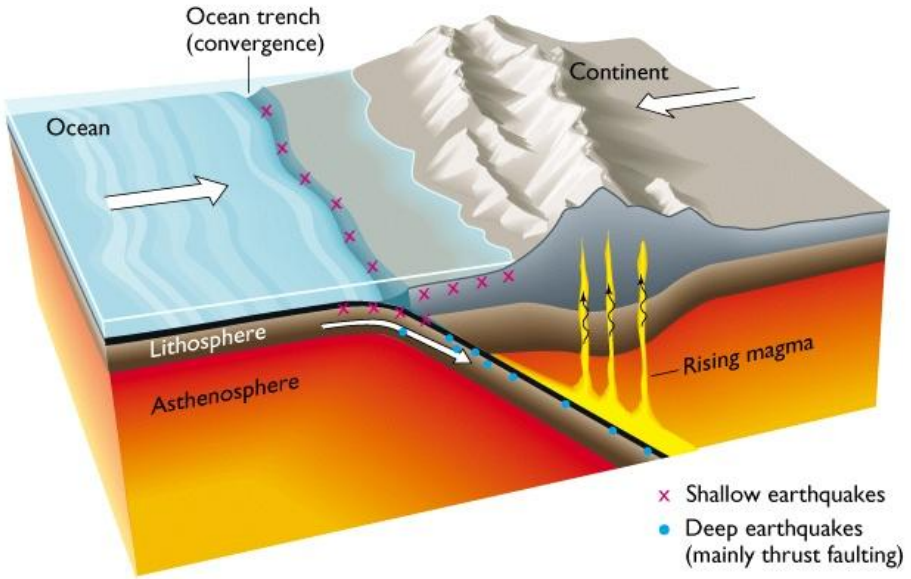


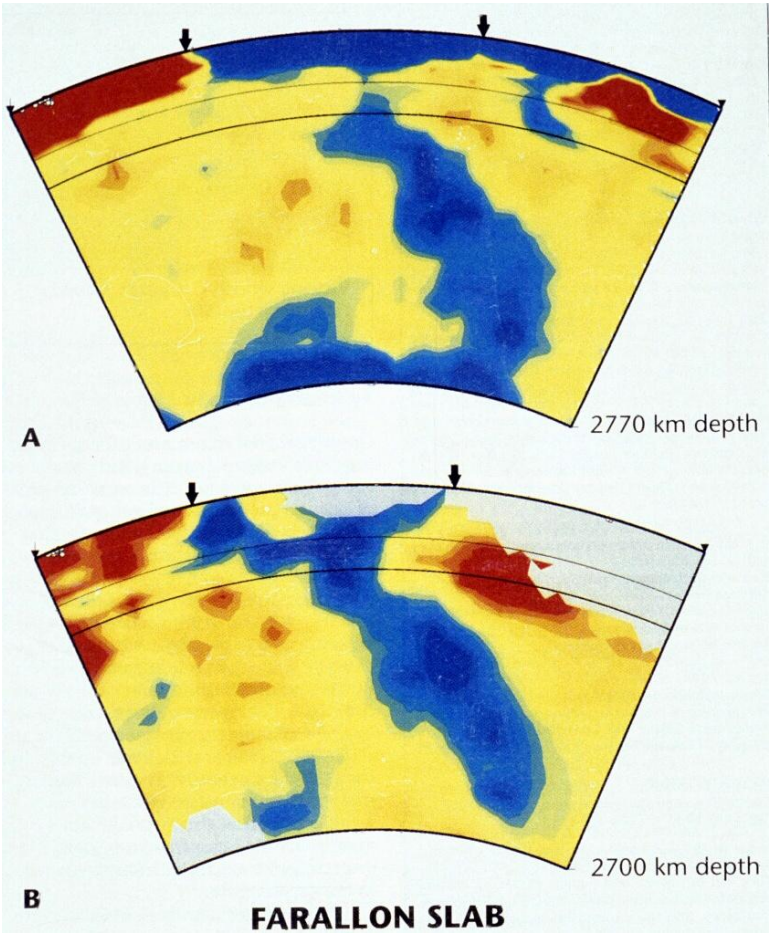
Active volcanoes



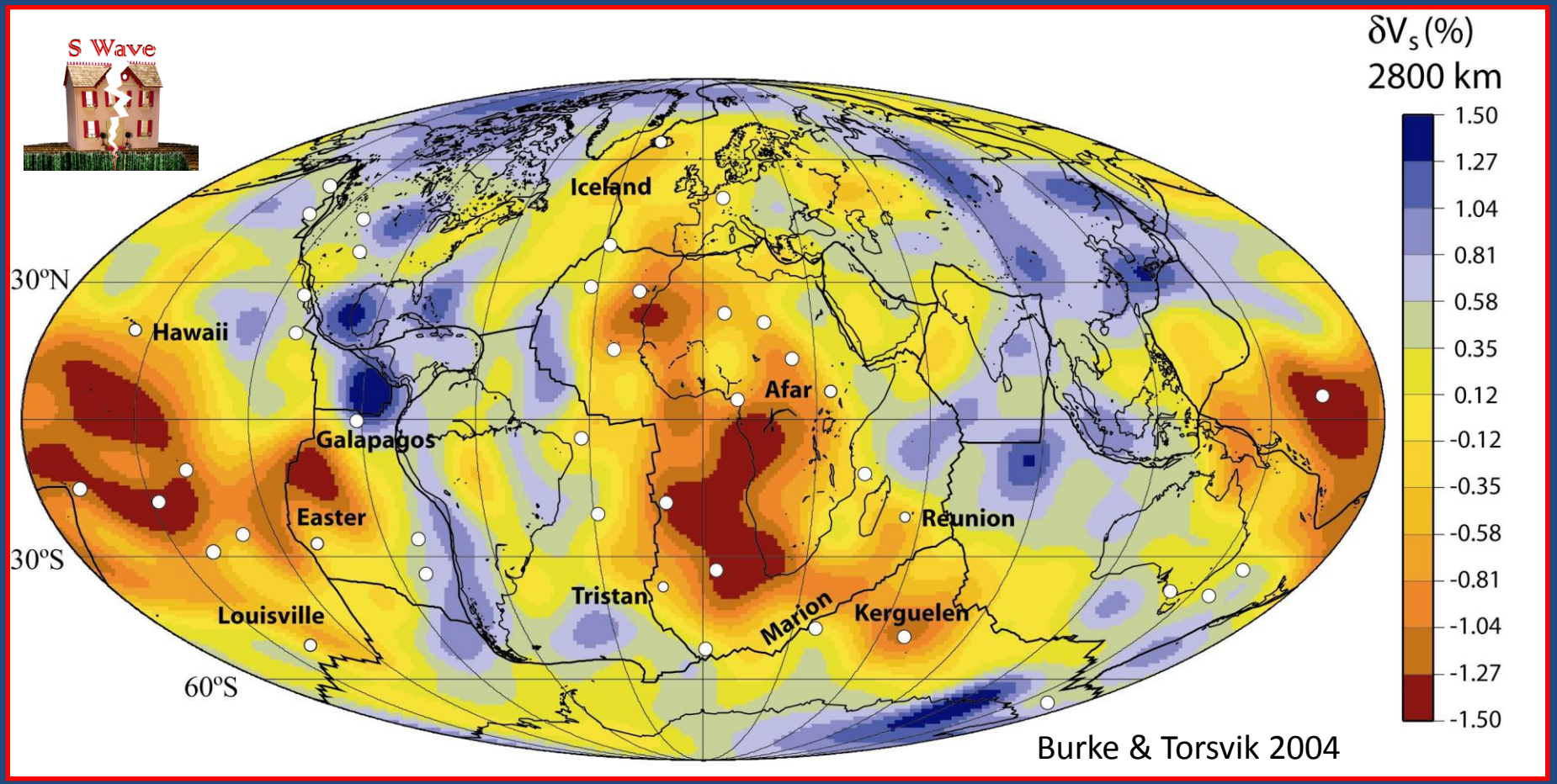

Crust
Mantle
Liquid iron
outer core
Solid iron
inner core
North American Plate
European Plate
Plate Motion
Iceland
0 km
LITHOSPHERE
MANTLE
Plumes
D"
2890 km
OUTER CORE
INNER
CORE
6370 km
TH Torsvik 2005

Seismic tomography is seismic imaging and usually has a specific purpose to estimate properties such as propagating velocities of compressional waves (P-wave) and shear waves (S-wave). Fast (blue) waves are usually cold/dense material and slower (red) waves are usually hot/lighter material





Detailed mapping of seismic velocities near the core-mantle boundary (2900 km) is extremely important to understand Earth history – Many hotspots seems to come from special regions



MAIN CAS Objective: Link surface and deep processes

REJECTED
BY
NATURE
NOV 2001

Large Igneous Provinces

formed by plumes from

the base of the Mantle

Kevin Burke*

OBLIQUE VIEW

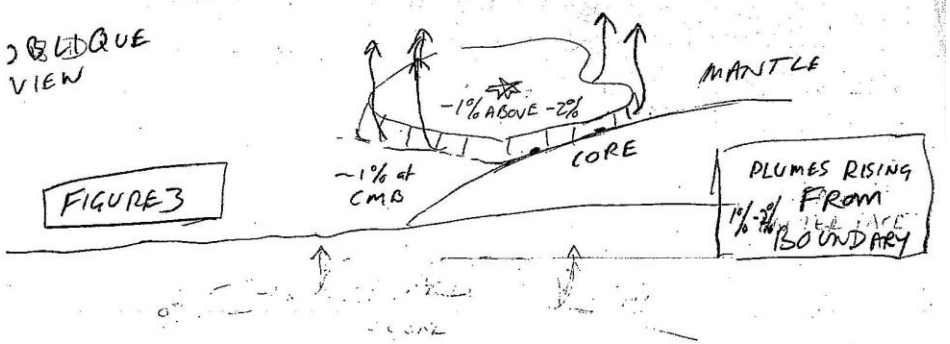


FIGURE 3

FIGURE 2

MAP OF D'' ZONE

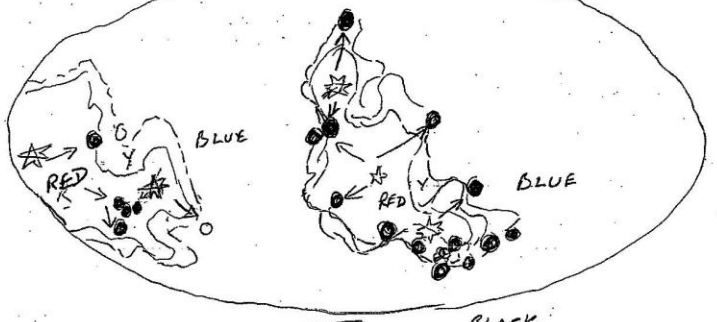


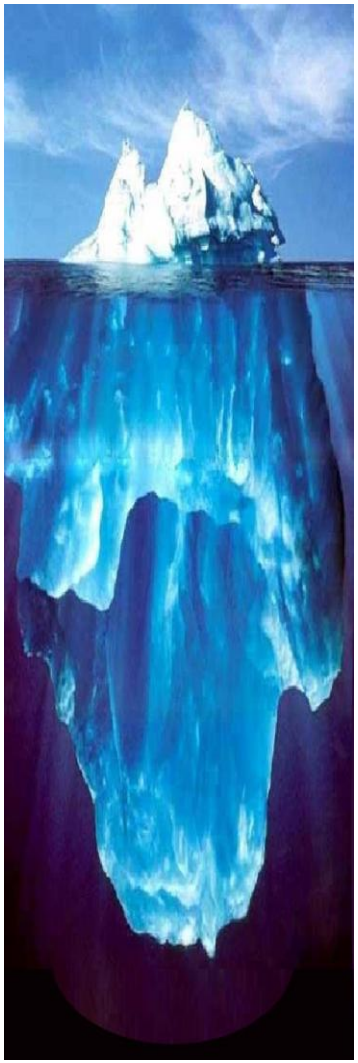
FIGURE 2 BLACK BLOBS FORMED NEAR CENTERS (STARS) MIGRATE TO -2% TO -1% BOUNDARY

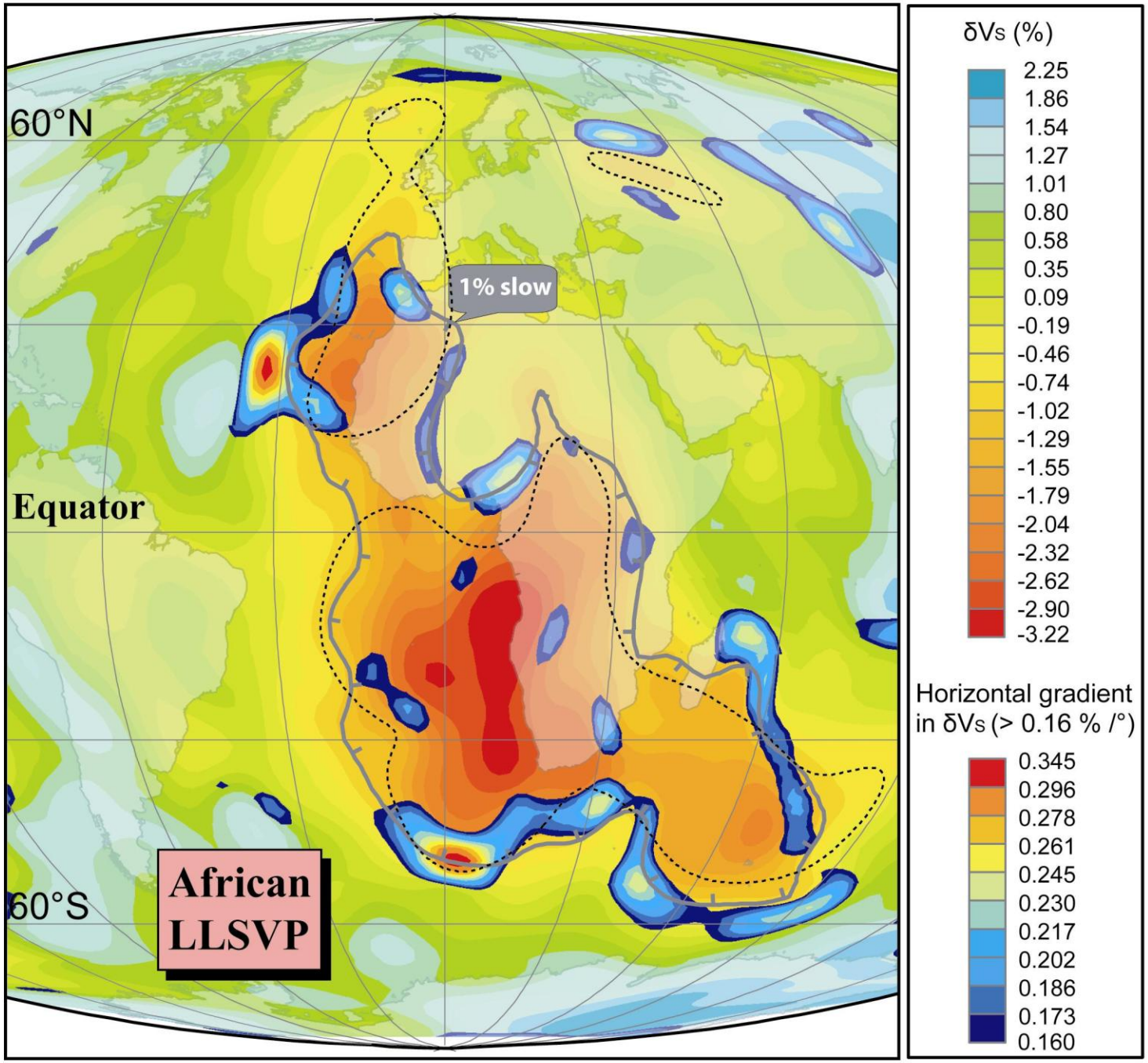
ARROWS INDICATE (NEAR HORIZONTAL) MIGRATION ROUTES

/Kevin
JAN 17th
2004

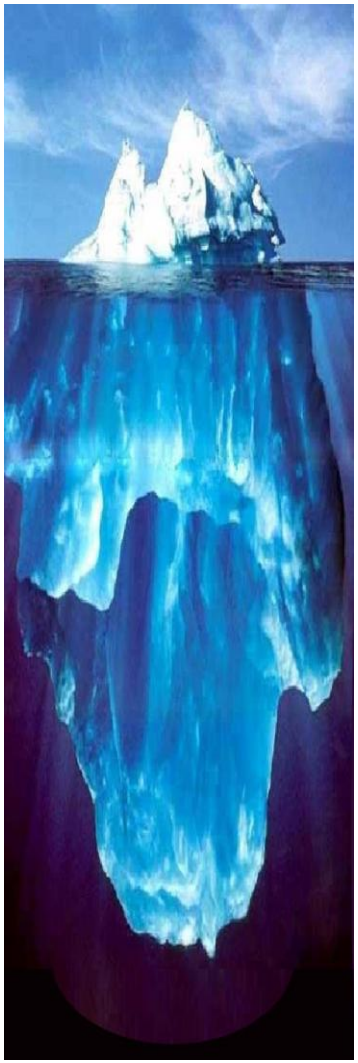
PAGE 2 OF 2

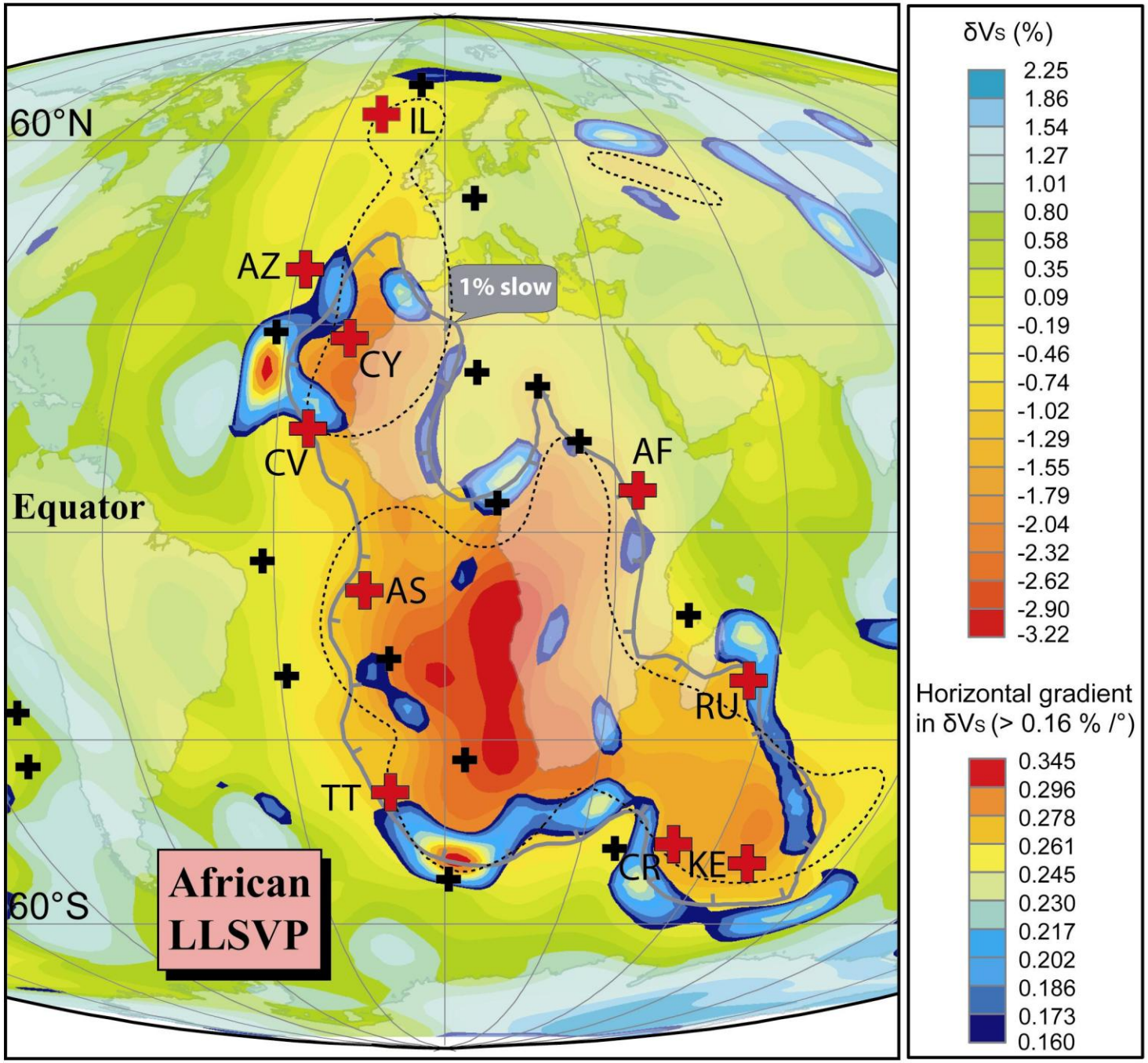
SMEAN (Becker & Boschi 2002), & D" 0.8% (Castle et al. 2000)





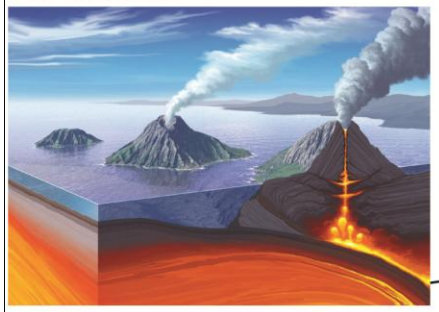
+ Hotspots

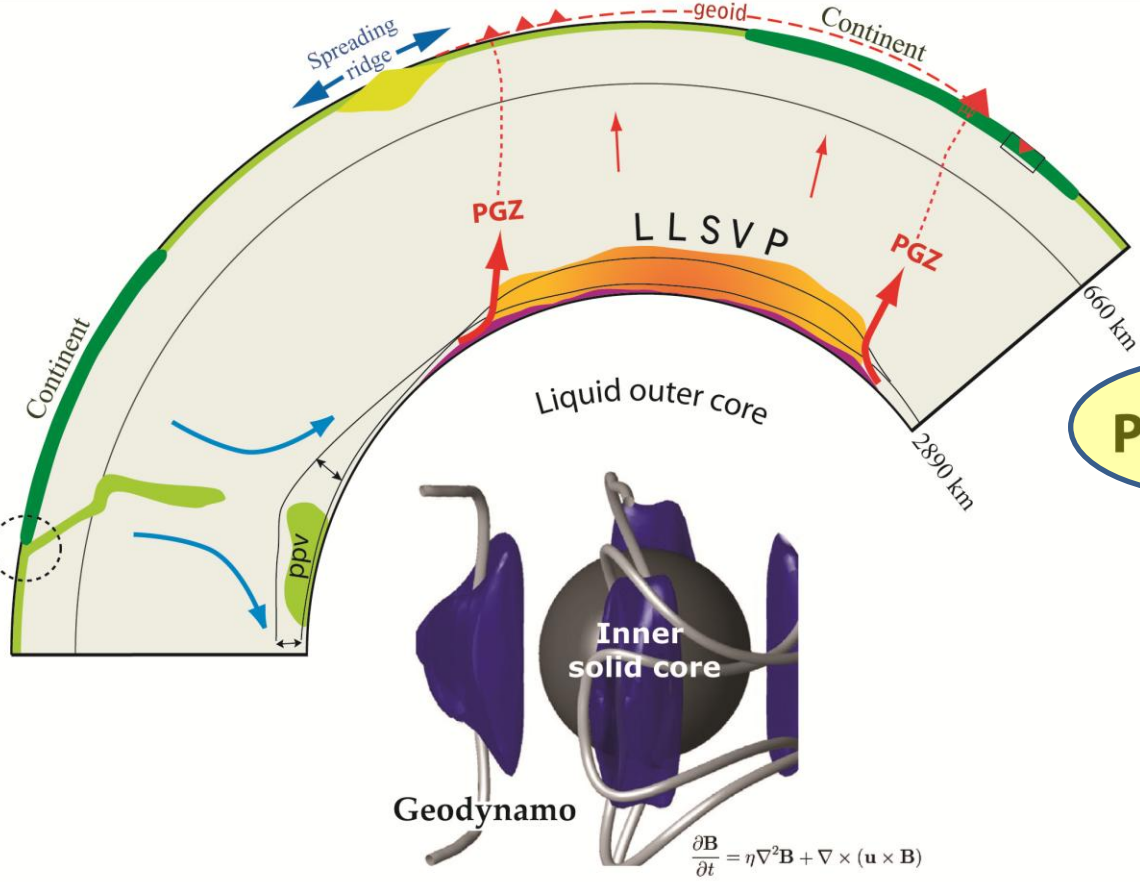



60°N
Equator
60°S
IL
AZ
CY
CV
AF
AS
RU
TT
CR
KE
1% slow
African
LLSVP
δVs (%)
2.25
1.86
1.54
1.27
1.01
0.80
0.58
0.35
0.09
-0.19
-0.46
-0.74
-1.02
-1.29
-1.55
-1.79
-2.04
-2.32
-2.62
-2.90
-3.22
Horizontal gradient
in δVs (> 0.16 % /°)
0.345
0.296
0.278
0.261
0.245
0.230
0.217
0.202
0.186
0.173
0.160

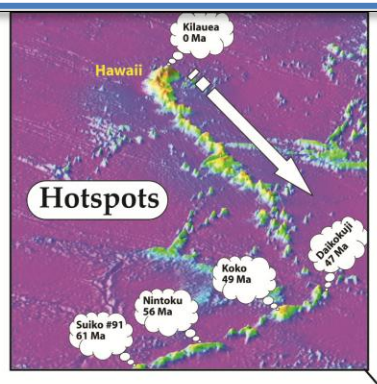
Plumes are formed from special regions (2900 km depth)

Subduction

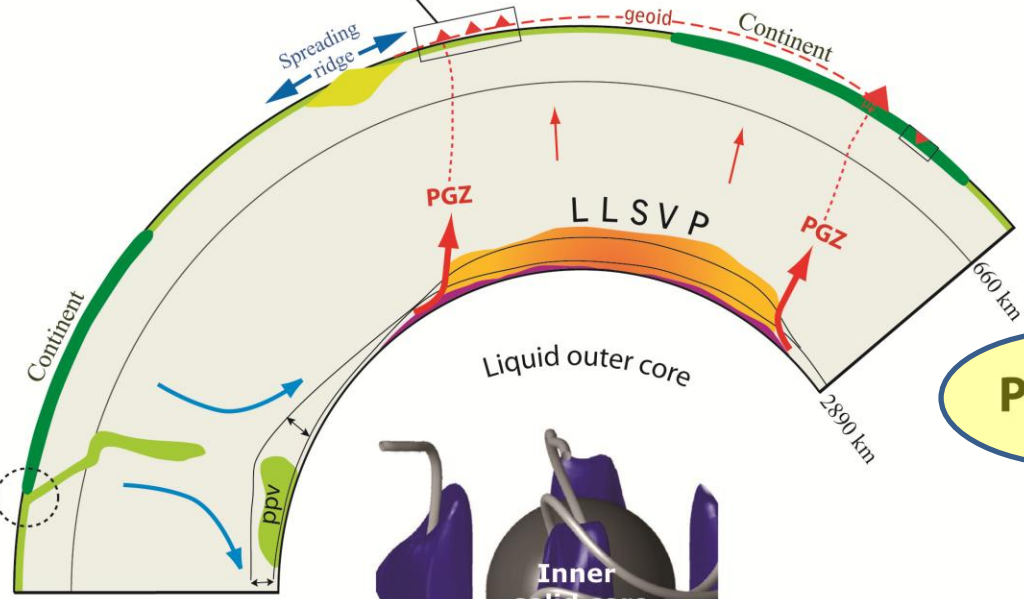




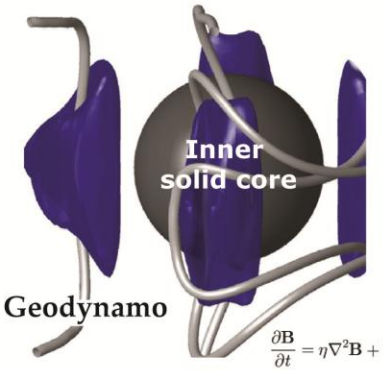
Plumes rises to the surface (ca. 20 Myr) and forms hotspots on the surface



Subduction

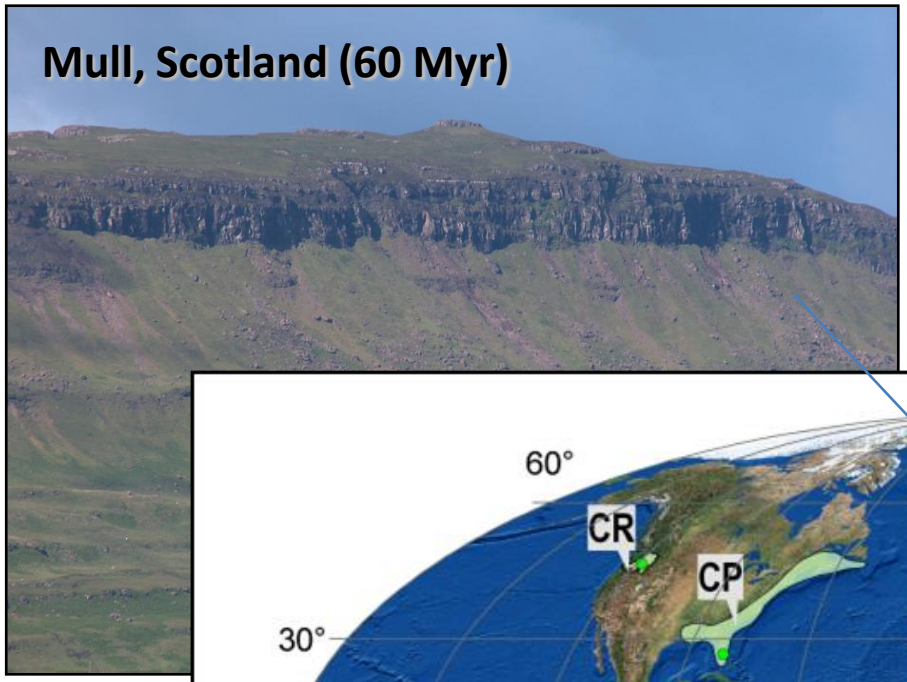


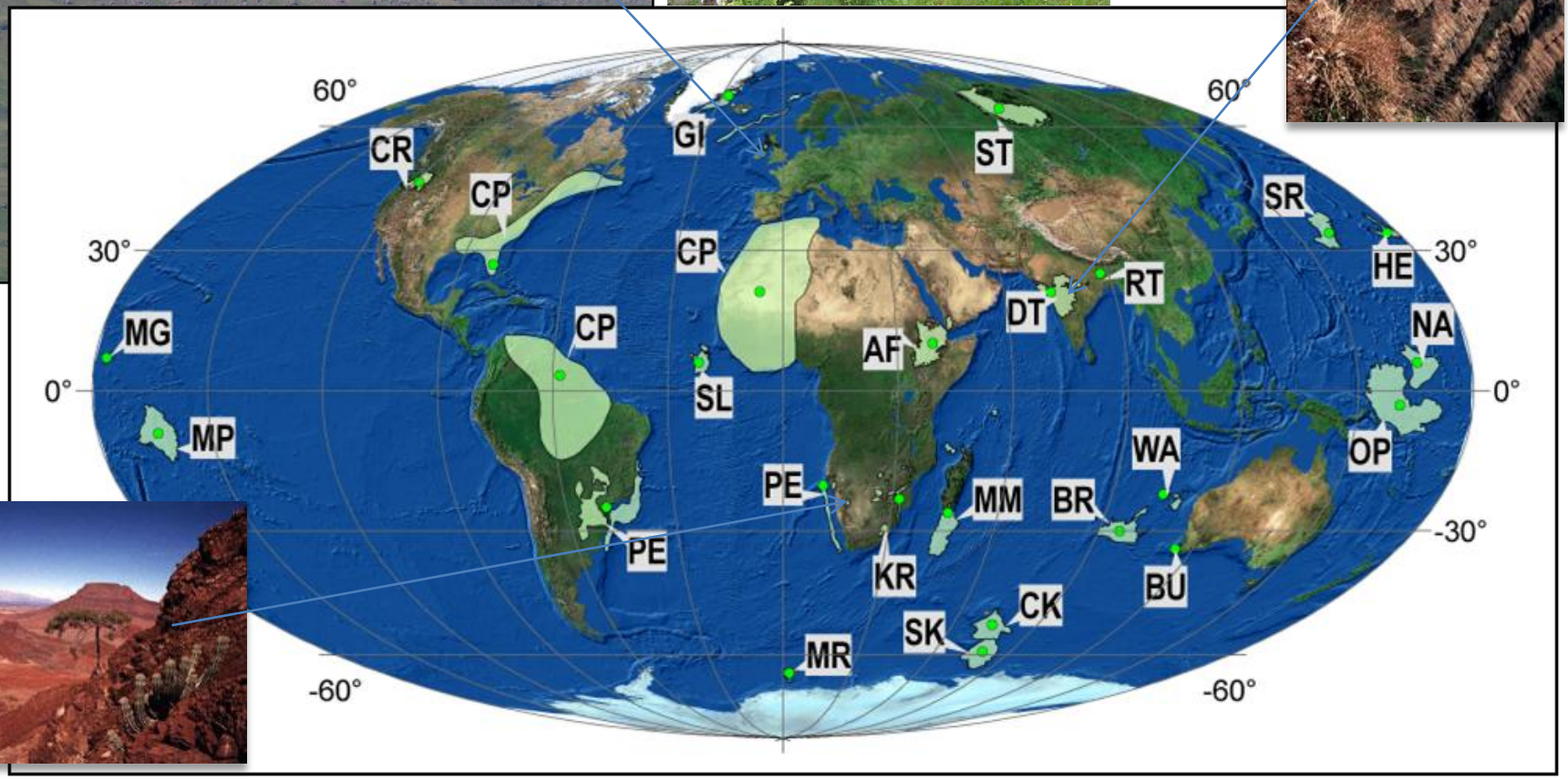
PLUMES



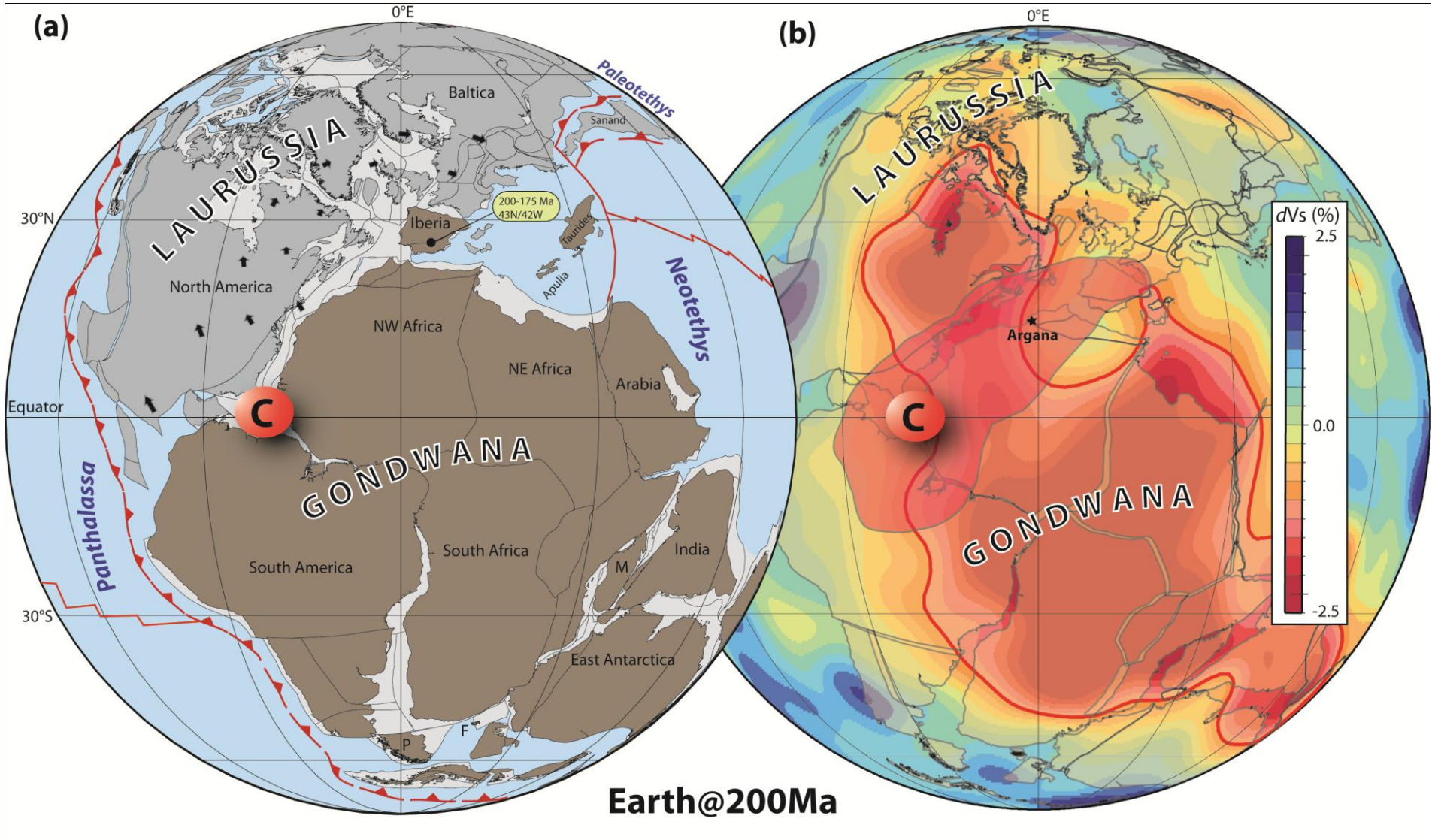
$$\frac{\partial \mathbf{B}}{\partial t} = \eta \nabla^2 \mathbf{B} + \nabla \times (\mathbf{u} \times \mathbf{B})$$

Most Large Igneous Provinces ("supervolcanoes", only 4 for the past 65 Myr) does not fit Plate Tectonic Theory either

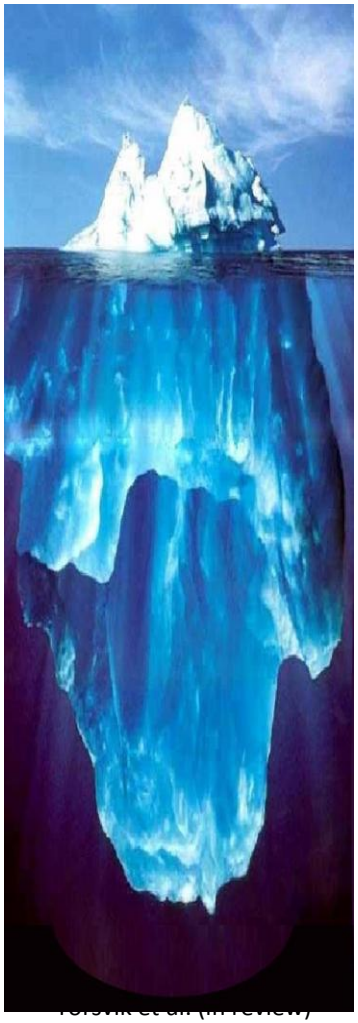


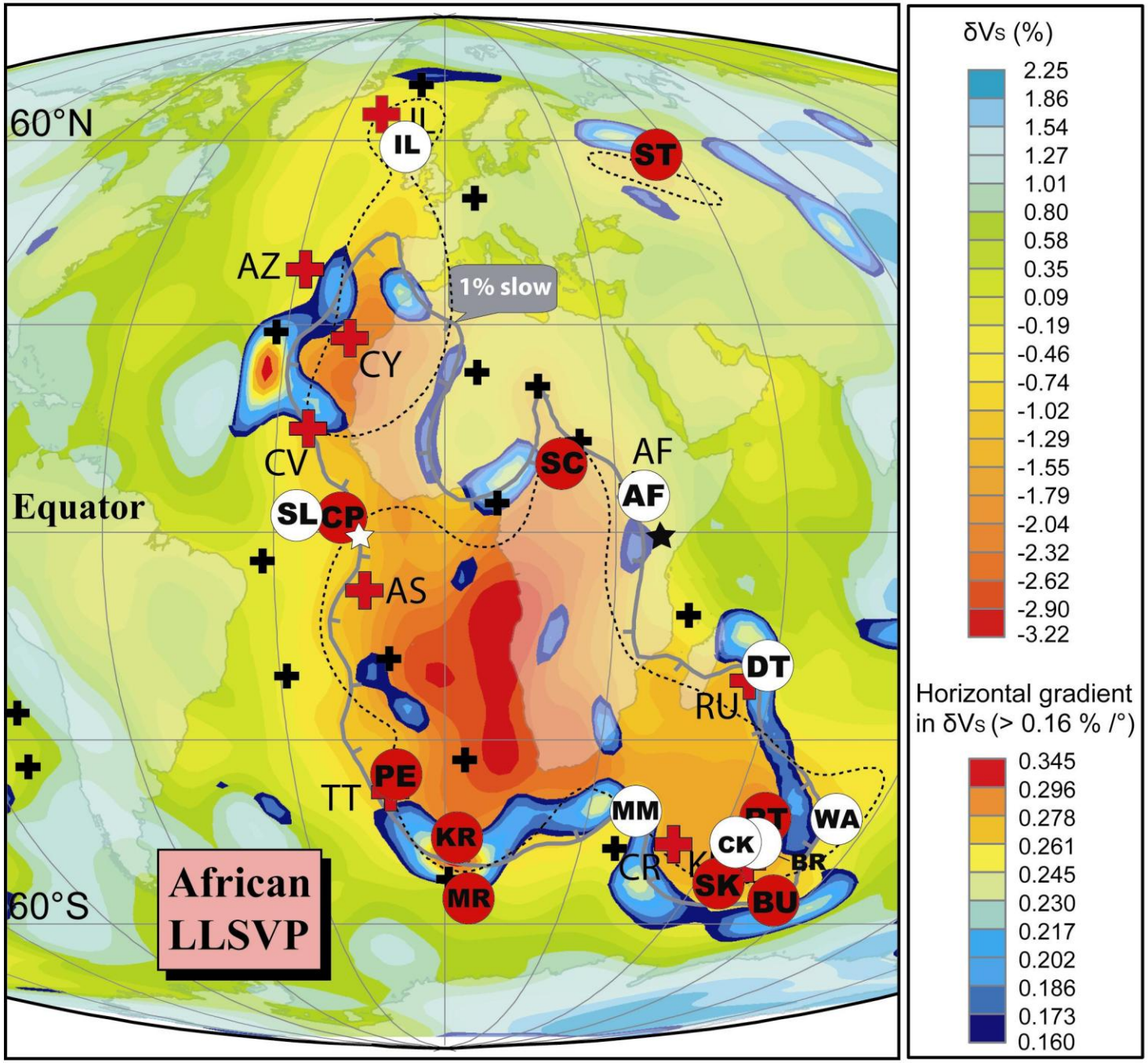


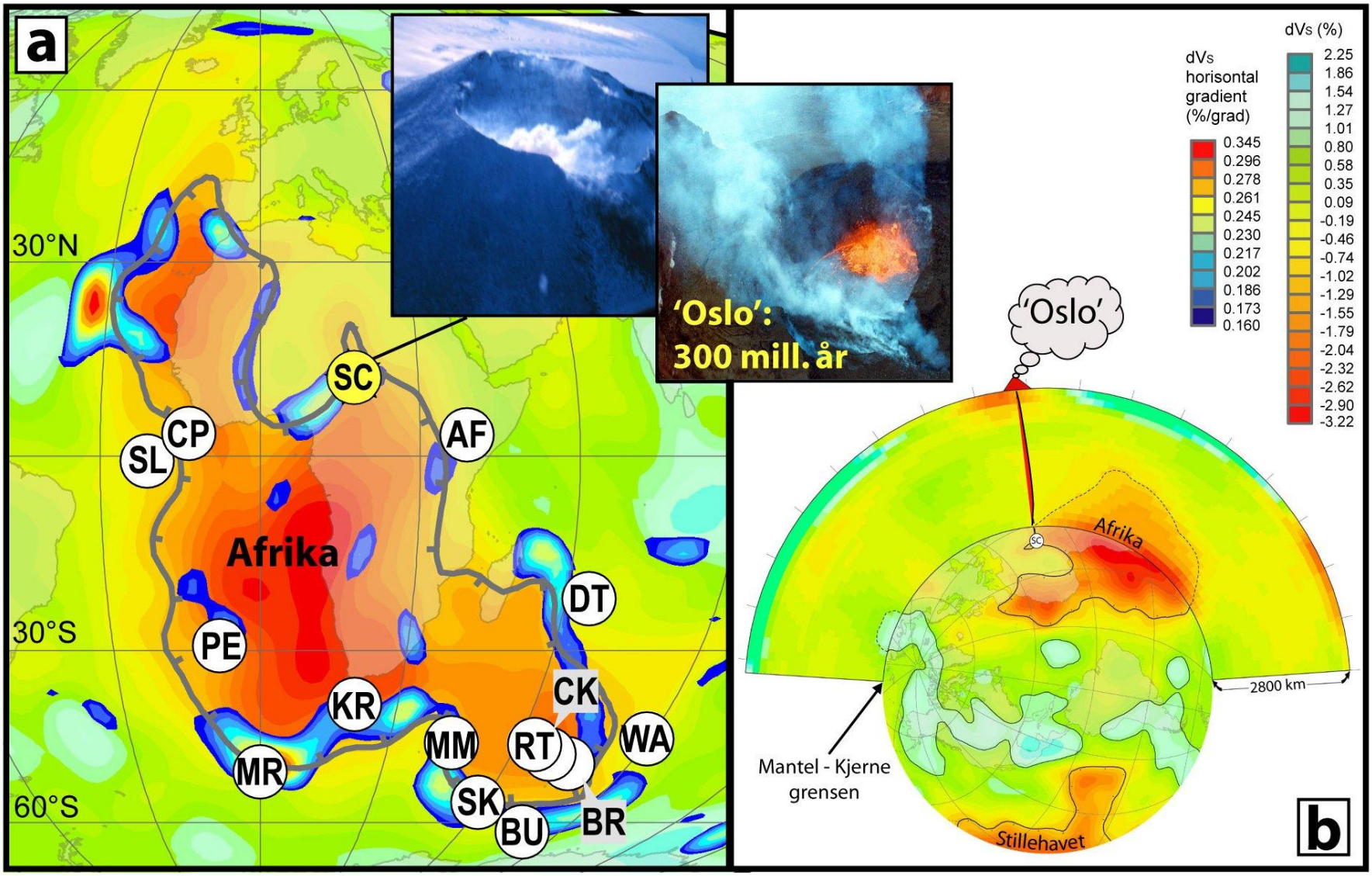
200 Myr: CAMP - the biggest supervolcano in Earth history?



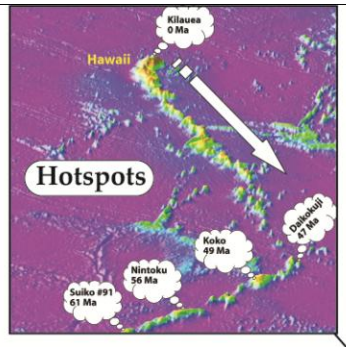
Hotspots and LIPs (supervolcanoes)

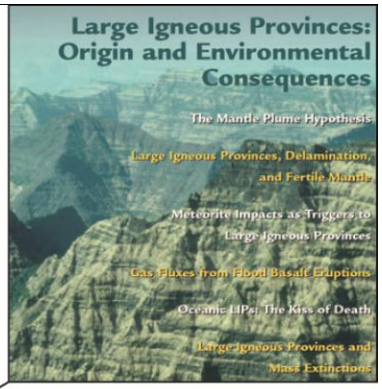




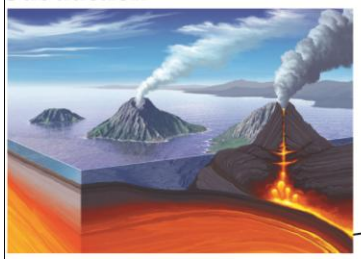

a
30°N
30°S
60°S
Afrika
SC
CP
SL
AF
DT
PE
KR
CK
MM
RT
WA
MR
SK
BU
BR
'Oslo':
300 mill. år
'Oslo'
dVs horisontal gradient (%/grad)
0.345
0.296
0.278
0.261
0.245
0.230
0.217
0.202
0.186
0.173
0.160
dVs (%)
2.25
1.86
1.54
1.27
1.01
0.80
0.58
0.35
0.09
-0.19
-0.46
-0.74
-1.02
-1.29
-1.55
-1.79
-2.04
-2.32
-2.62
-2.90
-3.22
Afrika
SC
2800 km
Mantel - Kjerne grensen
Stillehavet
b

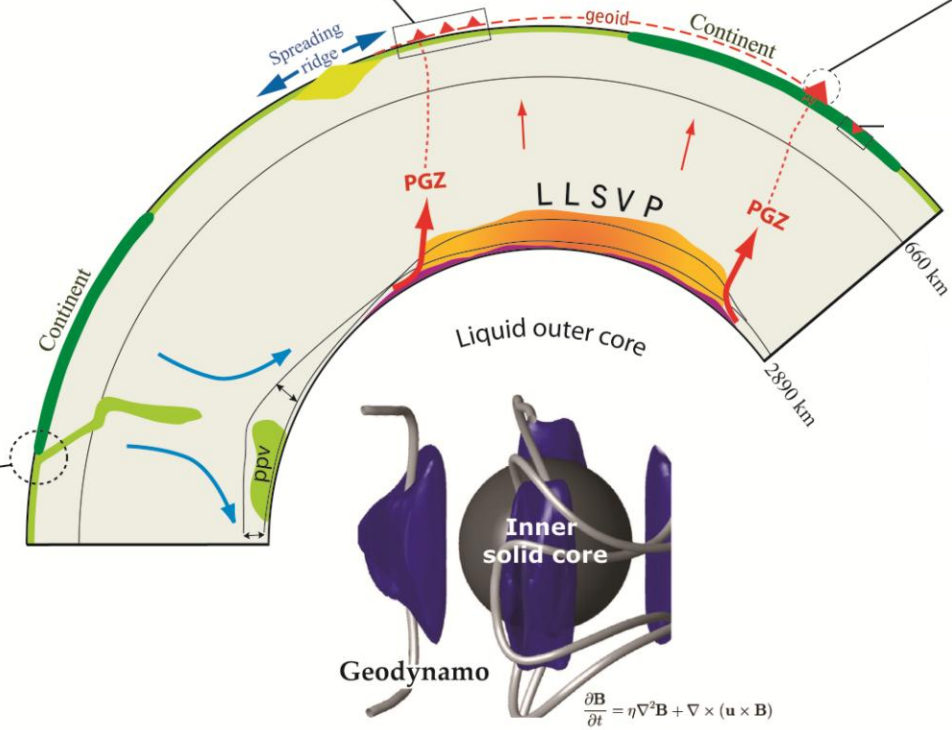
Plumes are also responsible for supervolcanoes

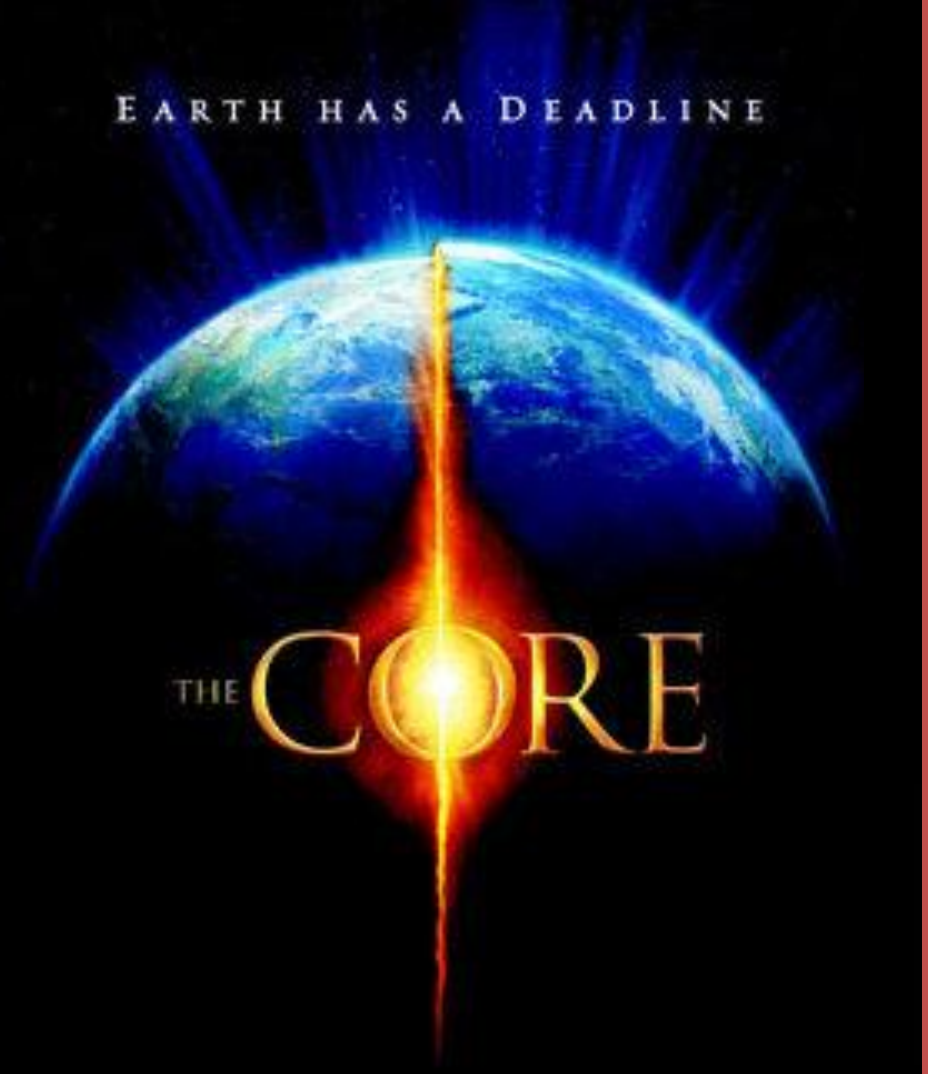




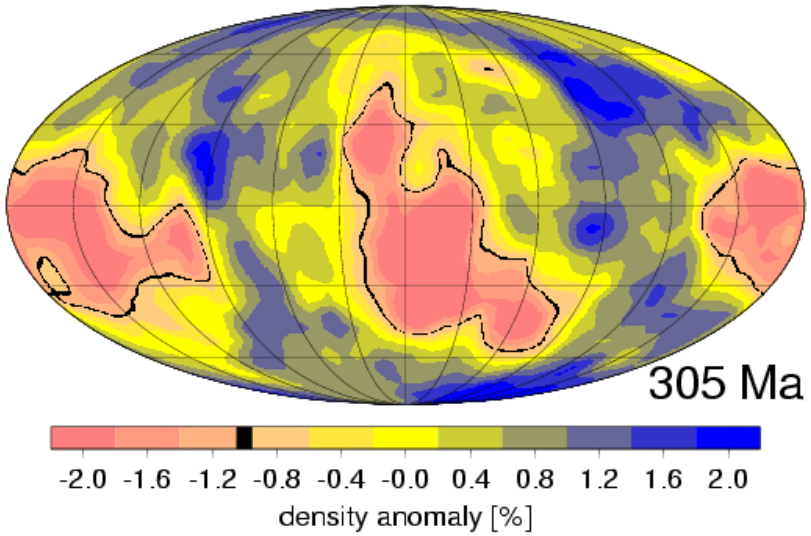
Subduction

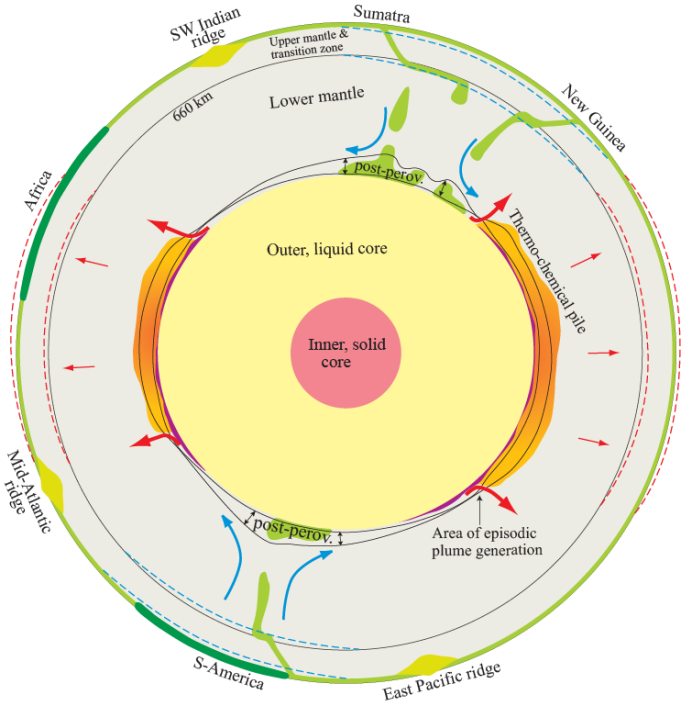


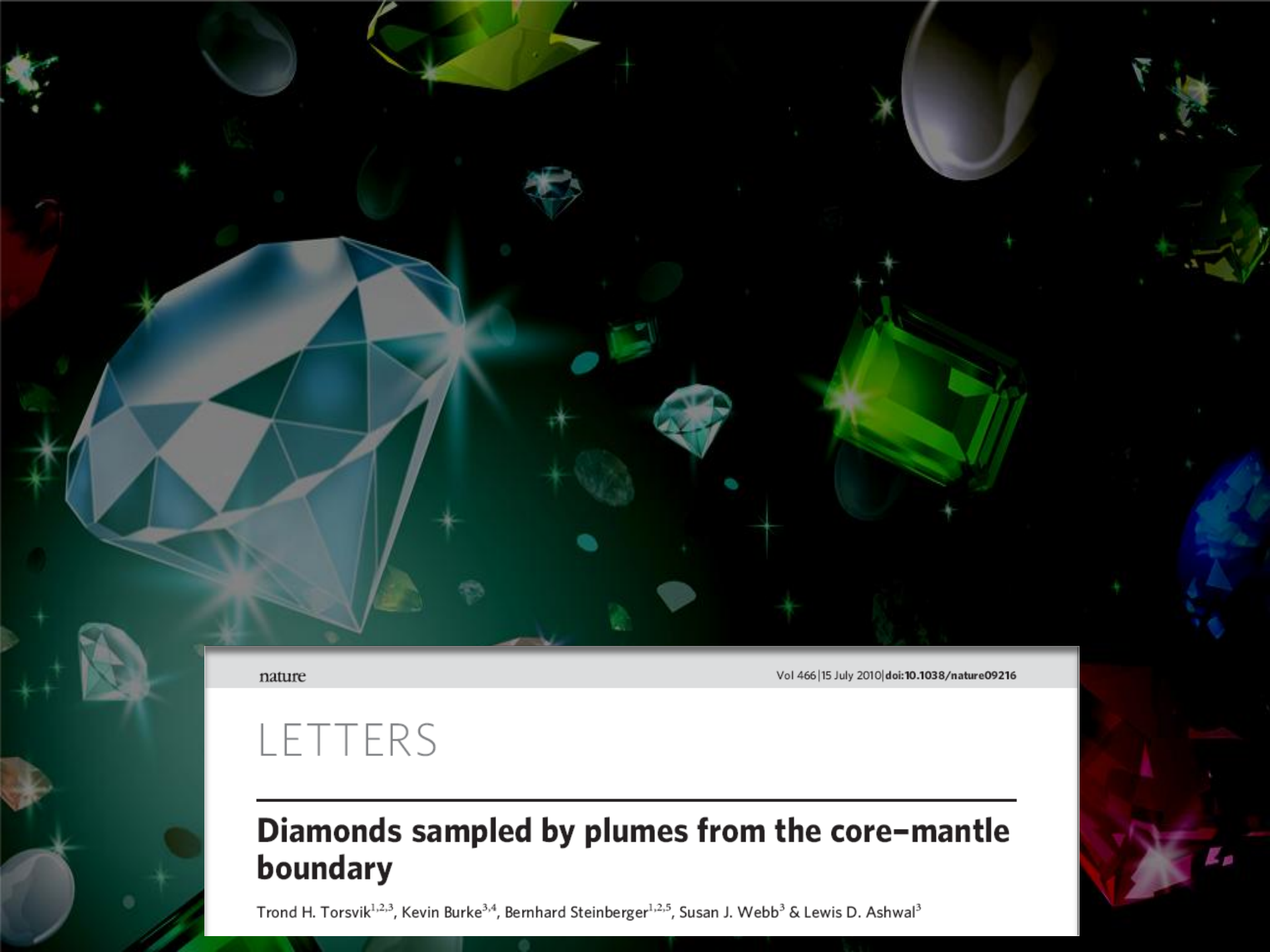




An amazing pattern







nature

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LETTERS

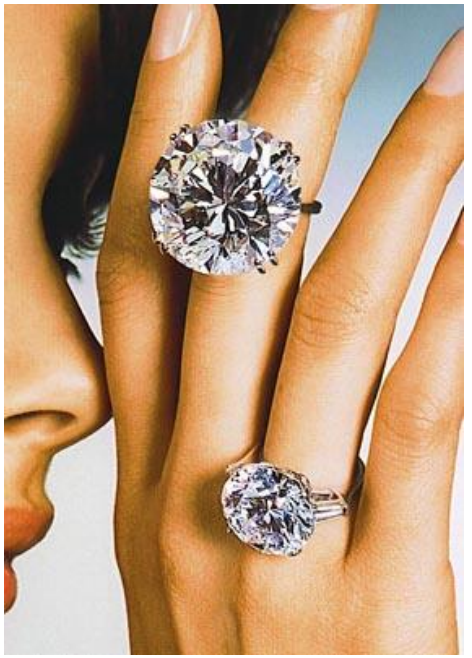
Diamonds sampled by plumes from the core–mantle boundary

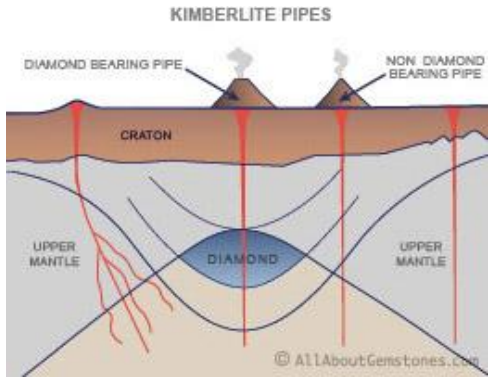
Trond H. Torsvik[1,2,3], Kevin Burke[3,4], Bernhard Steinberger[1,2,5], Susan J. Webb[3] & Lewis D. Ashwal[3]

Carbon is the 4th most abundant element in the universe by mass after hydrogen, helium, and oxygen. It is present in all known life-forms, and in the human body carbon is the second most abundant element by mass (c. 18.5%) after oxygen:

Carbon is the chemical basis of all known life.

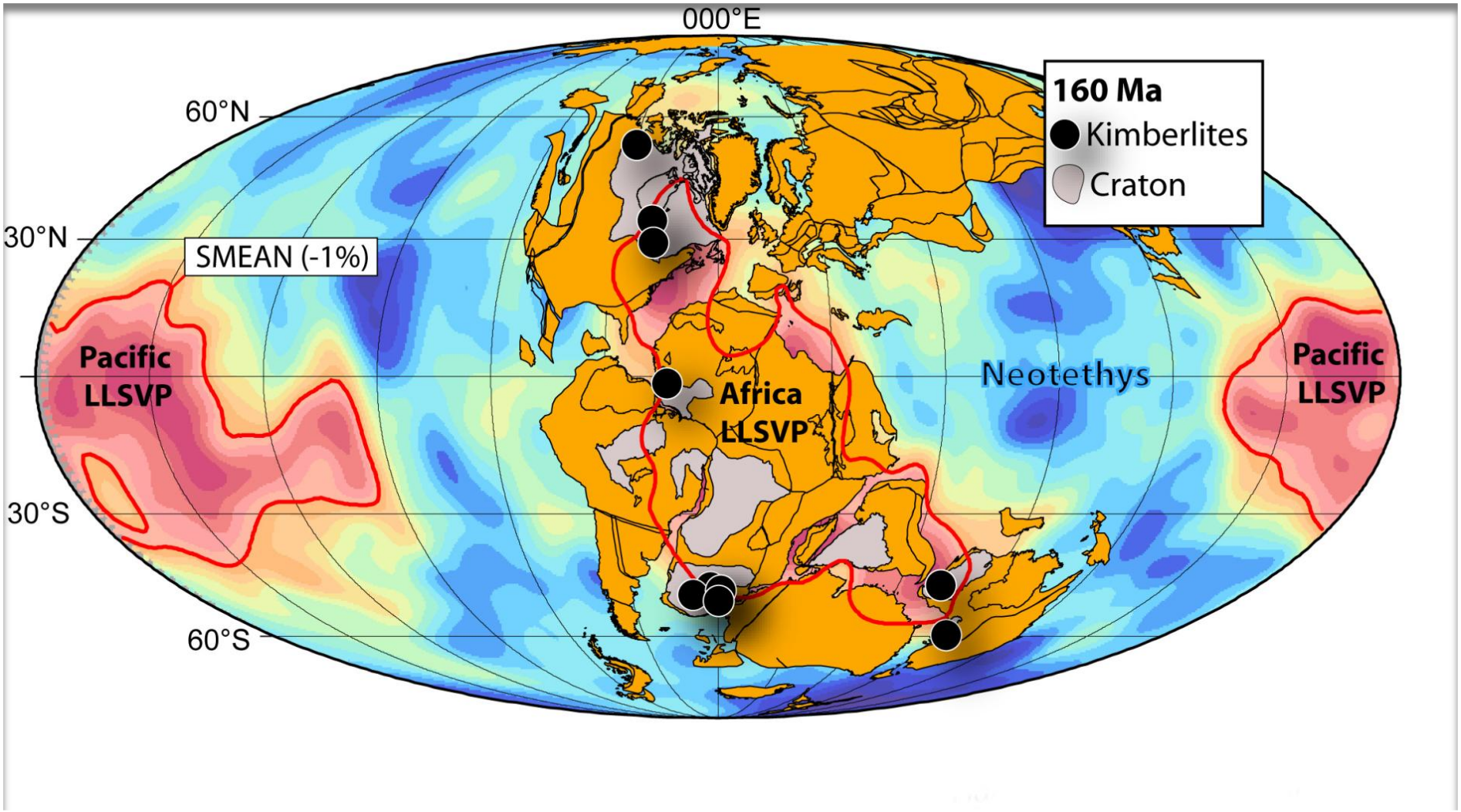
Diamonds are pure carbon formed at high-pressure/high-temperature conditions existing at depths of 150 to 180 kilometers in the Earth mantle – They are brought to the surface very fast by rocks known as kimberlites.



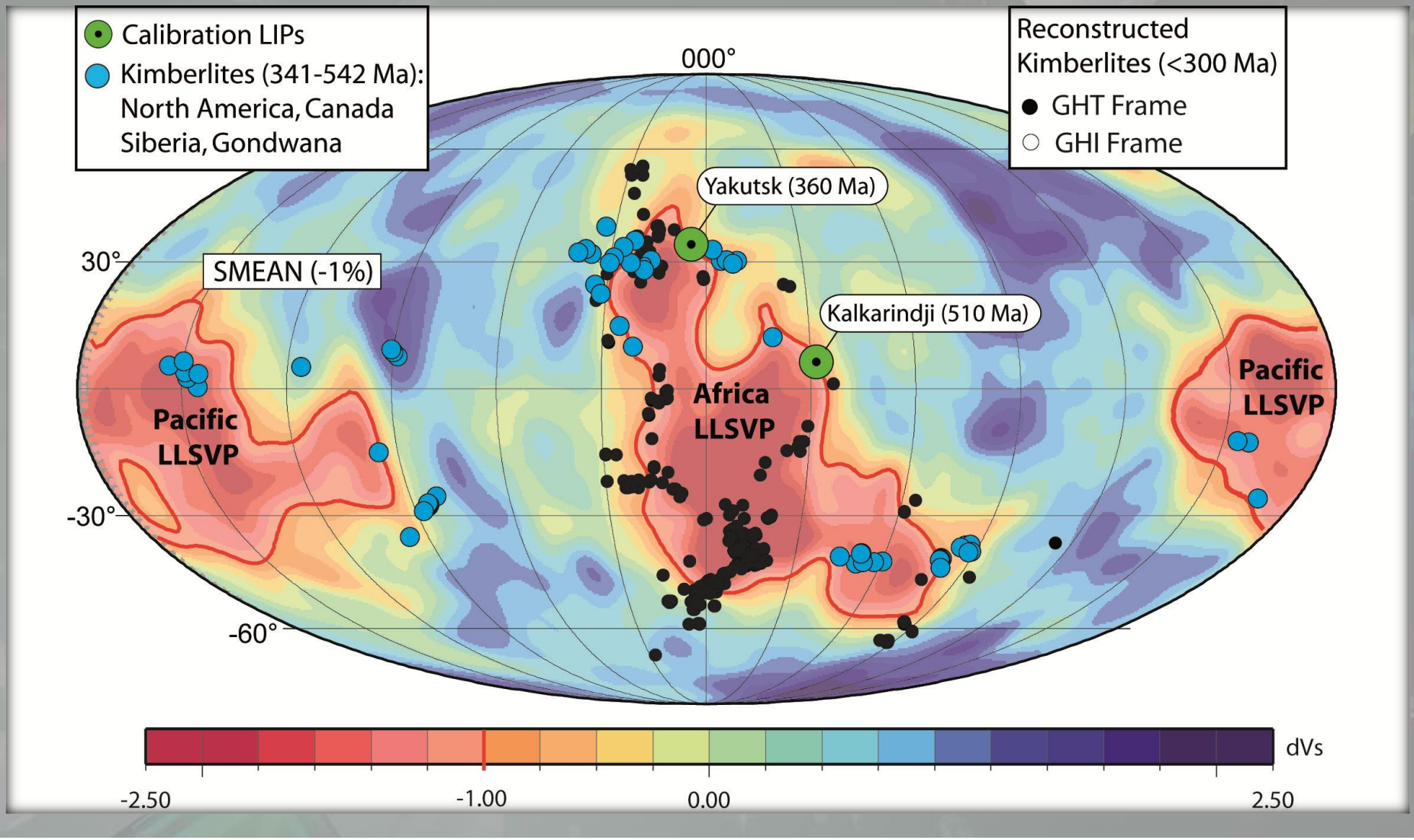


Kimberlite

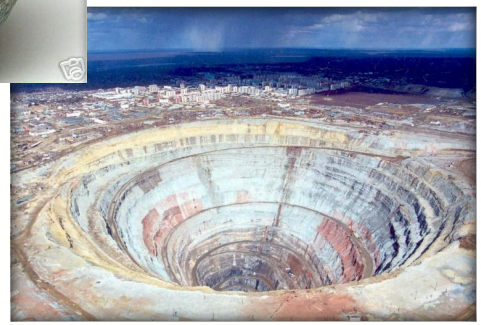
Lesotho mine (South Africa)

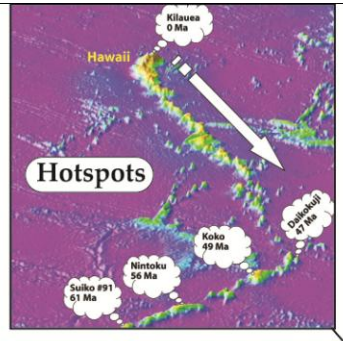

000°E
60°N
30°N
30°S
60°S
160 Ma
Kimberlites
Craton
SMEAN (-1%)
Pacific
LLSVP
Africa
LLSVP
Neotethys
Pacific
LLSVP

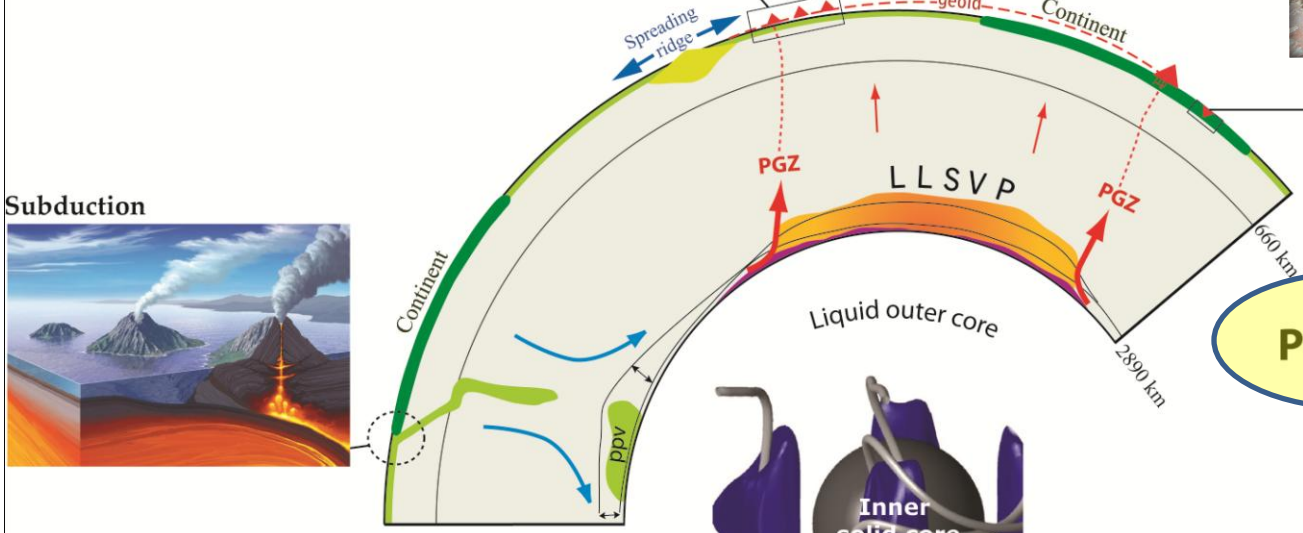
Kimberlites <= 542Ma



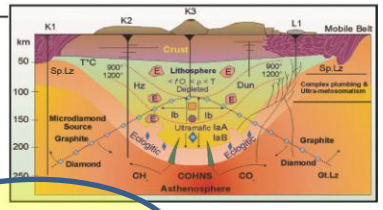
Plumes also explains kimberlites that pick up diamonds at 150-180 km depths and brings them to the surface in a few hours!



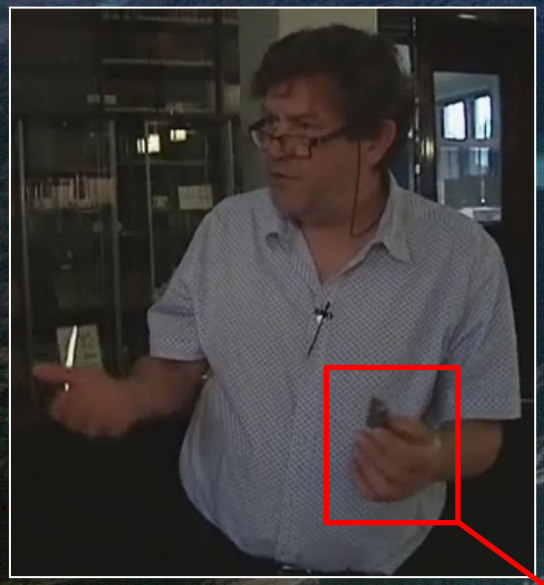




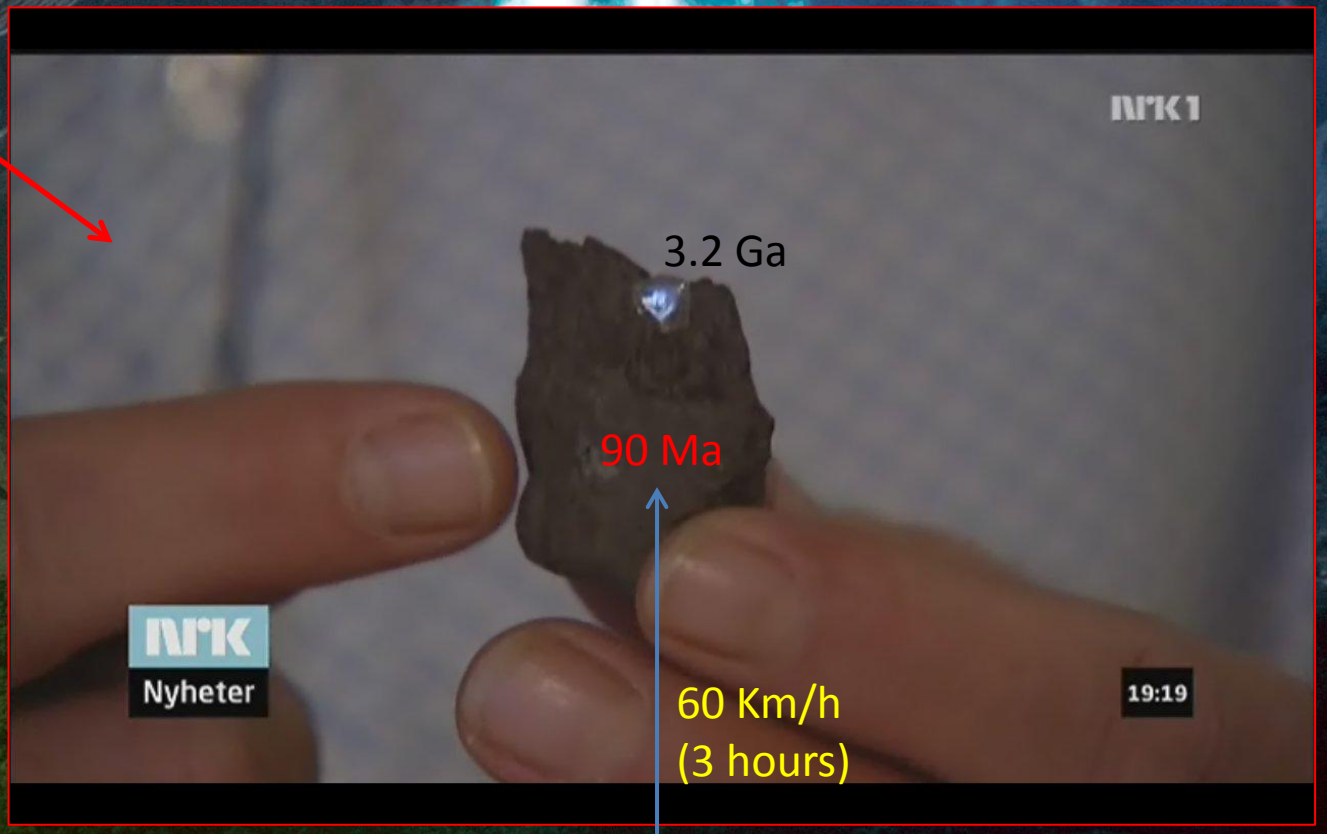
Kimberlites & Diamonds



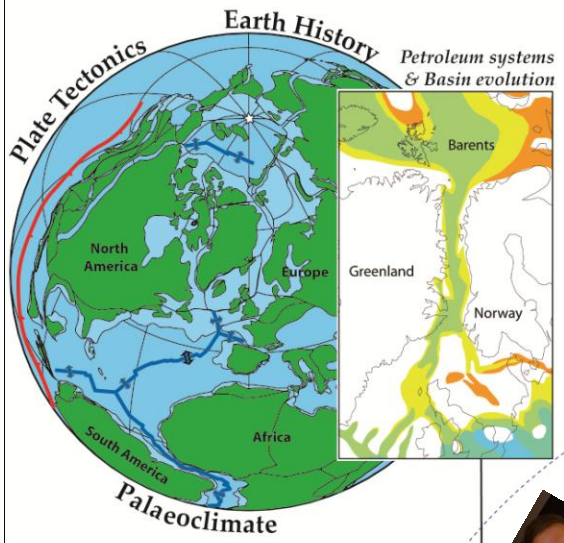
PLUMES

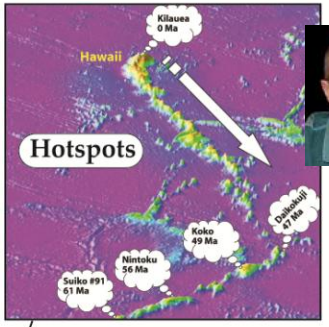


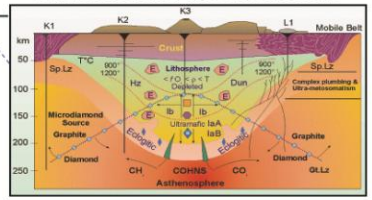

LESOTHO
KIMERLITE VOLCANO
ERODED PIPE
INTERNATIONAL KIMBERLITE CONFERENCE
20c


NRK1
3.2 Ga
90 Ma
60 Km/h
(3 hours)
nrk
Nyheter
19:19

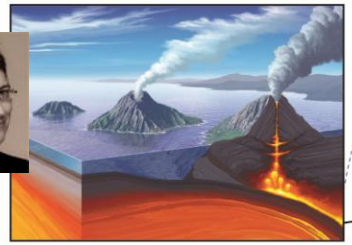
Earth and Beyond: Our playground



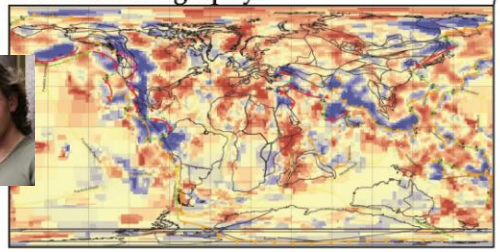




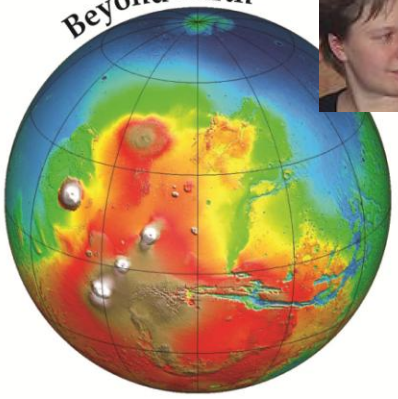
Subduction



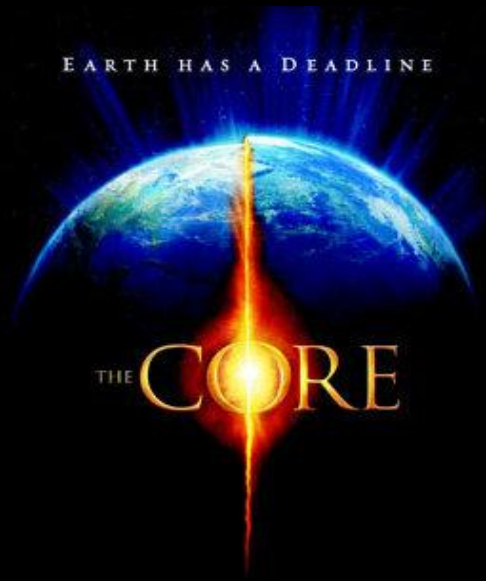
Seismic Tomography



$$\frac{\partial \mathbf{B}}{\partial t} = \eta \nabla^2 \mathbf{B} + \nabla \times (\mathbf{u} \times \mathbf{B})$$



MANTLE DYNAMICS



Linking Surface and Deep processes