Università di Trieste
Corso di Laurea in Geologia

Anno accademico 2014 - 2015

Geologia Marina

Parte I

Modulo 1.2 Oceani. Morfologia, struttura ed evoluzione

Docente
Martina Busetti

The oceans

1. The present oceans of the Earth
2. Morphology of the ocean sea floor
3. Structure of the ocean
4. Evolution of the ocean

1. Etymology

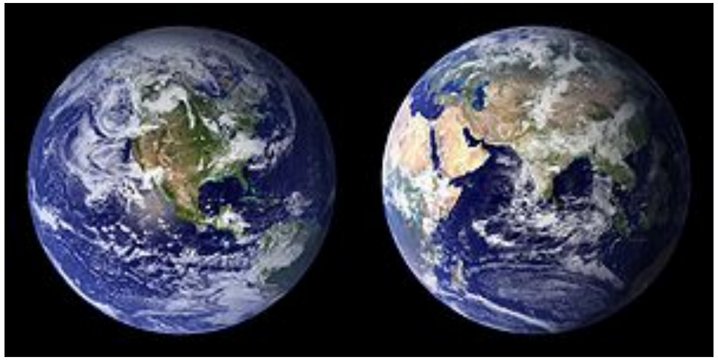
The term Ocean derives from Ὠκεανὸς (OKEANOS), greek river-god that was believed to surround the world, the external sea (not the Mediterranean).
But the rooth of word are from sanscrit ACAYANA, in the sense of "containing the waters.

Okeanos is one of the Titans,
son of Uran (sky) and Gea (earth),
husband of **Teti**,
and father of all the fluvial divinities.

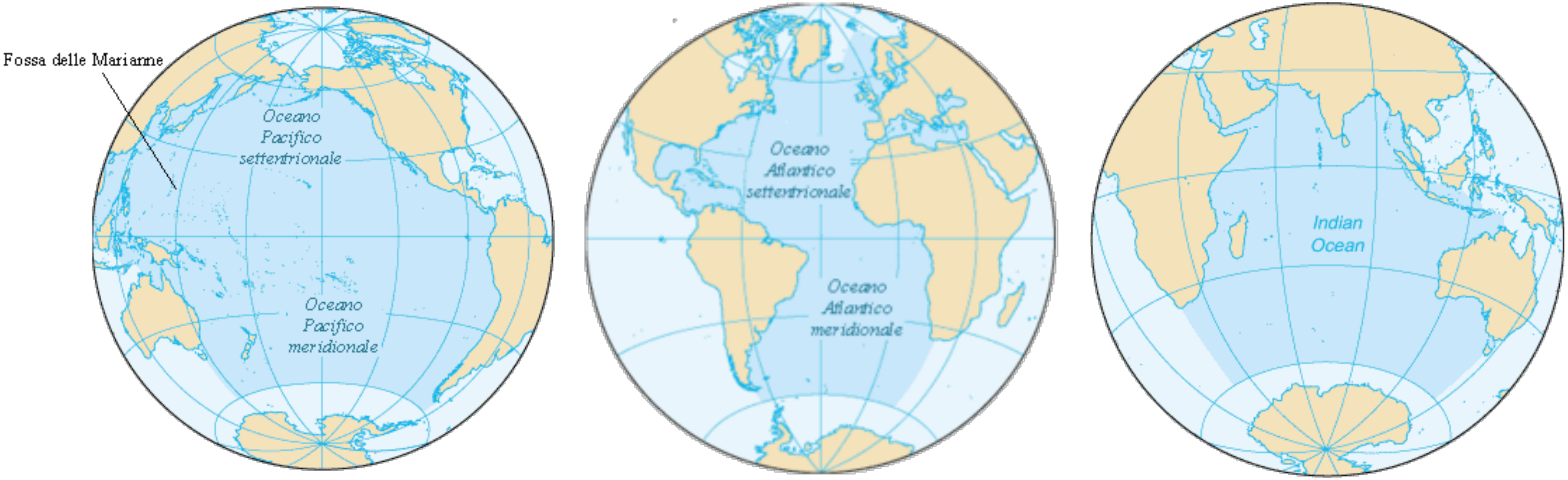
The Oceans are important because they:

- Cover 71-72% of the Earth surface
- Contain the 97% of the water of the Earth

but less than 5-10% has been explored



The present Oceans of the world



In the 1953, the International Hydrographic Bureau defined three oceans:

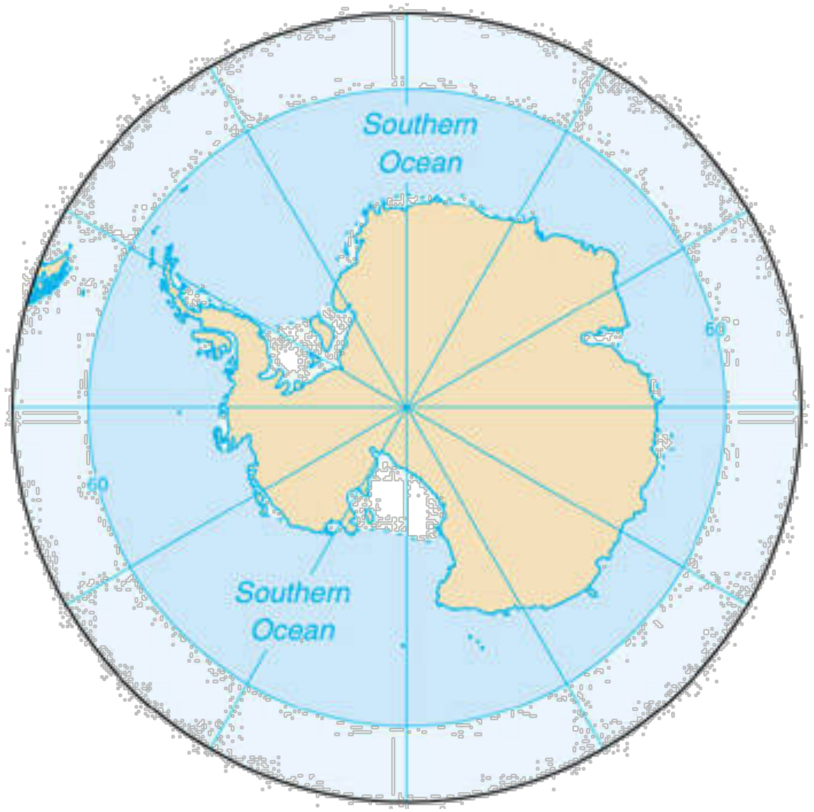
- the Pacific Ocean
- the Atlantic Ocean
- the Indian Ocean

Artic Ocean


Arctic Ocean
North Pole


Bering Sea
UNITED STATES
CANADA
GREENLAND
ICELAND
RUSSIA
Arctic Ocean
Beaufort Sea
Chukchi Sea
East Siberian Sea
Laptev Sea
Kara Sea
Barents Sea
Greenland Sea
Norwegian Sea
Baffin Bay
Hudson Bay
Labrador Sea
Atlantic Ocean
NORWAY
SWEDEN
FINLAND

Southern Ocean



In the Spring of 2000, the International Hydrographic Organization (IHO), published a draft definition of a new ocean:

the Southern Ocean

surrounding Antarctica and extending to 60° S. Up to now, the Southern Ocean is not formally defined by the IHO.

Ocean	Area	Average Depth (m)	Deepest depth (m)
Pacific Ocean	165,250,000 km^2	4,028 m	Mariana Trench 11,033 m
Atlantic Ocean	106,400,000 km^2	3,926 m	Puerto Rico Trench 8,604 m
Indian Ocean	73,560,000 km^2	3,963 m	Java Trench, 7,725 m
Southern Ocean	20,330,000 km^2	4,000 to 5,000 m	the southern end of the South Sandwich 7,236 m
Arctic Ocean	13,990,000 km^2	1,205 m	Eurasia Basin, 5,540 m

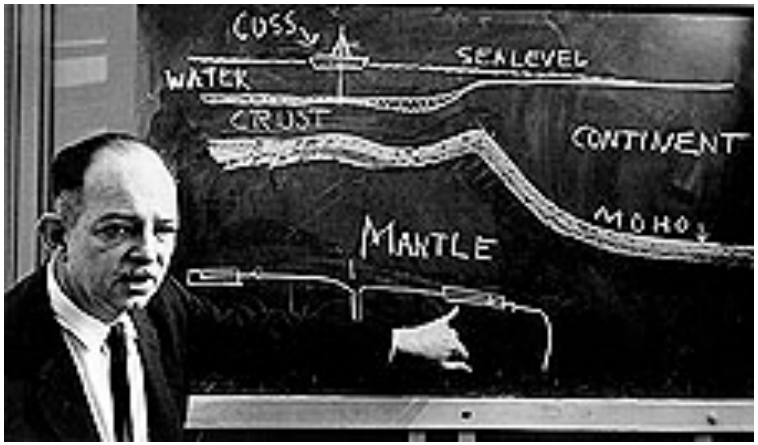
SEA FLOOR MORPHOLOGY

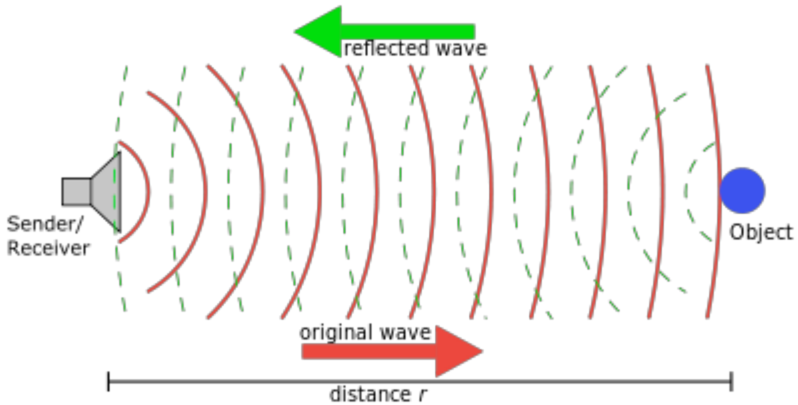
Harry Hess (1906 – 1969)

Professor of geology at Princeton University

During the Second World War, Hess was the captain of a ship equipped with a SONAR (SOund NAvigation and Ranging, invented in 1917 by Paul Langevin).

Hess discovered the Mid-oceanic ridges and the guyots, and in the ’62 he published the Sea floor Spreading theory, fundamental for the Plate Tectonic theory.



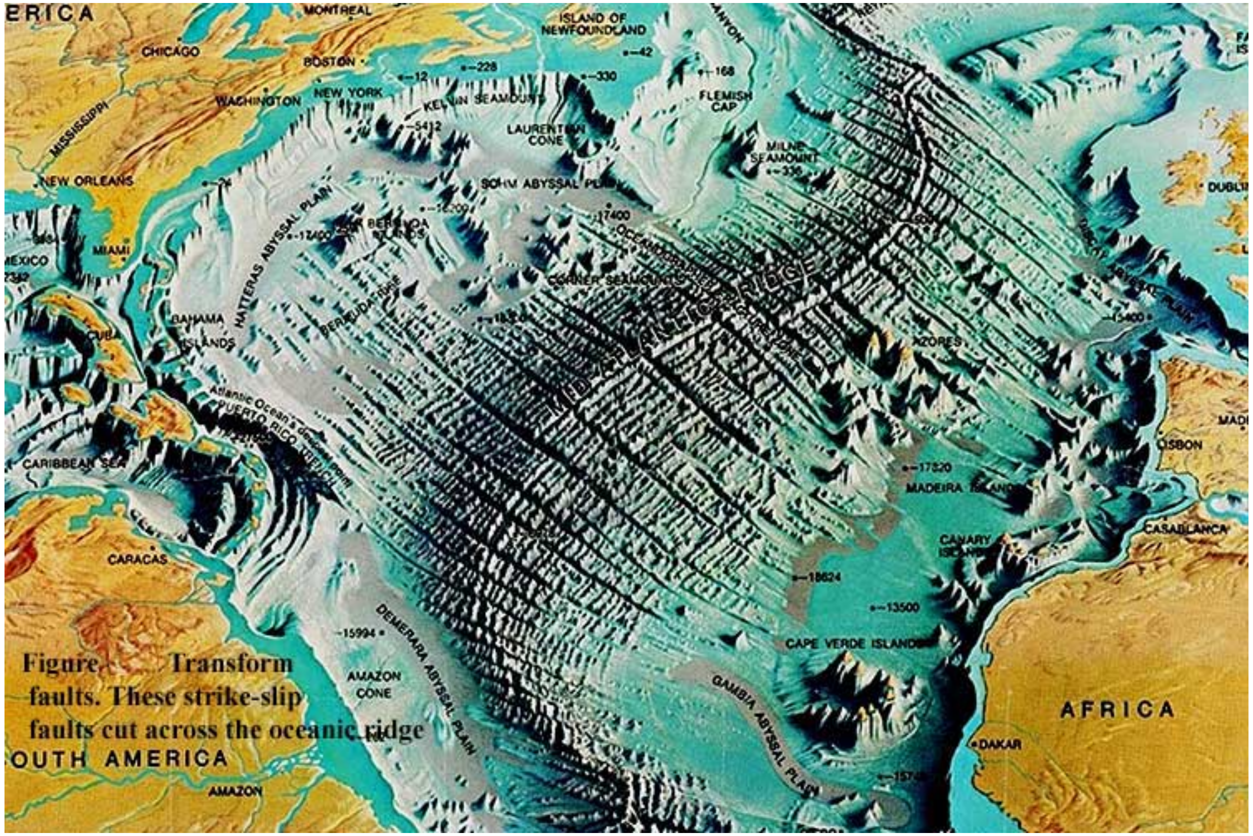


The SONAR principle

SEA FLOOR MORPHOLOGY 1977

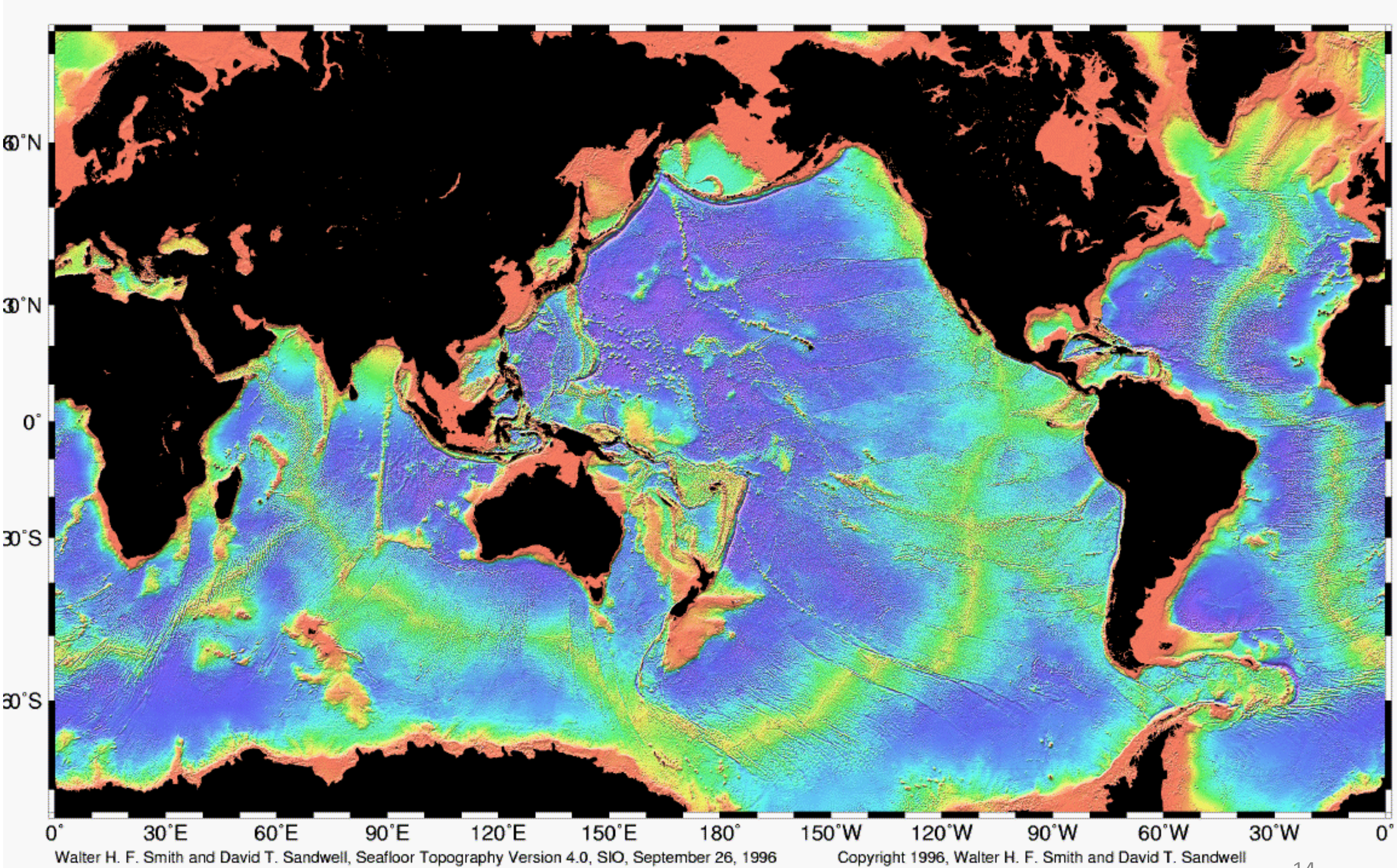
Marie Tharp and Bruce Heezen, oceanographers of the Columbia University's Lamont Geological Observatory.
They discovered the 60.000 km of underwater ridges
The map was painted by Heinrich C. Berann.

Mid-Ocean Ridges



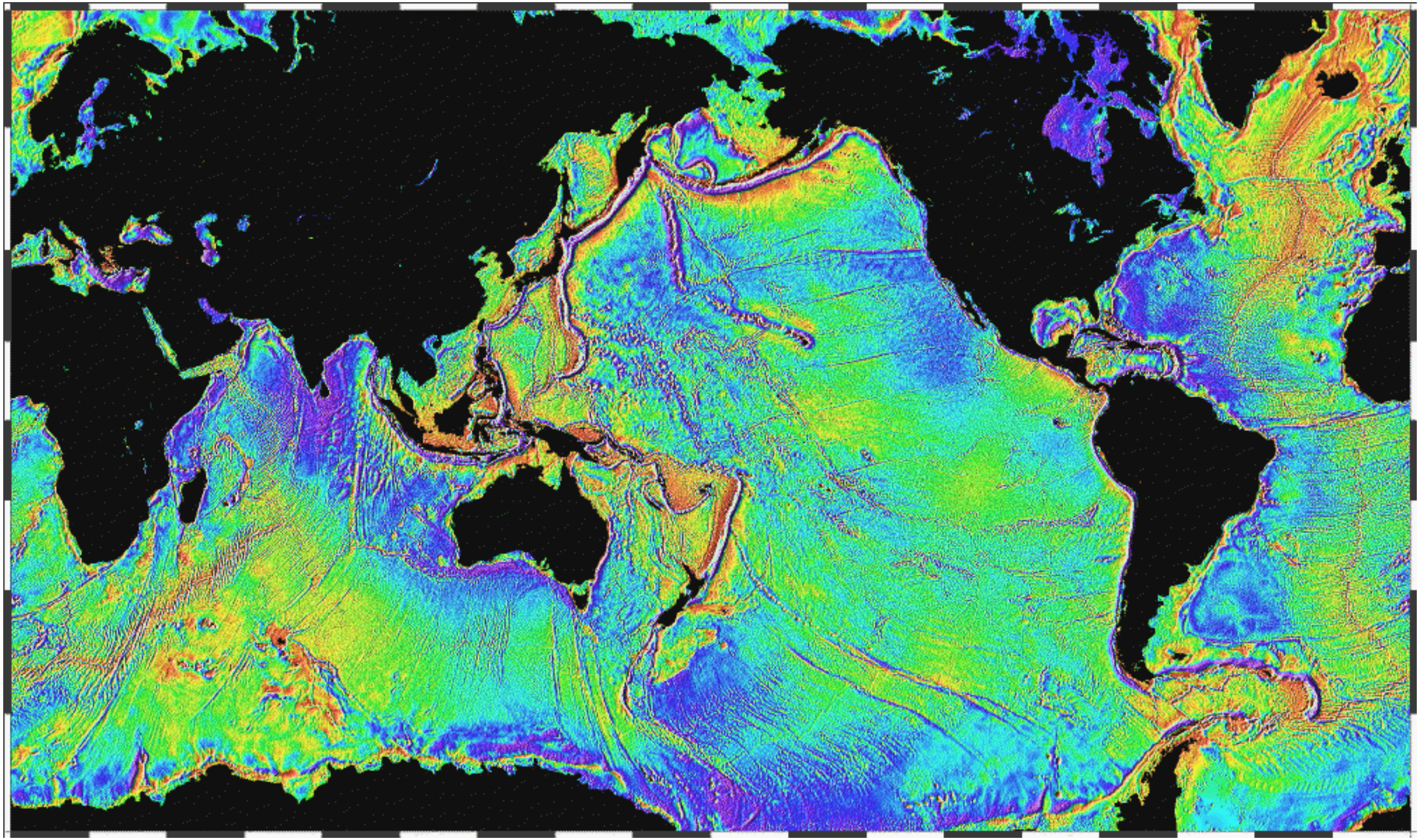
- The largest feature of the ocean floor.
- Linear belt of submarine mountains about 60.000 km long.
- Plate boundaries: new magma forces its way up between two plates and pushes them apart.

Global sea floor topography from gravity data derived from satellite altimetry and shipboard depth soundings



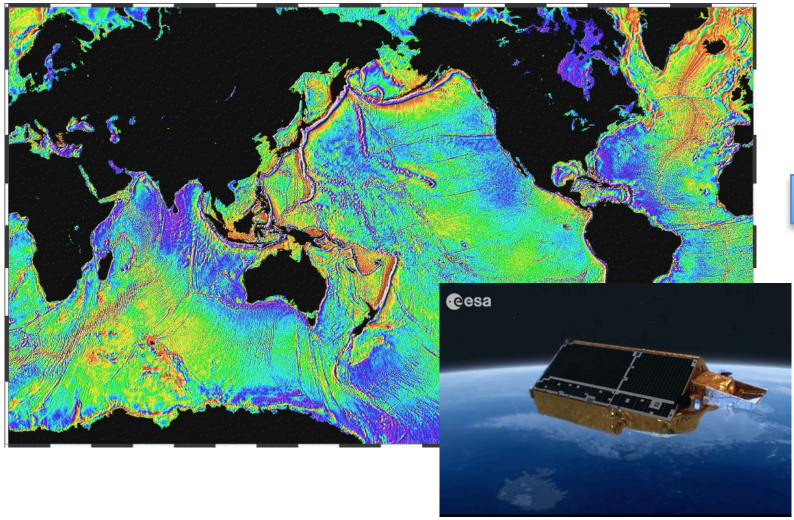
SMITH AND SANDWELL, 1996

Global gravity map of the oceans - from GEOSAT and ERS-1

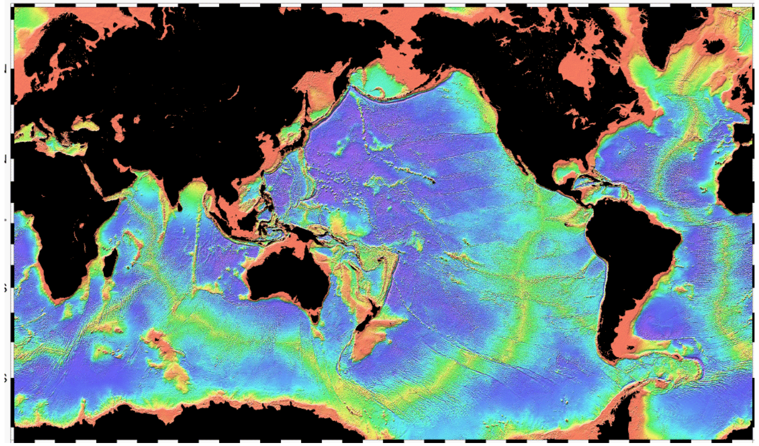


SMITH AND SANDWELL, 1996

Global gravity map of the oceans
from GEOSAT and ERS-1



Global sea floor topography
from gravity data and shipboard depth soundings

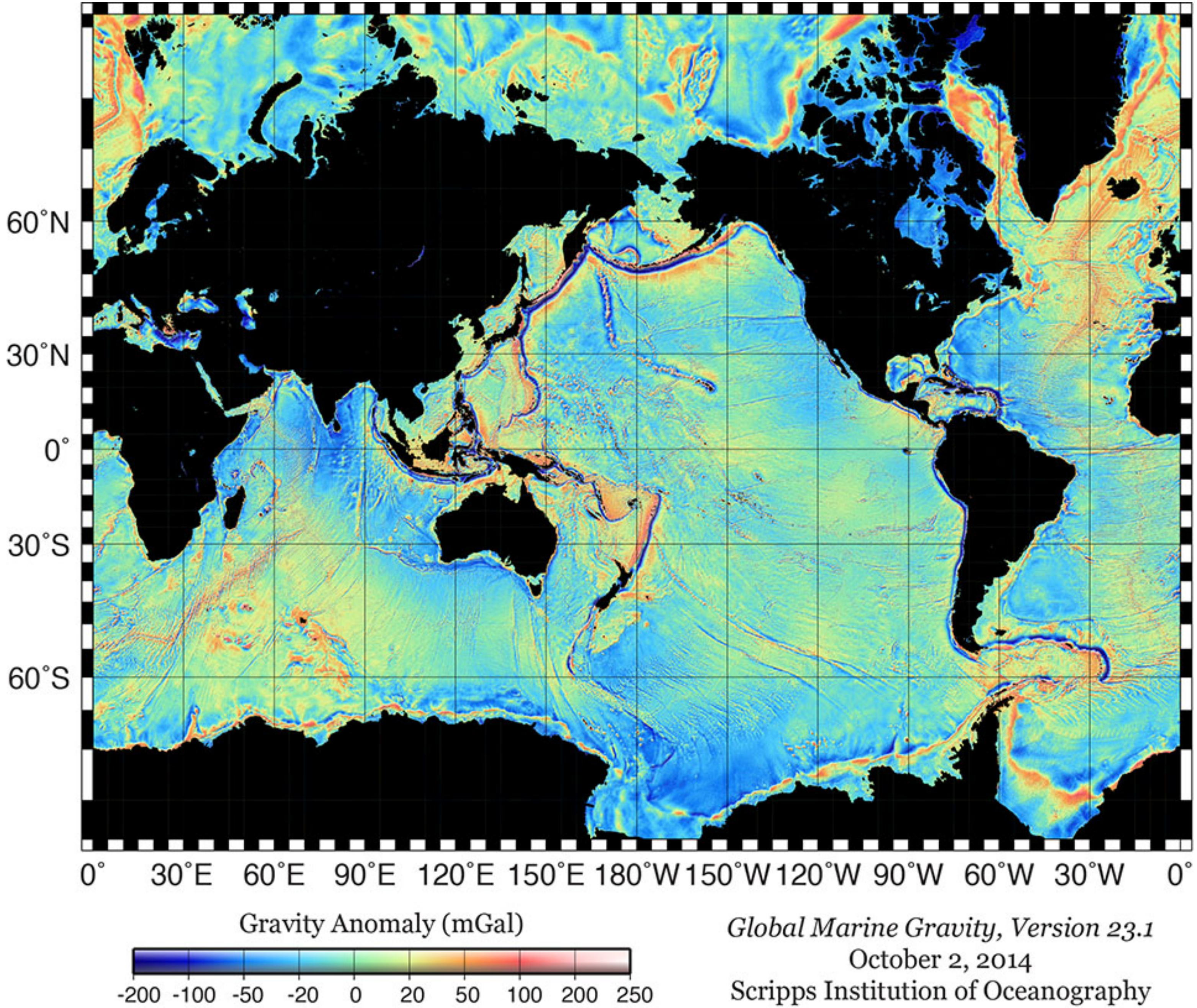


SMITH AND SANDWELL, 1996

Dixon *et al., JGR, (*1983) have summarized the basic theory for estimating sea floor topography from gravity anomalies.

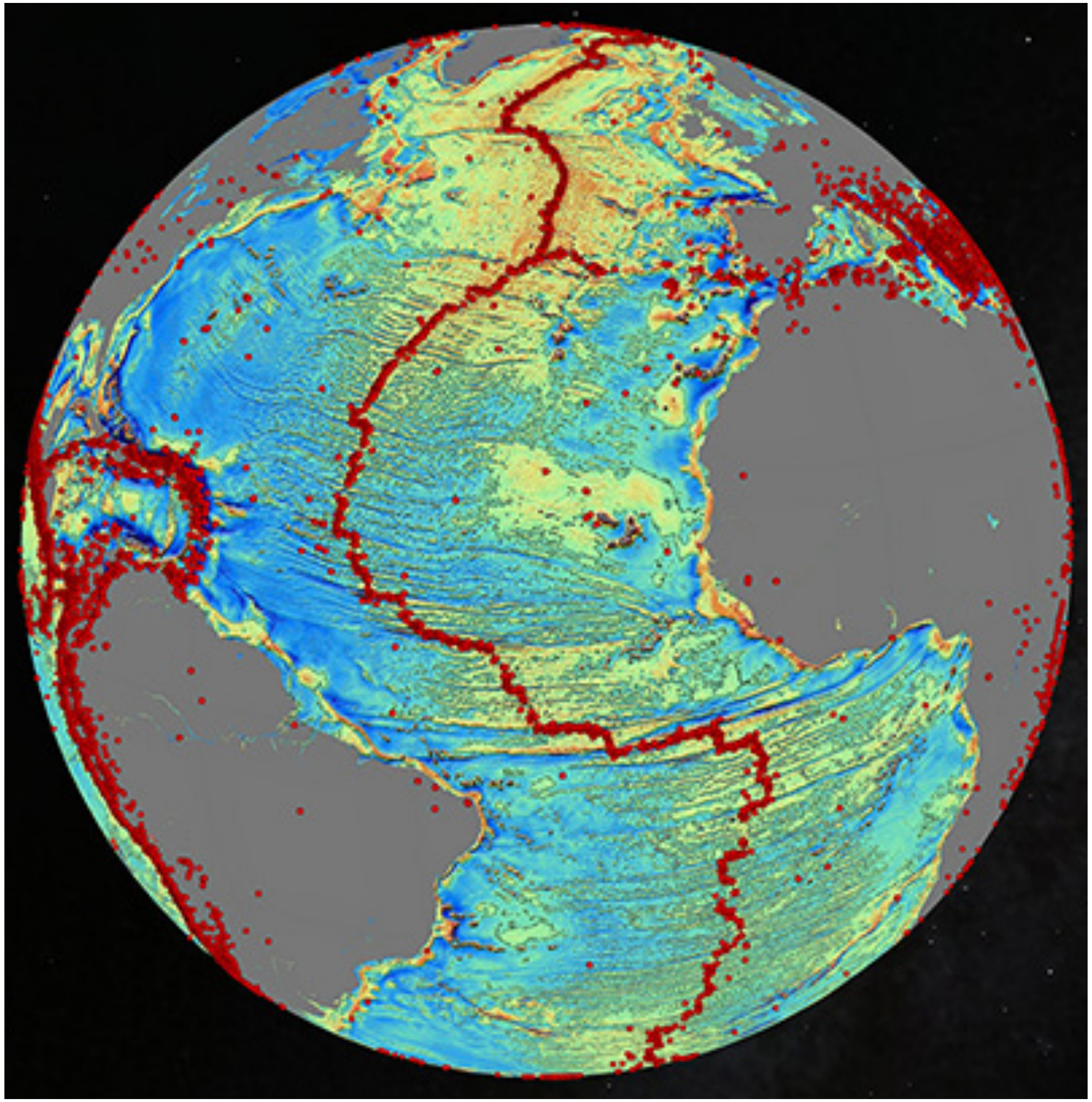
Models of the isostatic compensation of sea floor topography furnish a spectral transfer function that predicts the gravity anomaly expected from sea floor topography.

This transfer function depends on: mean depth, crustal density and thickness, and elastic lithosphere thickness.



Sandwell et alii, Science 2014

Marine gravity model of the North Atlantic

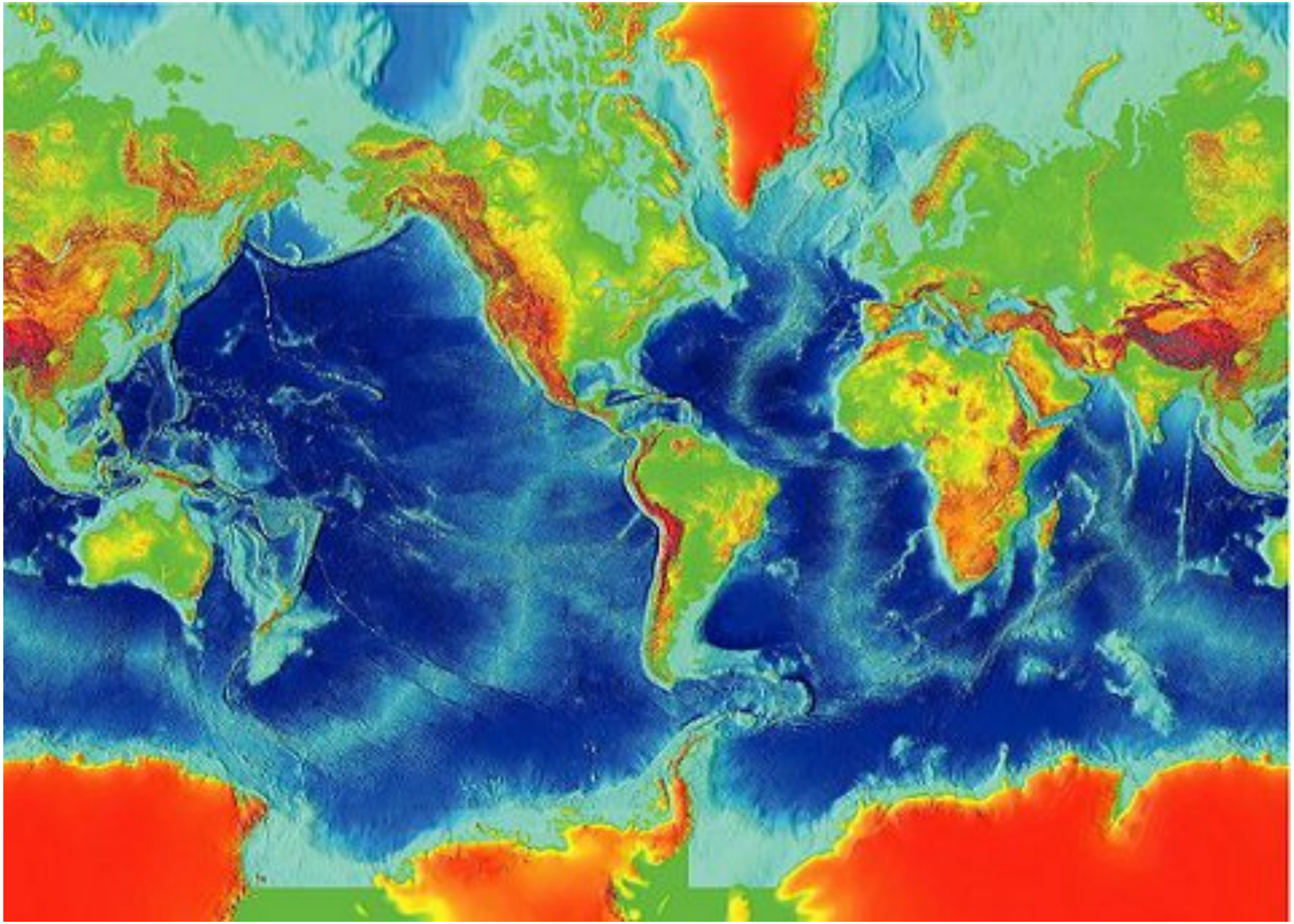


Red dots show locations of earthquakes with magnitude > 5.5 and they highlight the present-day location of the seafloor spreading ridges and transform faults.

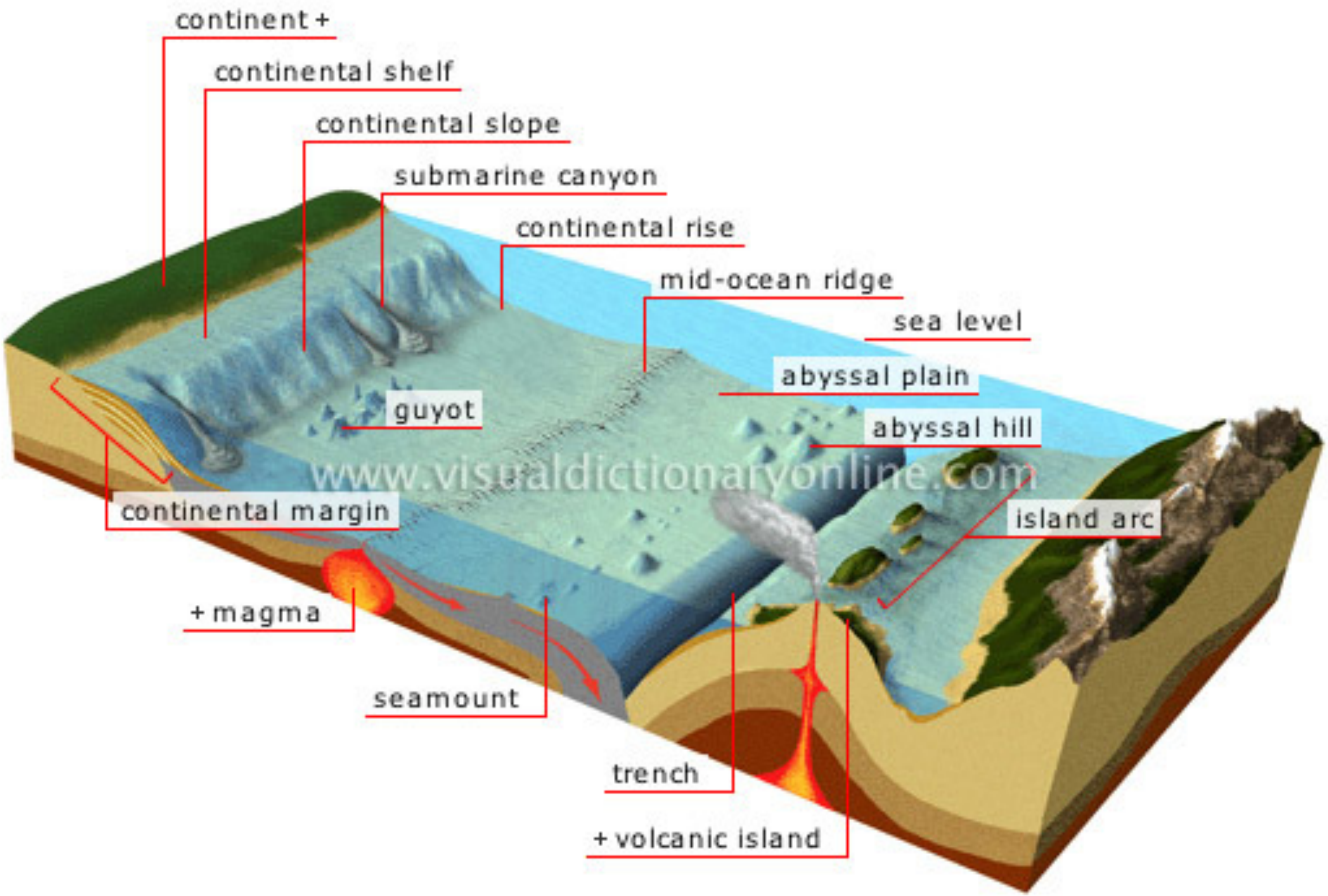
This gravity information shows the details of the plate tectonic history of the rifting of these continents including the subtle signatures of fracture zones that are currently buried by sediment.

Sandwell et alii, Science 2014

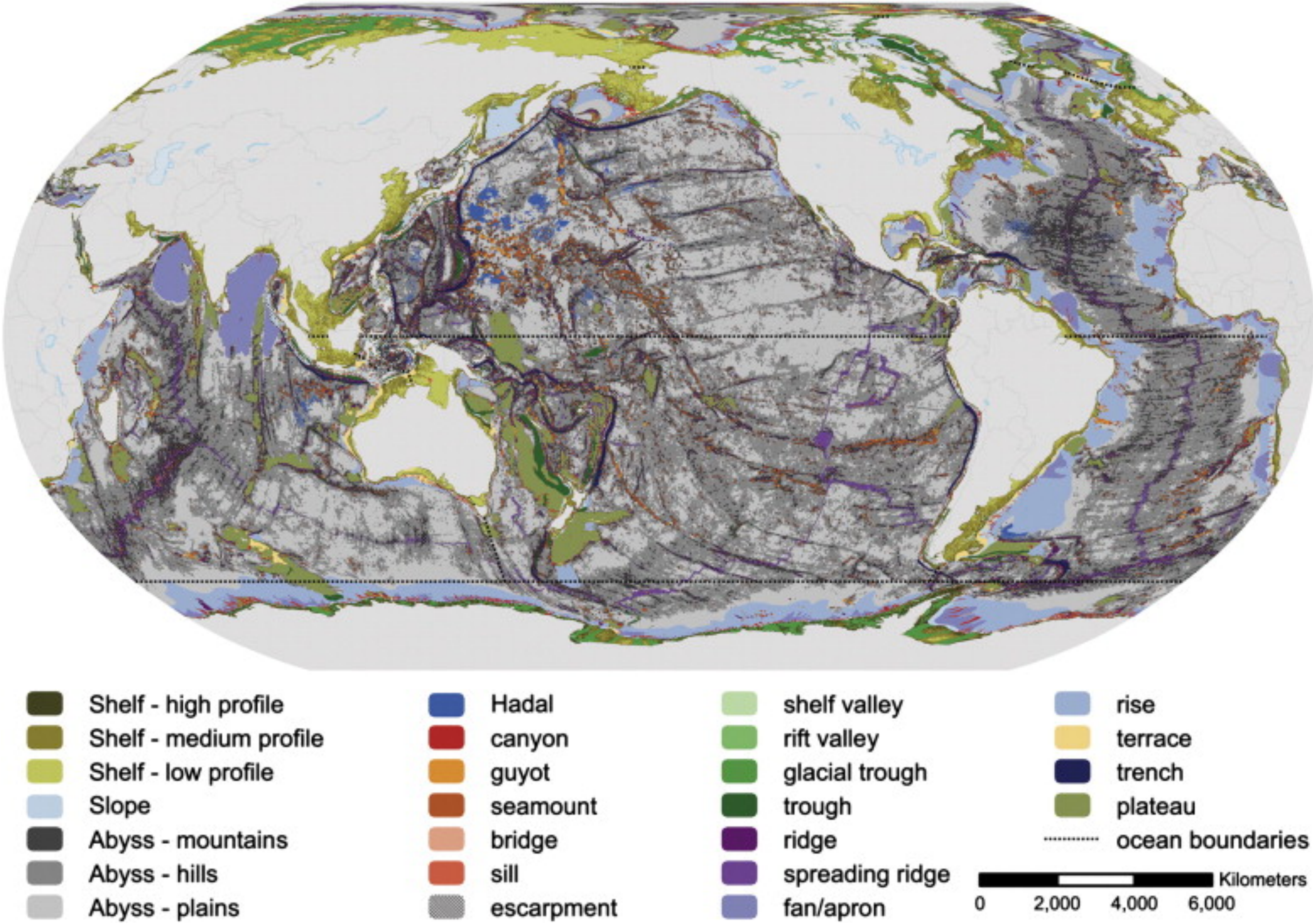
SEA FLOOR MORPHOLOGY



SEA FLOOR MORPHOLOGY

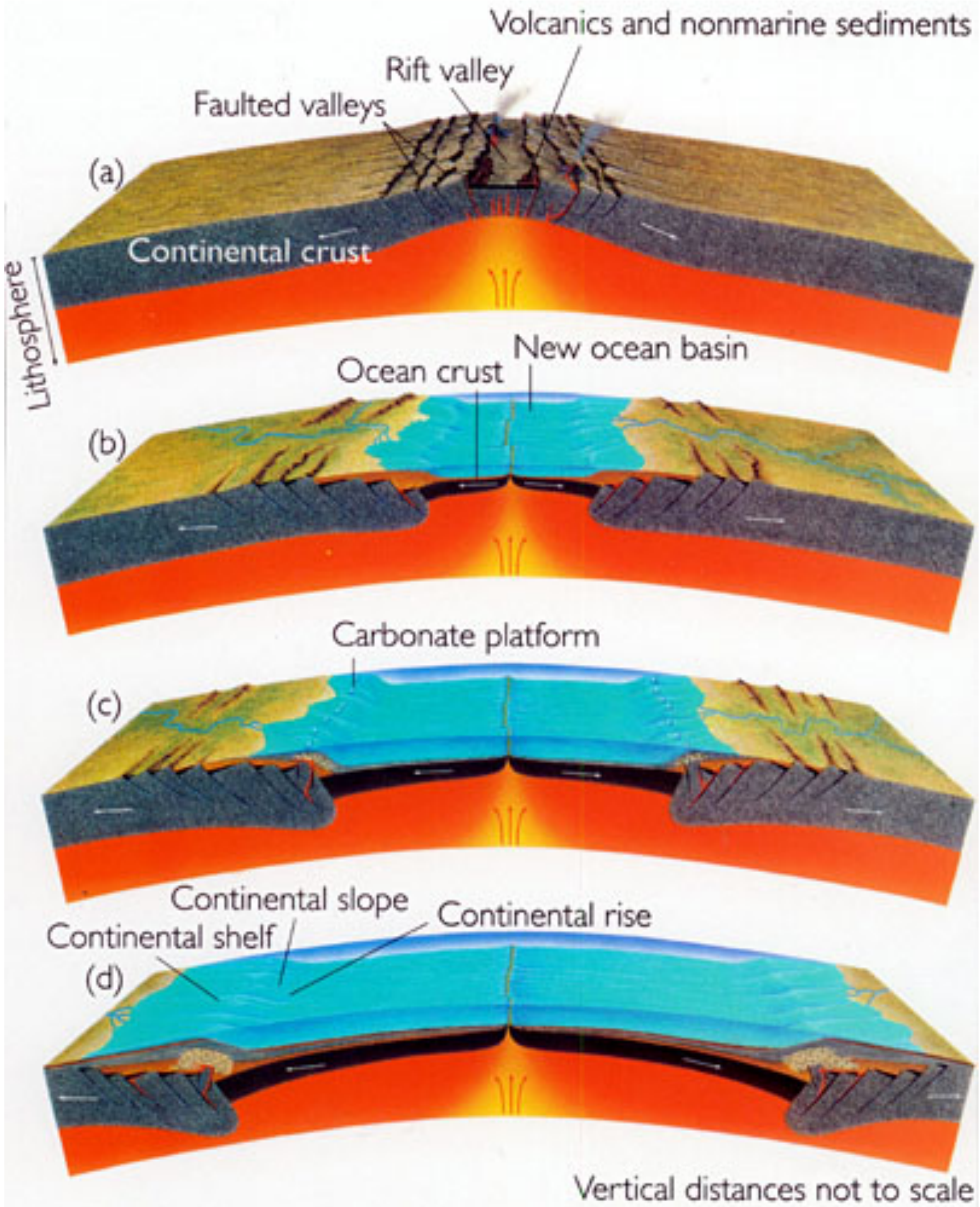


Geomorphic features map of the world's oceans.



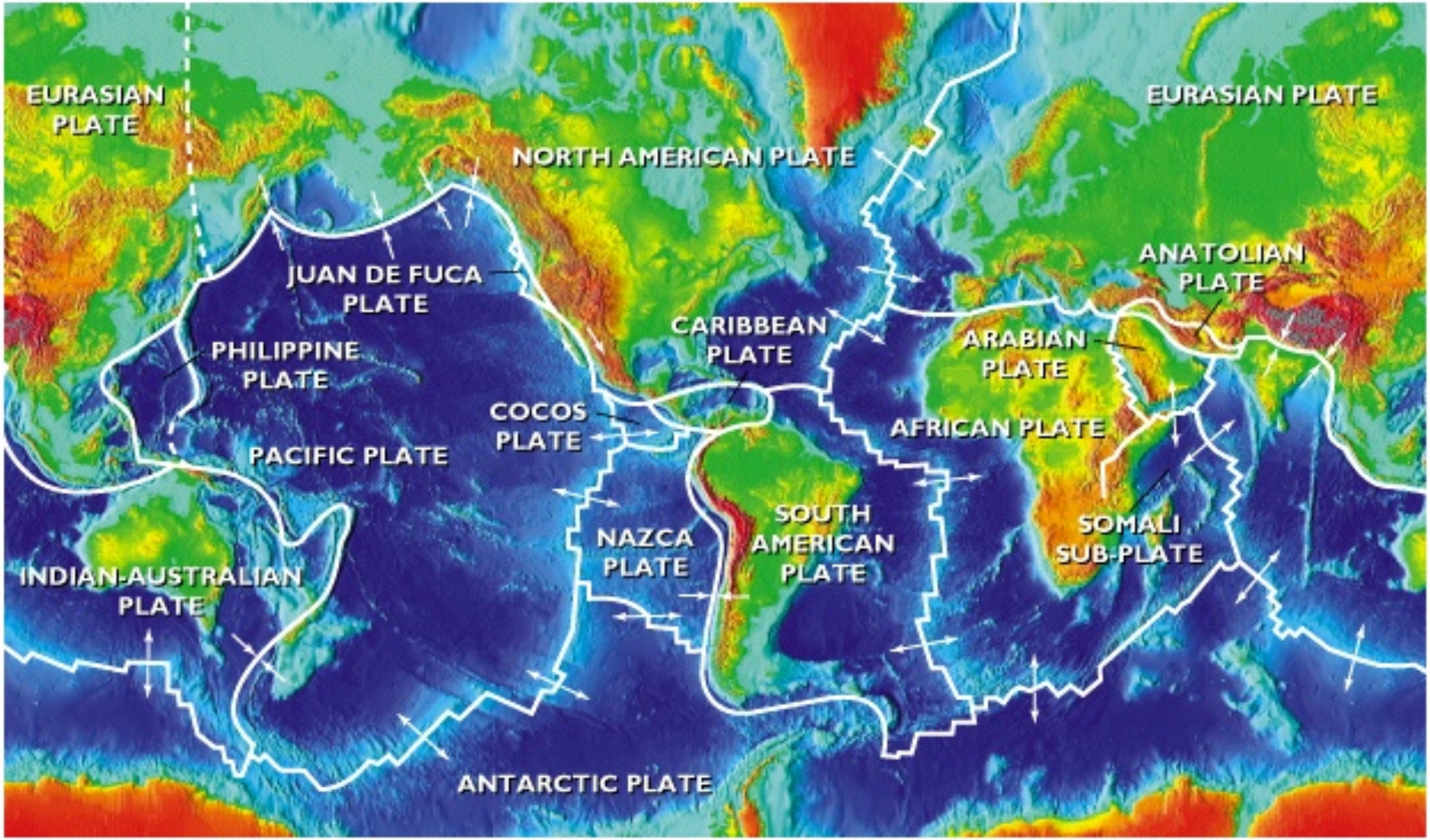
Harris, Macmillan-Lawler, Rupp, Baker, 2014. **Geomorphology of the oceans.** Marine Geology, 352, 2014, 4–24.
http://dx.doi.org/10.1016/j.margeo.2014.01.011

The Ocean formation

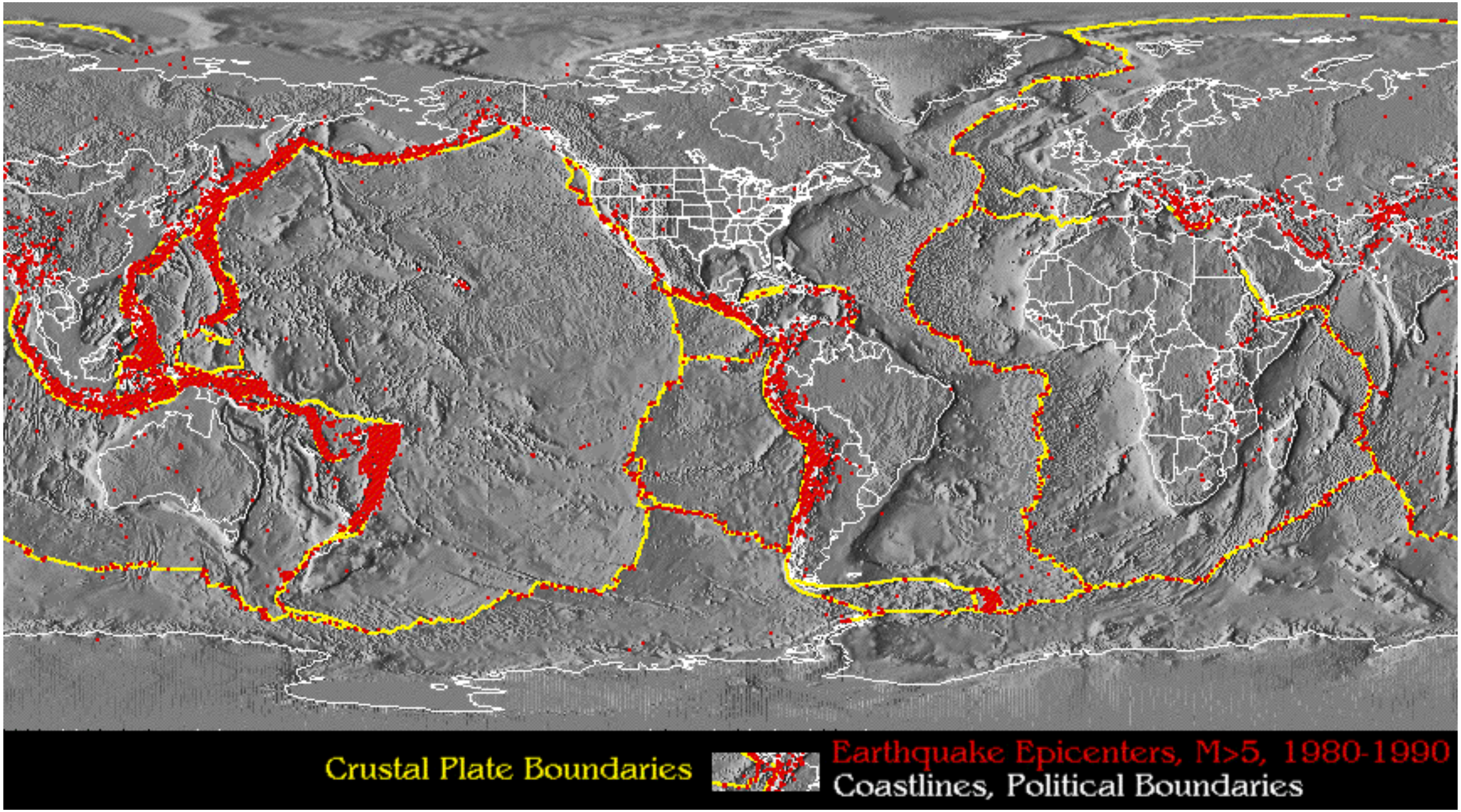


continental rift

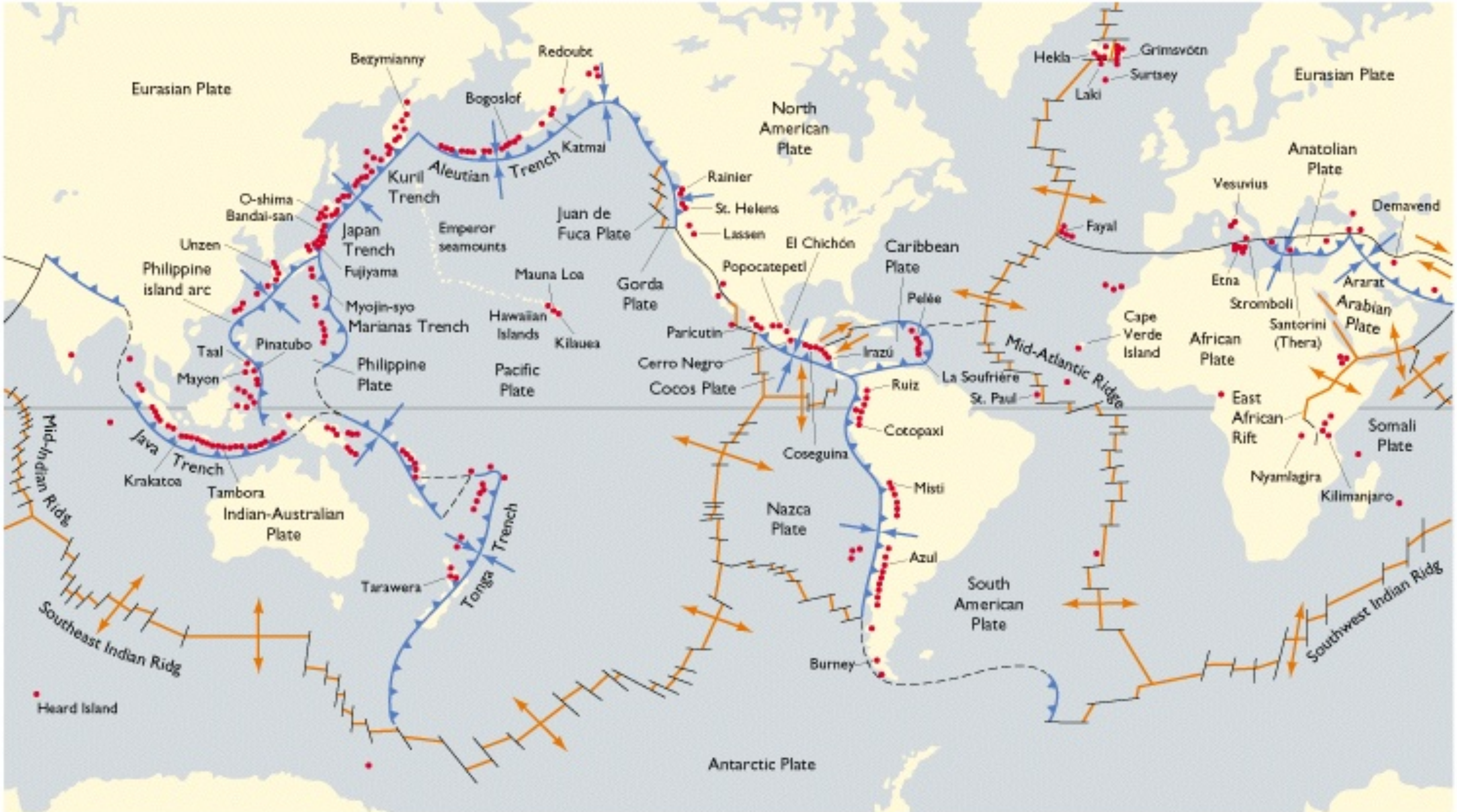
SEA FLOOR MORPHOLOGY

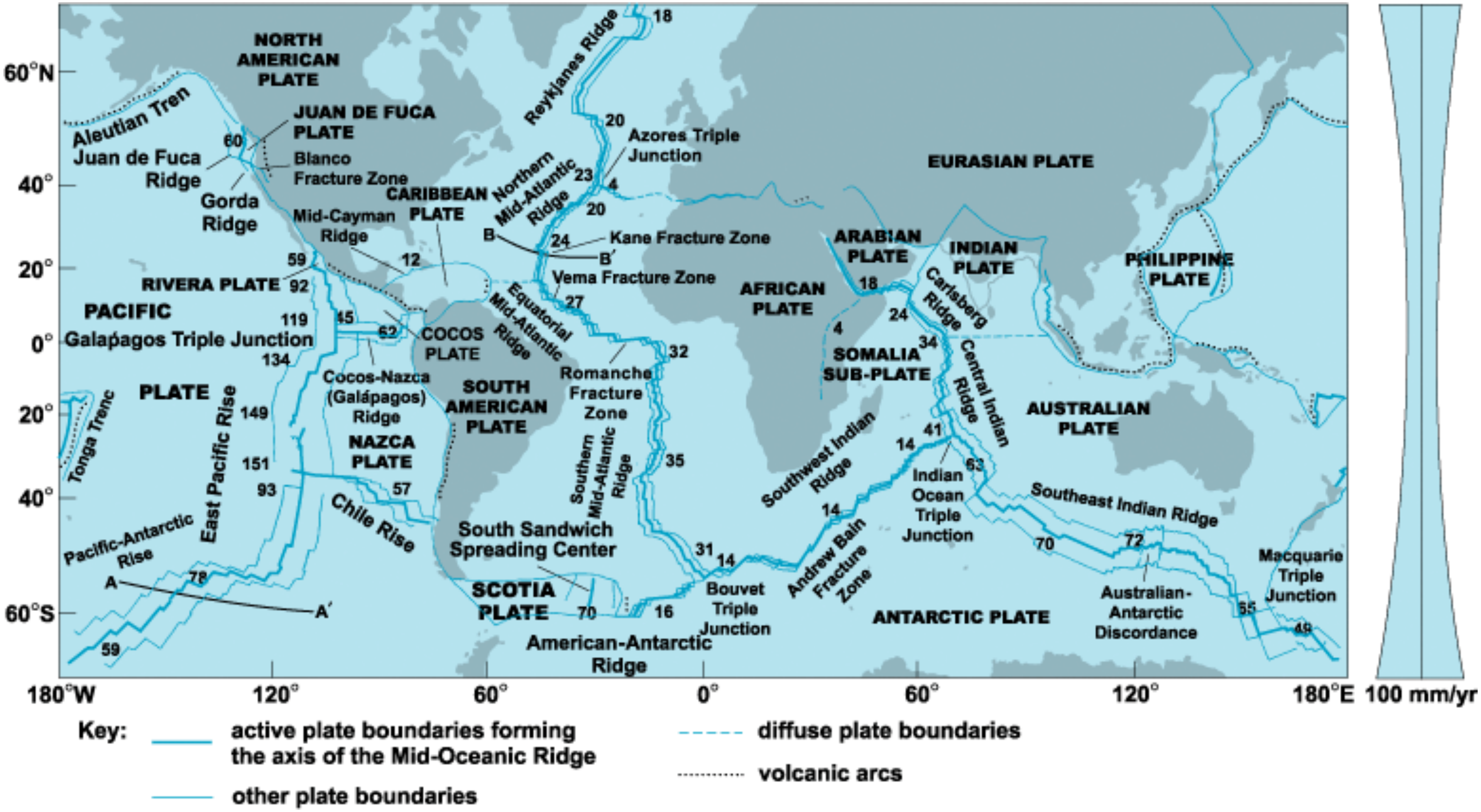


Mid-oceanic ridge system is 60,000 km long, 2000 km wide, 3000 m high



Shallow earthquakes at the Ocean Ridges

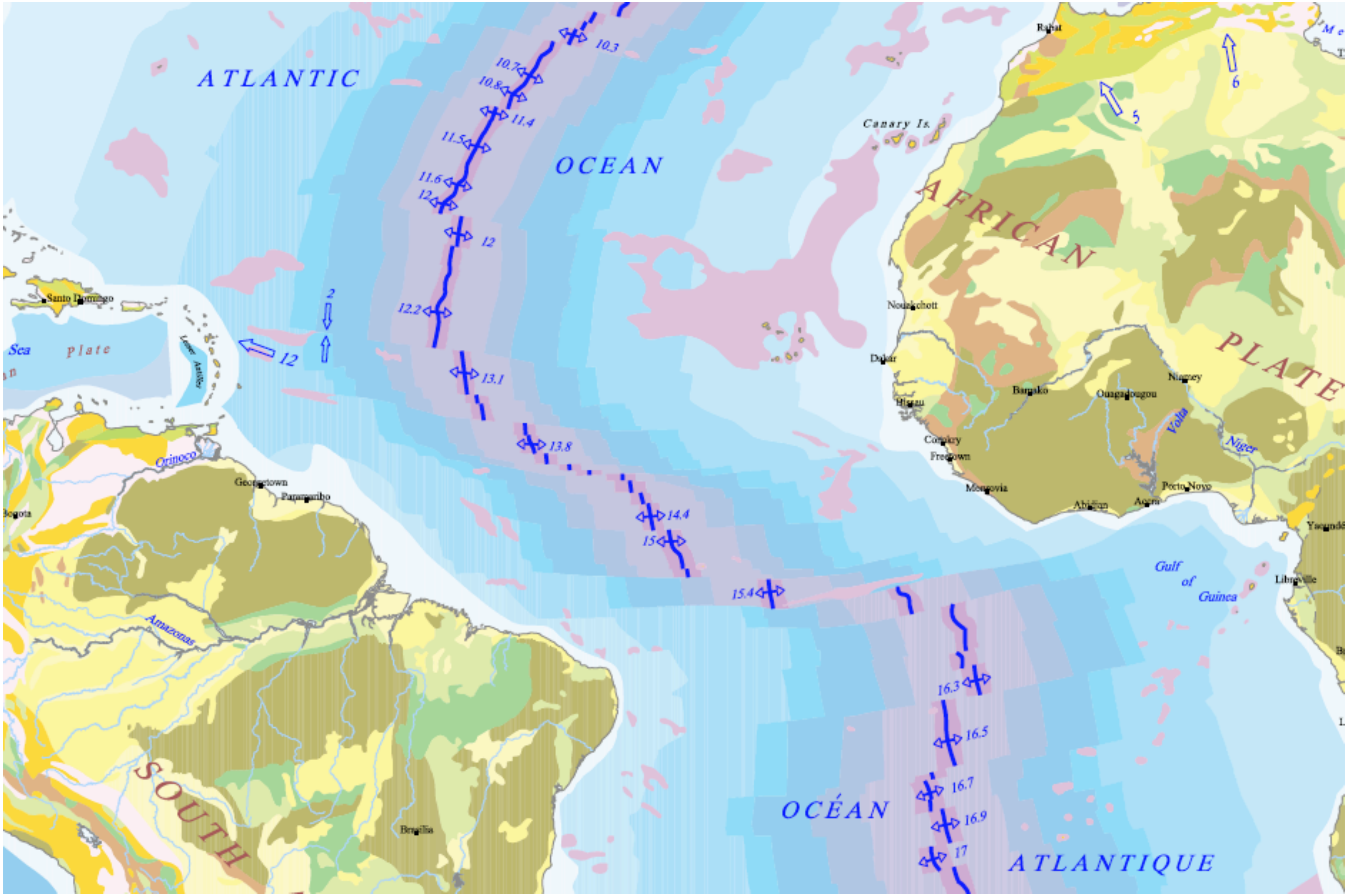

Eurasian Plate
Bezymianny
Redoubt
Bogoslof
Katmai
Aleutian Trench
Kuril Trench
Japan Trench
O-shima
Bandai-san
Unzen
Fujiyama
Philippine island arc
Emperor seamounts
Juan de Fuca Plate
Gorda Plate
Mauna Loa
Hawaiian Islands
Kilauea
Myojin-syo
Marianas Trench
Philippine Plate
Pacific Plate
Taal
Pinatubo
Mayon
Java Trench
Krakatoa
Tambora
Indian-Australian Plate
Mid-Indian Ridge
Southeast Indian Ridge
Heard Island
Tarawera
Tonga Trench
North American Plate
Rainier
St. Helens
Lassen
El Chichón
Popocatepetl
Paricutin
Cerro Negro
Cocos Plate
Irazú
Coseguina
Caribbean Plate
Pelée
La Soufrière
Ruiz
Cotopaxi
Misti
Azul
Burney
Nazca Plate
South American Plate
Antarctic Plate
Hekla
Grimsvötn
Surtsey
Laki
Fayal
Mid-Atlantic Ridge
St. Paul
Cape Verde Island
Eurasian Plate
Anatolian Plate
Vesuvius
Etna
Stromboli
Santorini (Thera)
Demavend
Ararat
Arabian Plate
African Plate
East African Rift
Nyamlagira
Kilimanjaro
Somali Plate
Southwest Indian Ridge



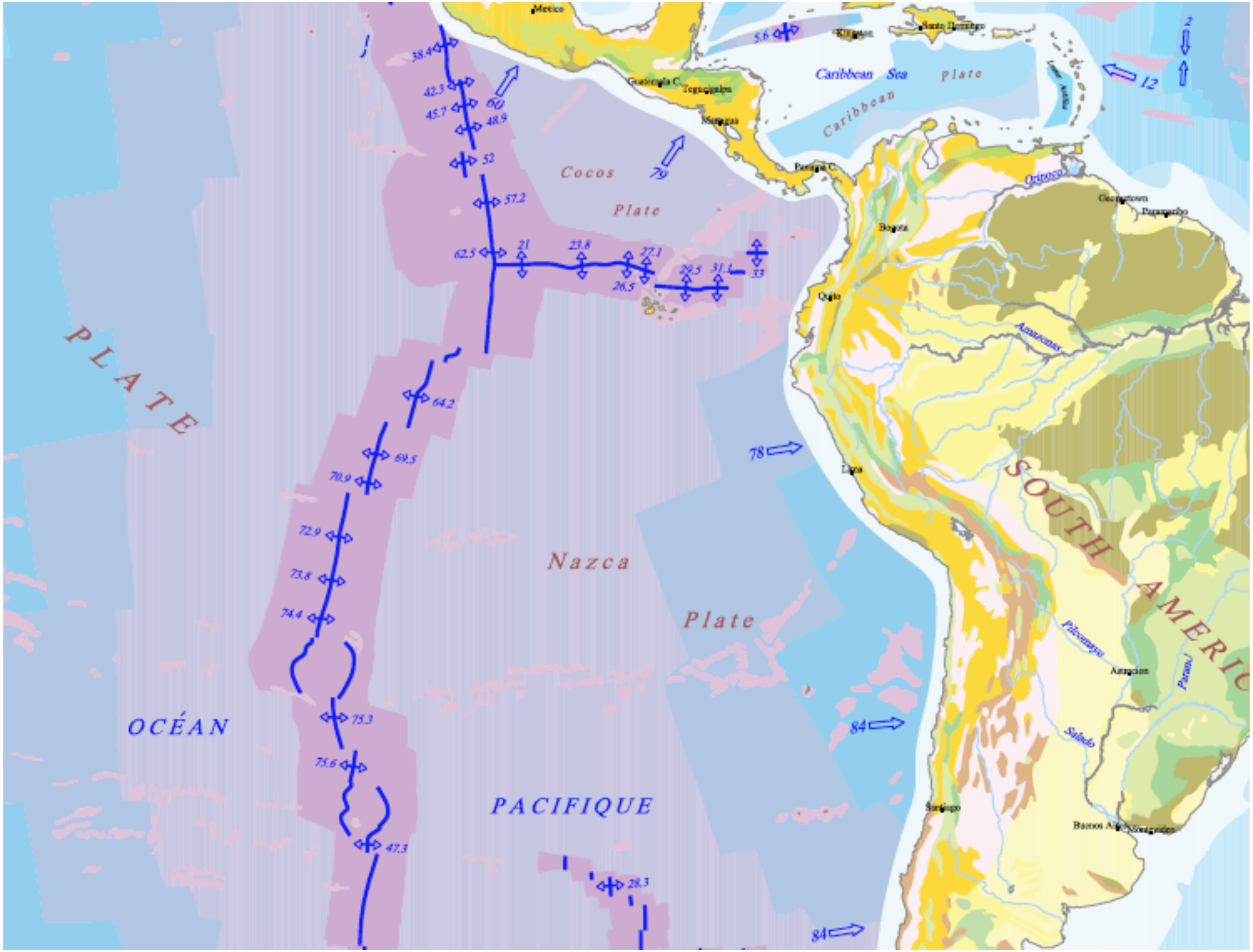
Mid-Oceanic Ridge system

Paired lines on either side of the axis show the amount of crust generated in the last 10 million years at the current opening rates.

Dotted lines show the volcanic arcs, which are lines of volcanoes and volcanic islands formed from magma rising from the subducted plate. The distortion caused by plotting these lines on a Mercator projection is indicated by the hourglass-shaped graph on the right, which gives the amount of crust generated at a 100 mm/yr opening rate (1 mm = 0.04 in.).



half spreading rate in mm/year



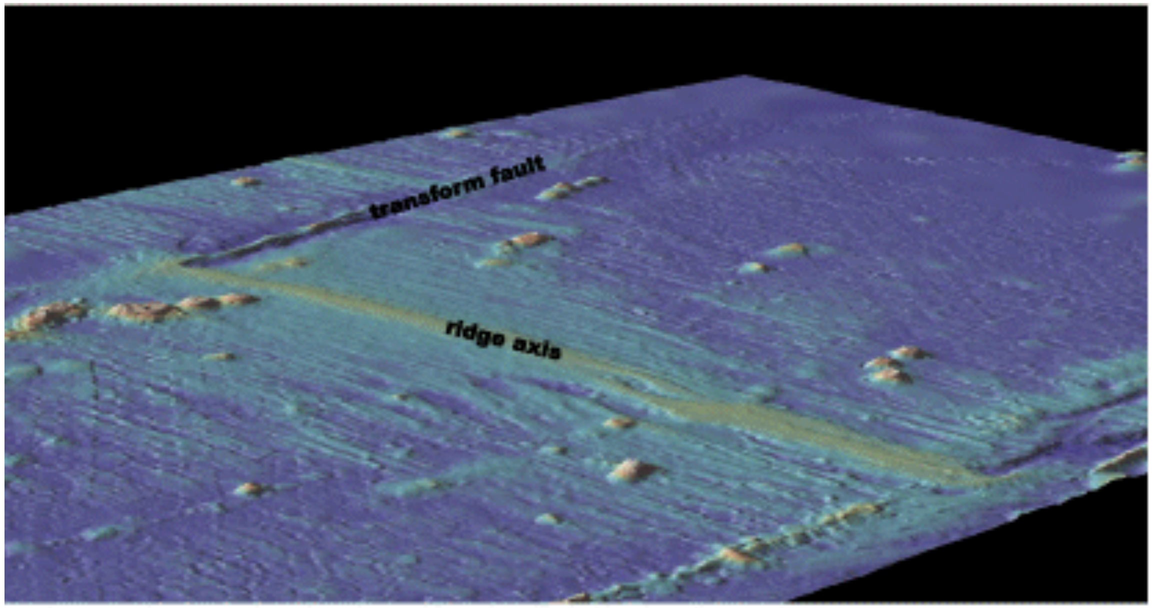
half spreading rate in mm/year

Pacific-Antarctic Ridge: fast-spreading, broad and smooth

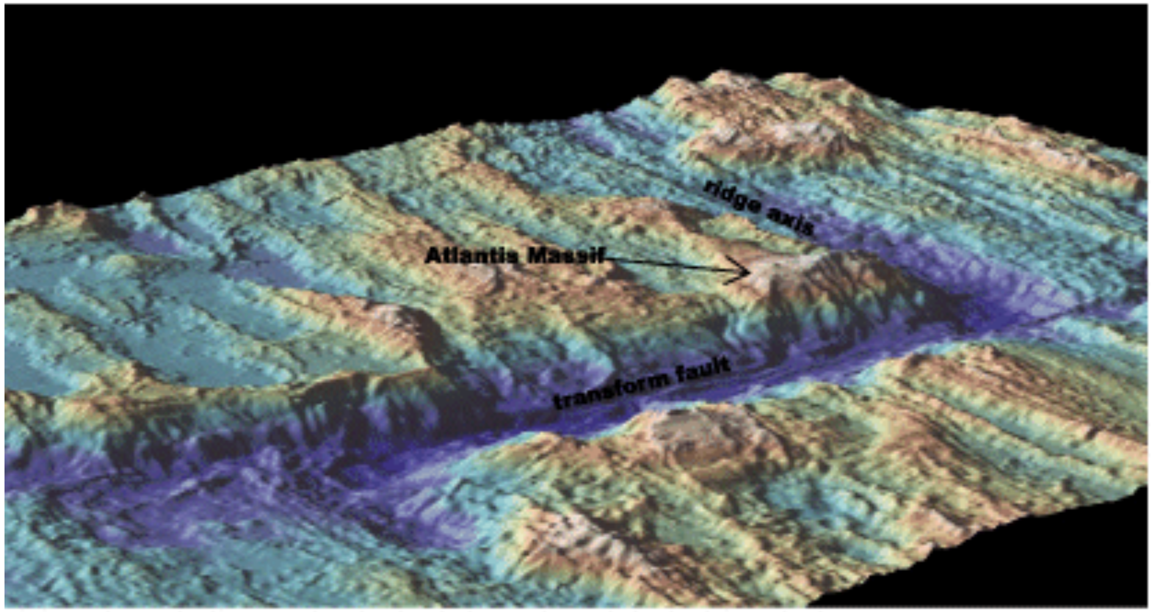
Mid-Atlantic Ridge: slow-spreading, narrow and rough

In places where spreading is fastest (more than 80 millimeters per year), the ridge has relatively gentle topography and is roughly dome-shaped in cross-section as a result of the many layers of lava that build up over time.
At slow- and ultra-slow spreading centers, the ridge is much more rugged, and spreading is dominated more by tectonic processes rather than volcanism.

The more prominent ridges and valleys on the flanks are fracture zones (transform fault zones) that were crossed at an oblique angle.
(After B. C. Heezen, The deep-sea floor, in S. K. Runcorn, ed., Continental Drift, Academic Press, 1962)



(a)



(b)

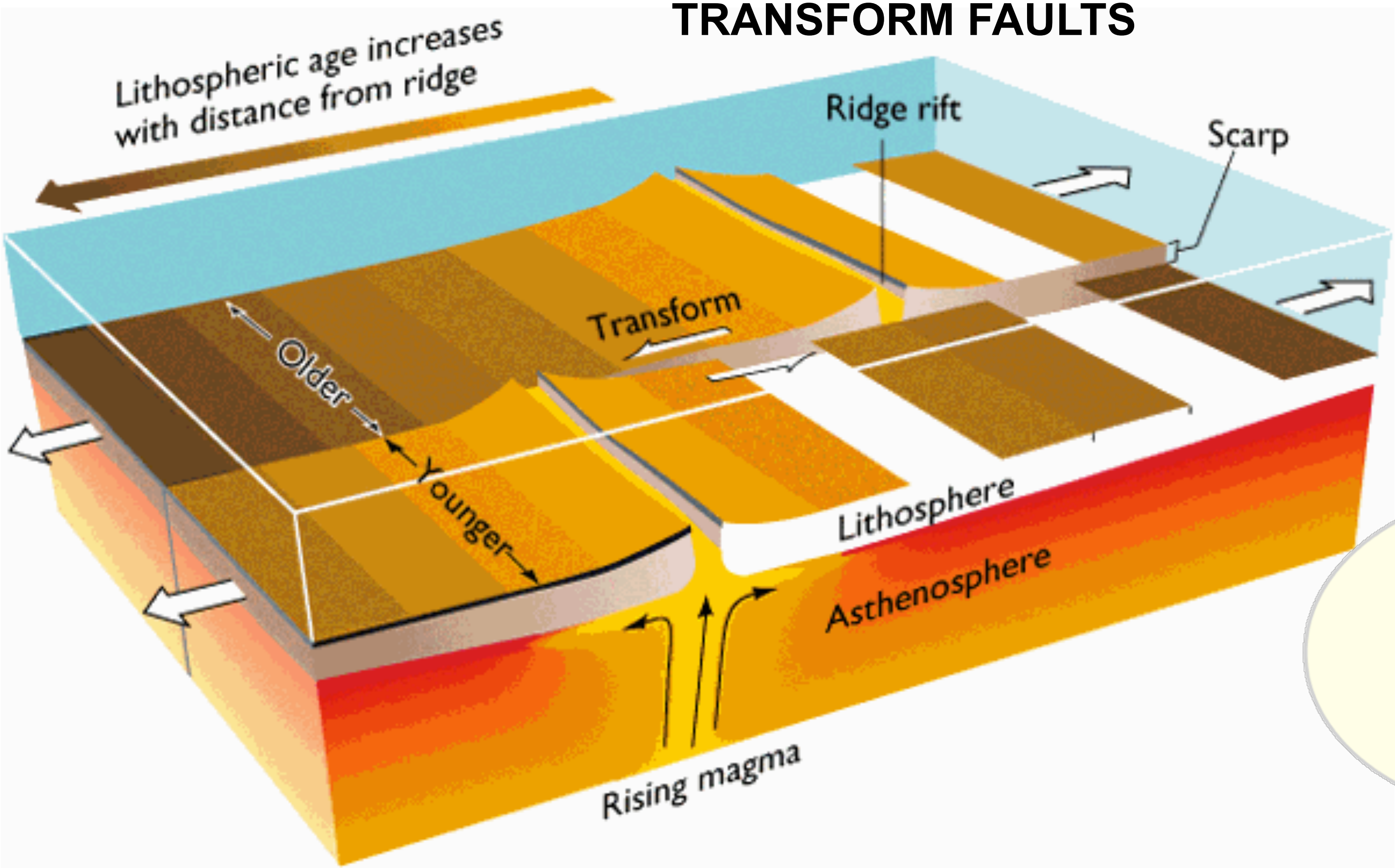
Oblique view of fast- and slow-spreading mid-ocean ridges, showing differences in morphology along the ridge.

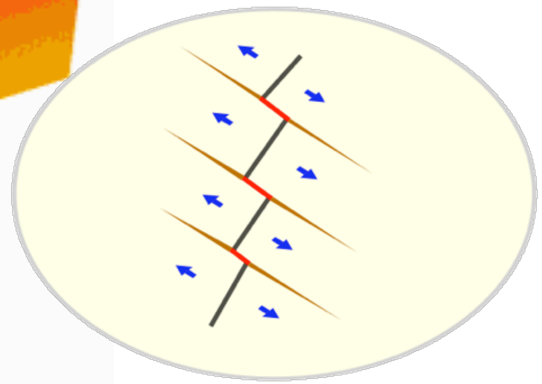
a) Fast-spreading East Pacific Rise at 19°S, viewed toward the north.

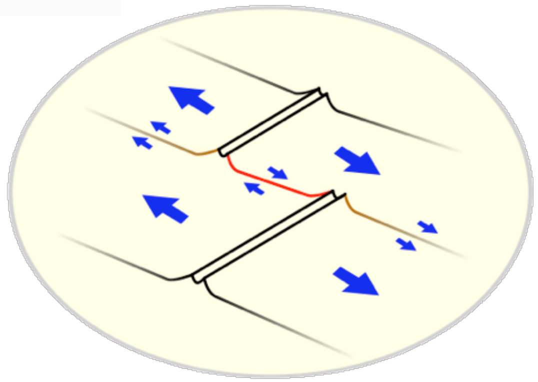
b) Slow-spreading Mid-Atlantic Ridge at 30°N and the Atlantis transform view toward the northeast.

Images made with GeoMapApp software with multibeam sonar data (each with 2× vertical exaggeration).
(W. Haxby 2006, GeoMapApp; Marine Geosciences Data Management System, http://www.GeoMapApp.org/)

TRANSFORM FAULTS







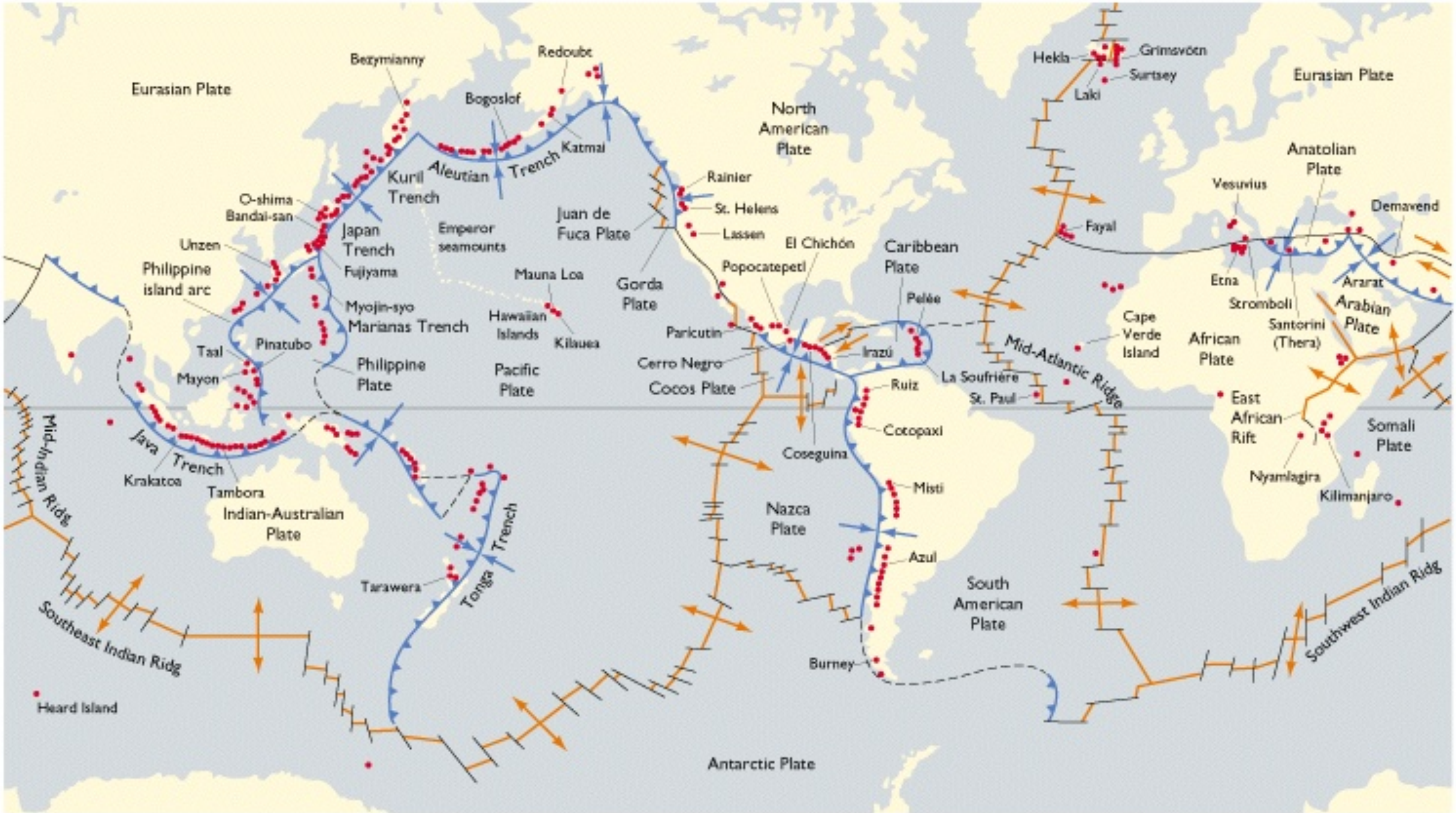
A transform fault or transform boundary, also known as conservative plate boundary since these faults neither create nor destroy lithosphere, is a type of fault whose relative motion is predominantly horizontal in either sinistral or dextral direction.

TRANSFORM FAULTS

First discovered in the Pacific Ocean by Vacquier (1965): left-lateral offset along the Mendocino and Pioneer faults amount of 1450 km, while the right-lateral offset across the Murray fault is 600 km in the west and only 150 km in the east.

Wilson (1965) termed the faults "Transform" as:
the lateral displacement across the fault is taken up by transforming it into either the formation of new lithosphere at a terminated ocean ridge segment or lithosphere subduction at a trench.

The transtorm faults can form a tectonic plate boundary


Eurasian Plate
Bezymianny
Redoubt
Bogoslof
Katmai
Aleutian Trench
Kuril Trench
Japan Trench
O-shima
Bandai-san
Unzen
Fujiyama
Myojin-syo
Marianas Trench
Philippine island arc
Pinatubo
Taal
Mayon
Philippine Plate
Emperor seamounts
Juan de Fuca Plate
Gorda Plate
Mauna Loa
Hawaiian Islands
Kilauea
Pacific Plate
North American Plate
Rainier
St. Helens
Lassen
El Chichón
Popocatepetl
Paricutin
Cerro Negro
Cocos Plate
Irazú
Caribbean Plate
Pelée
La Soufrière
St. Paul
Ruiz
Cotopaxi
Coseguina
Misti
Nazca Plate
Azul
Burney
South American Plate
Hekla
Grimsvötn
Surtsey
Laki
Fayal
Mid-Atlantic Ridge
Cape Verde Island
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African Plate
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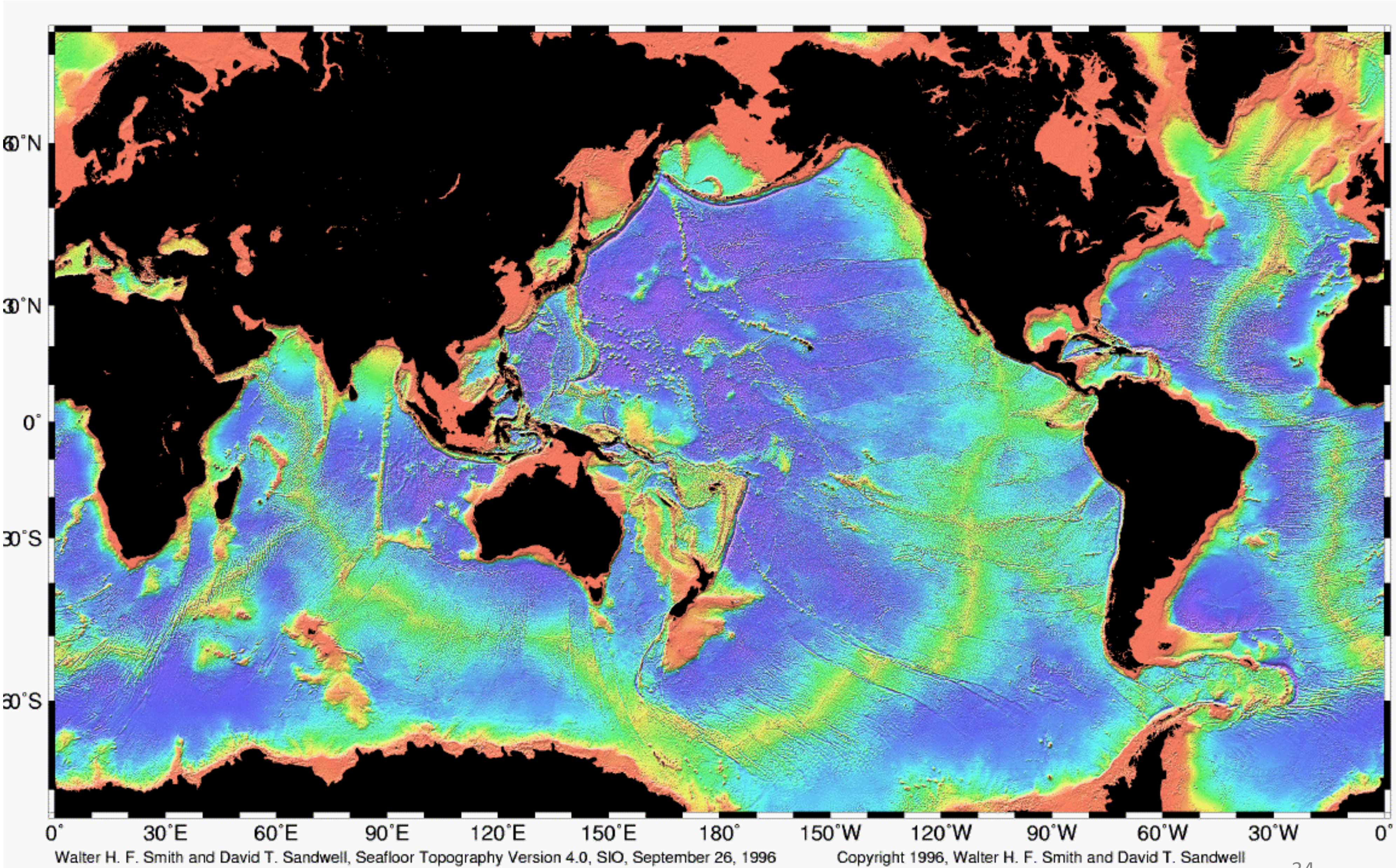
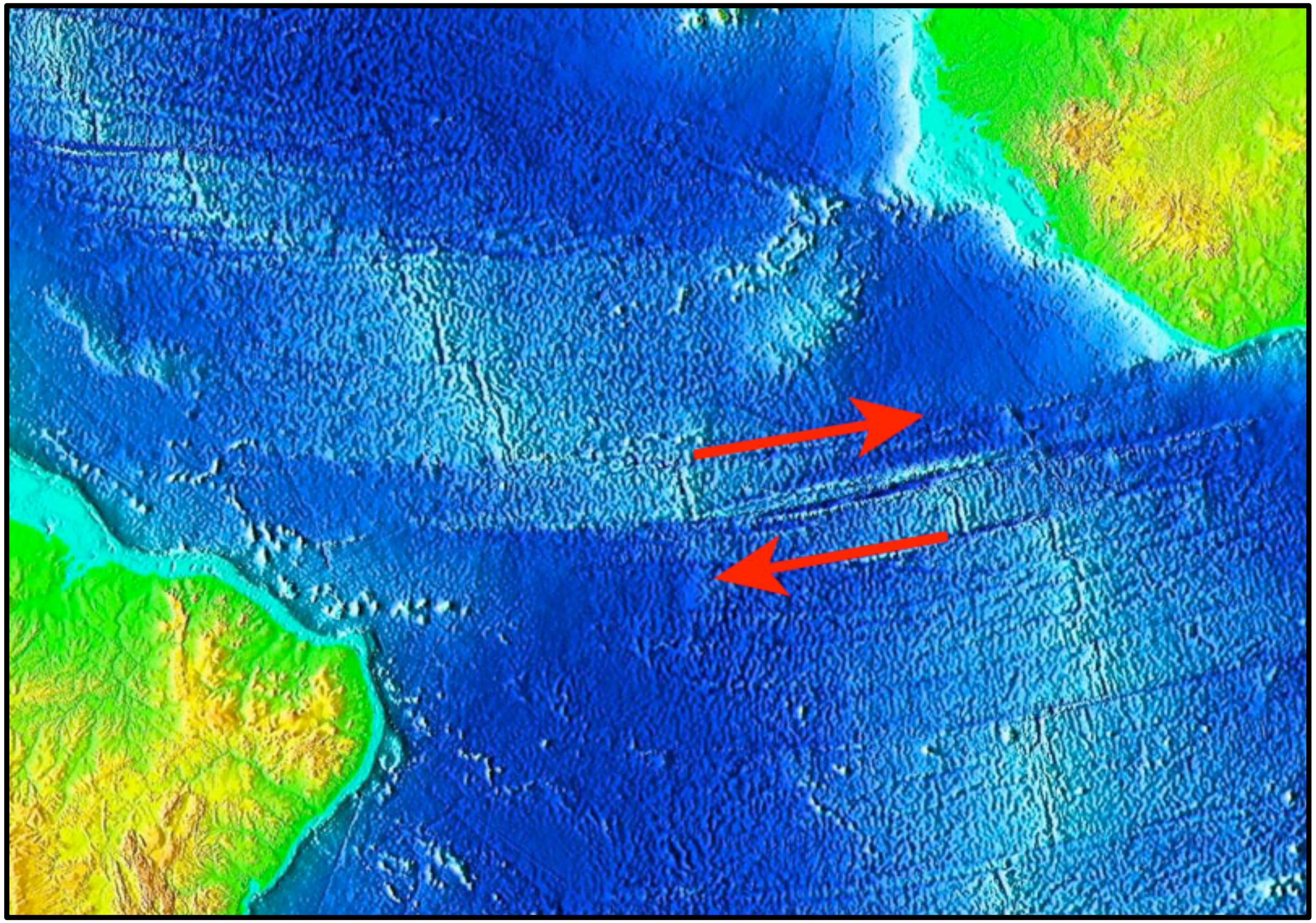
Nyamlagira
Kilimanjaro
Somali Plate
Mid-Indian Ridge
Java Trench
Krakatoa
Tambora
Indian-Australian Plate
Tarawera
Tonga Trench
Southeast Indian Ridge
Southwest Indian Ridge
Heard Island
Antarctic Plate

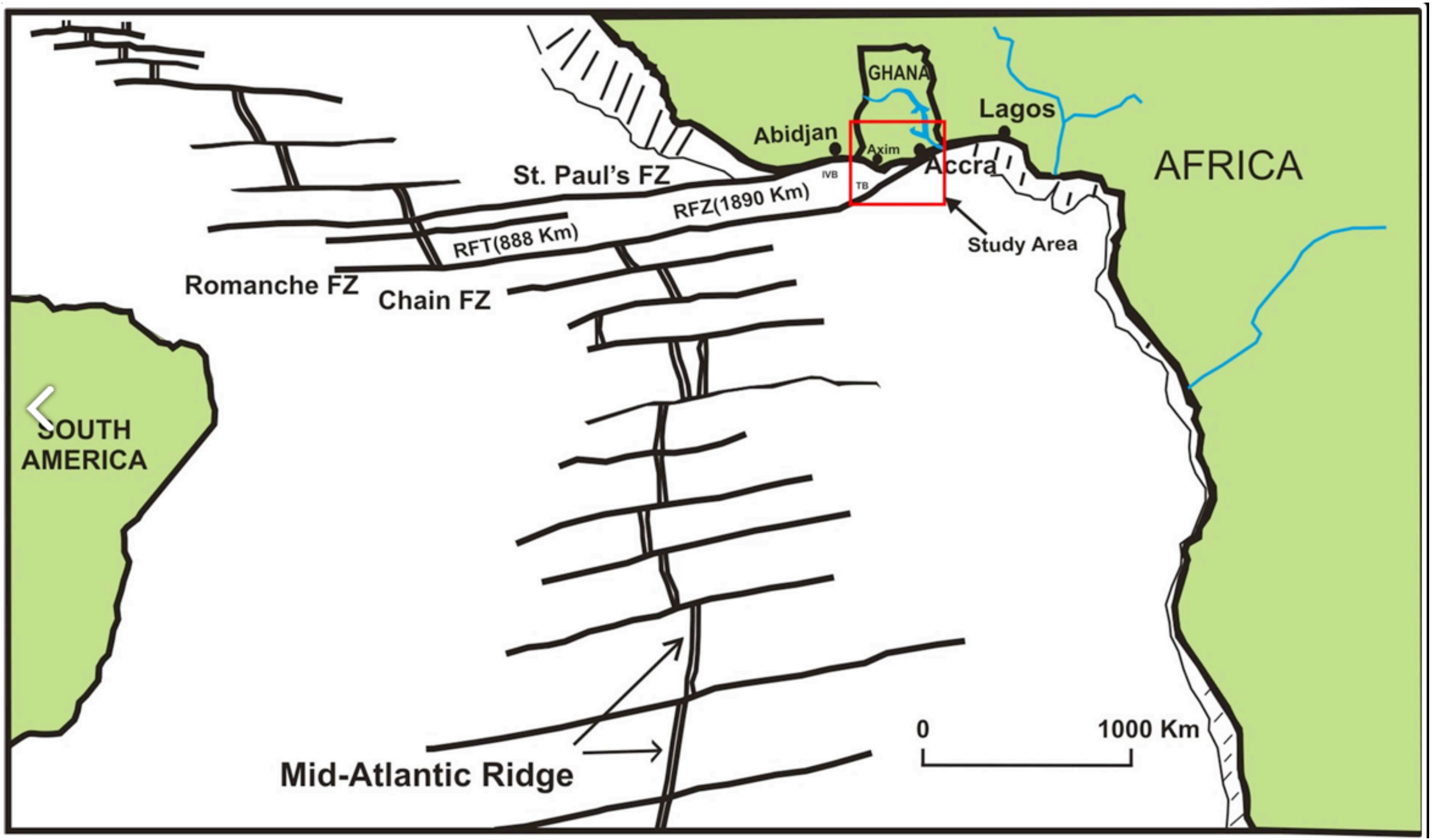
Global sea floor topography from gravity data derived from satellite altimetry and shipboard depth soundings

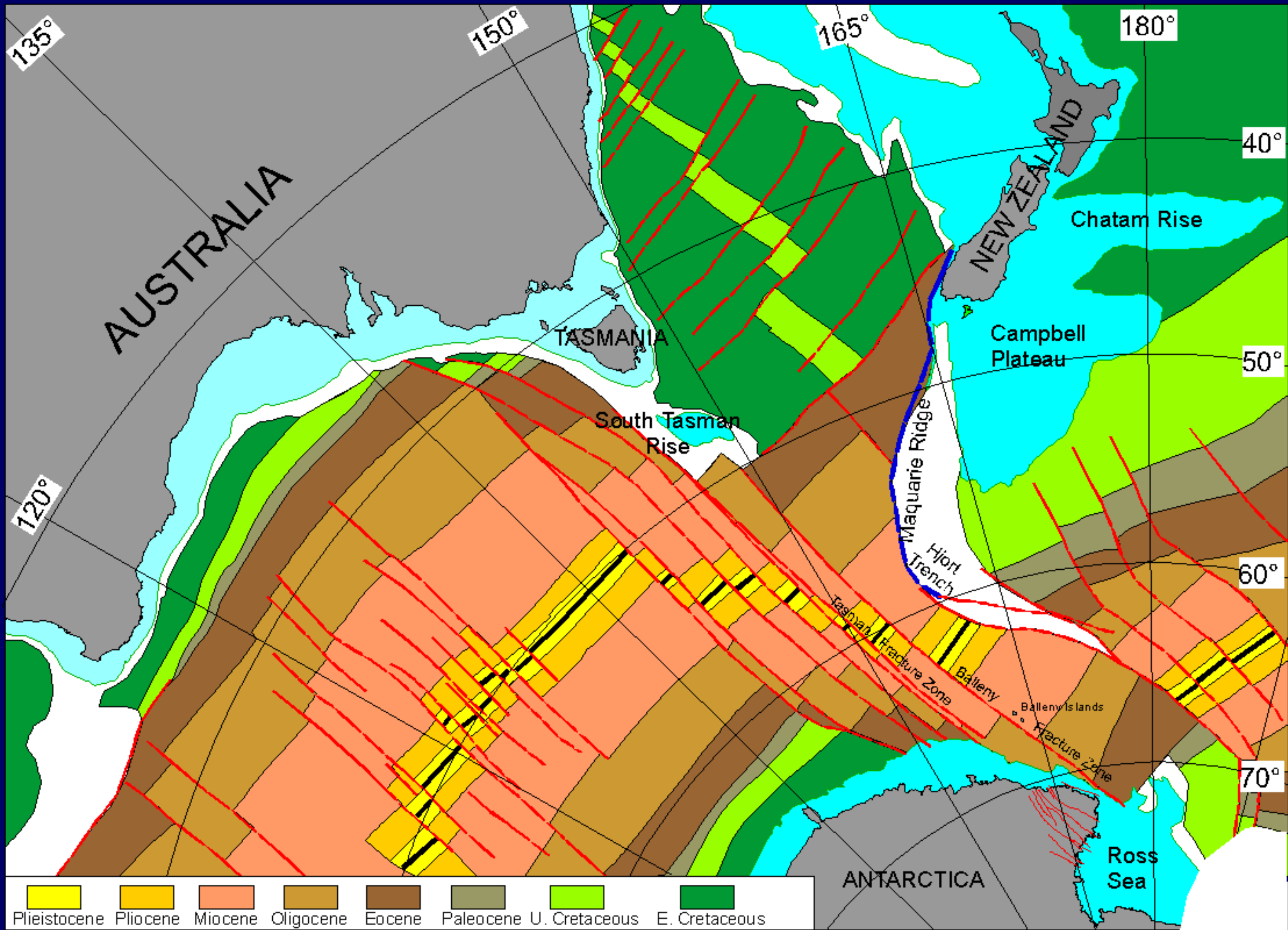


SMITH AND SANDWELL, 1996

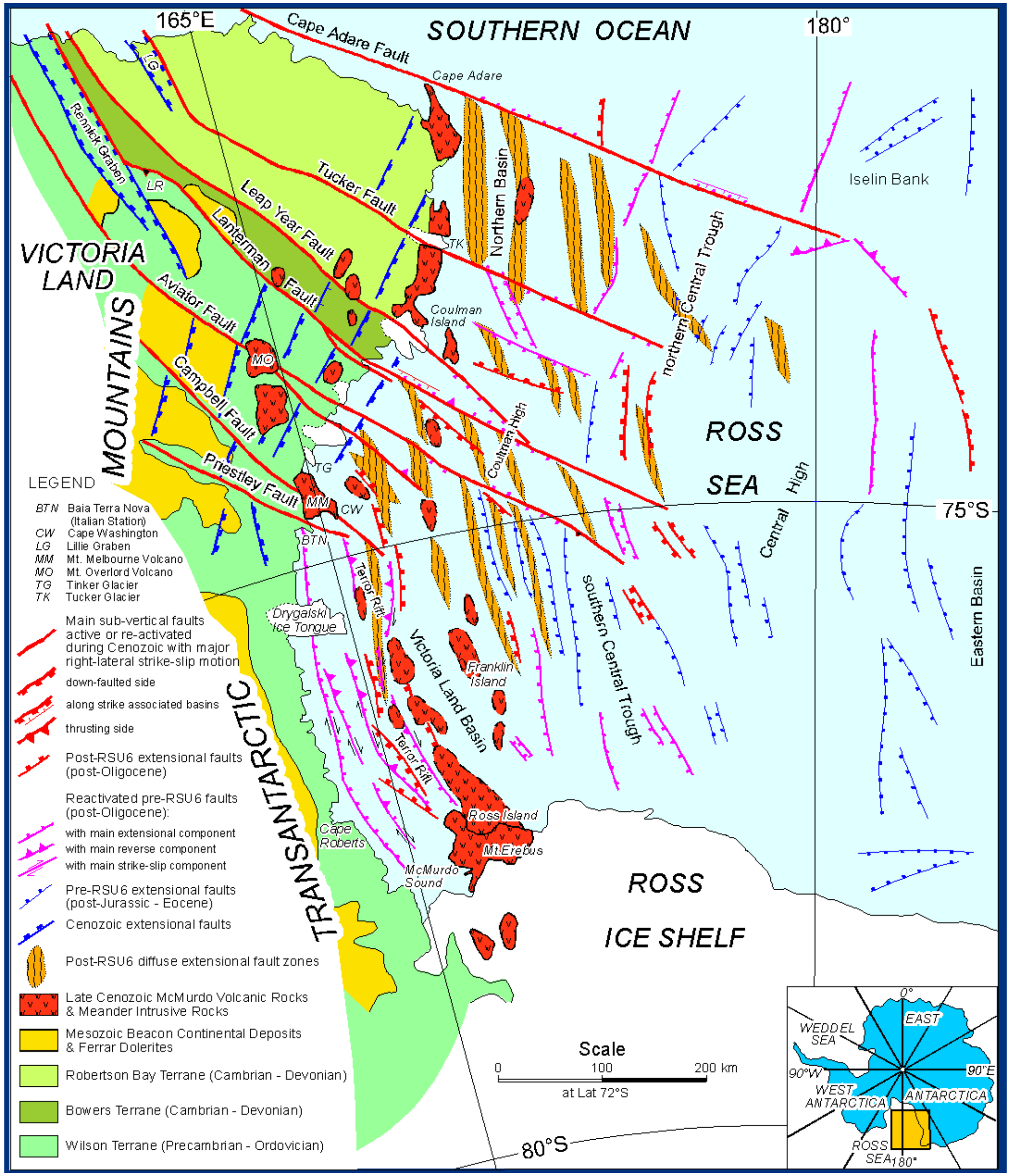


The Romanche Trench bisects the Mid-Atlantic Ridge just north of the equator at the narrowest part of the Atlantic between Brazil and West Africa.


GHANA
Lagos
Abidjan
Axim
Accra
AFRICA
St. Paul's FZ
IVB
TB
RFZ(1890 Km)
Study Area
RFT(888 Km)
Romanche FZ
Chain FZ
SOUTH AMERICA
0
1000 Km
Mid-Atlantic Ridge



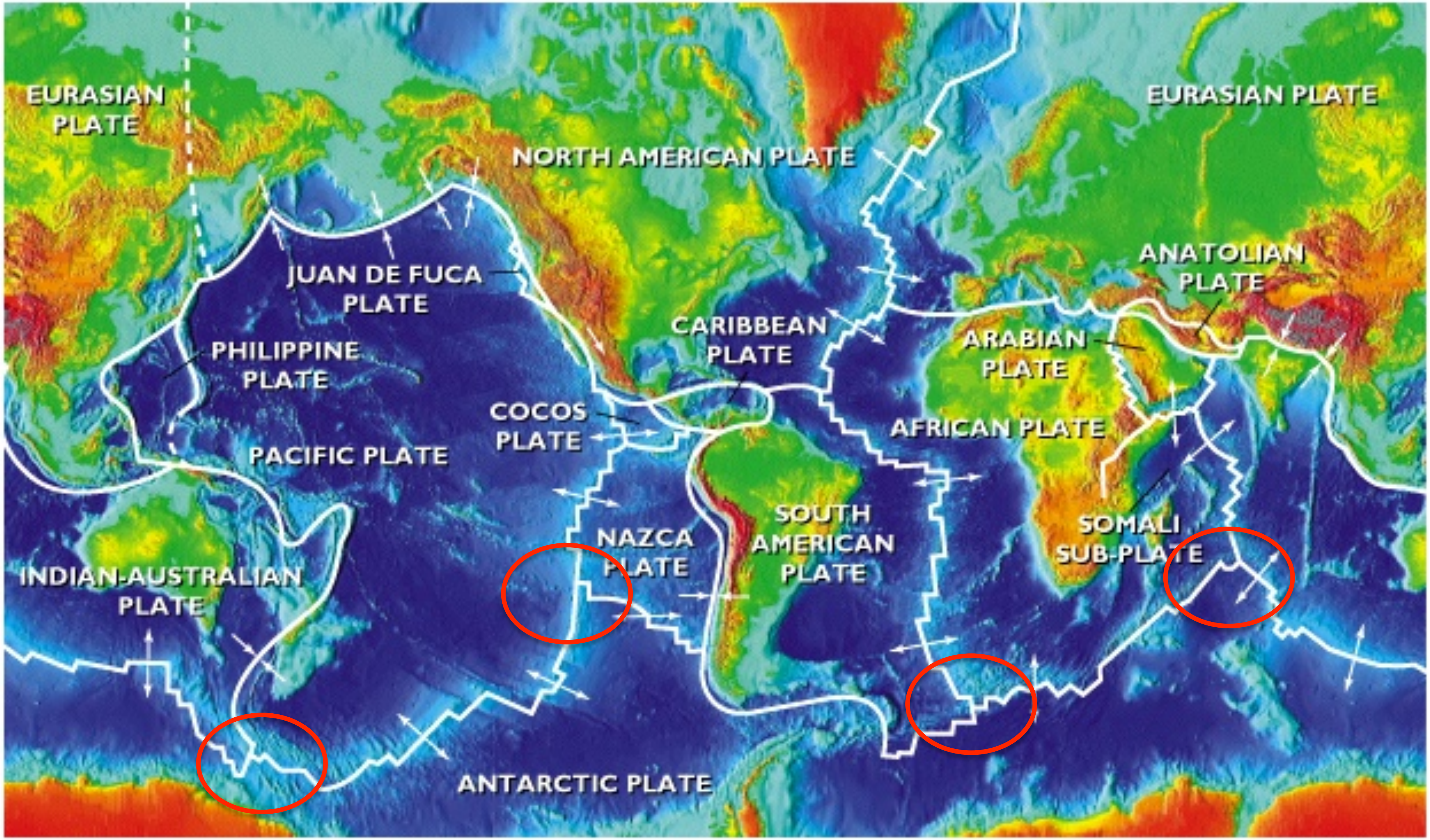
Modified from Hayes, 1991

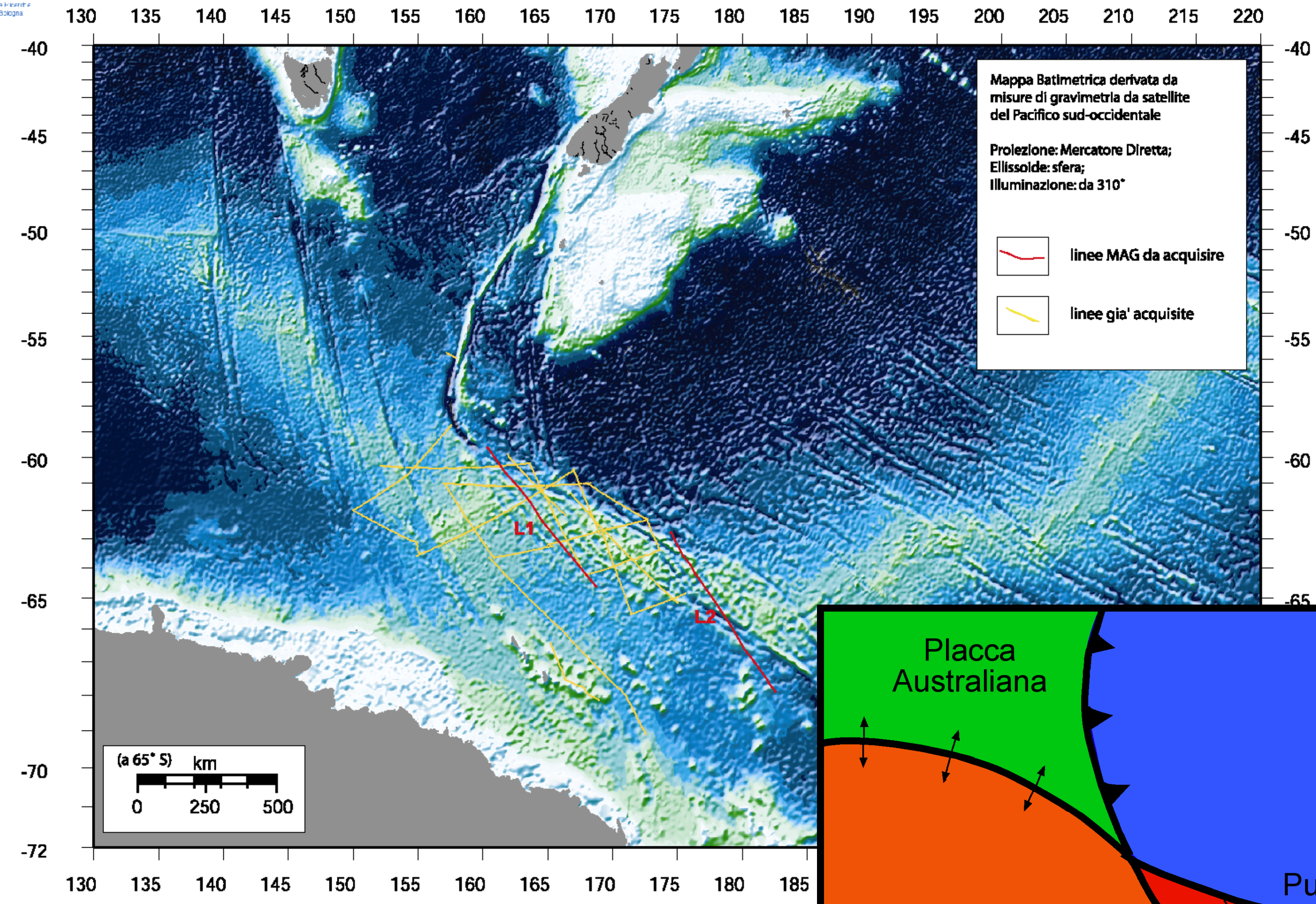


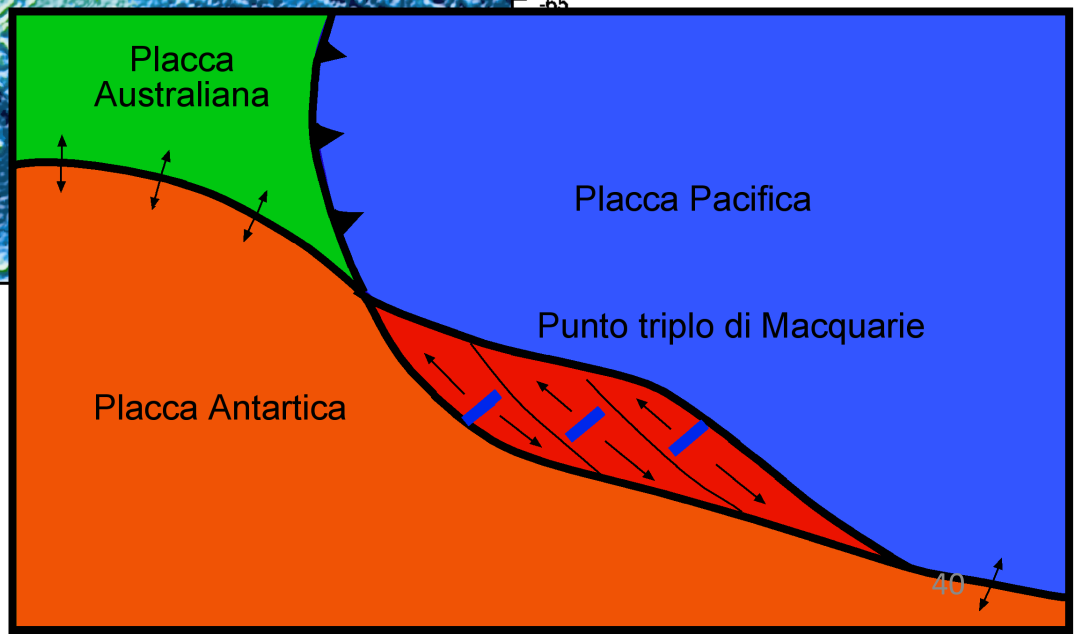
Salvini et al., 1997, Journal of Geophysical Research

La faglie principali nella Terra Vittoria Settentrionale e nel Mare di Ross.

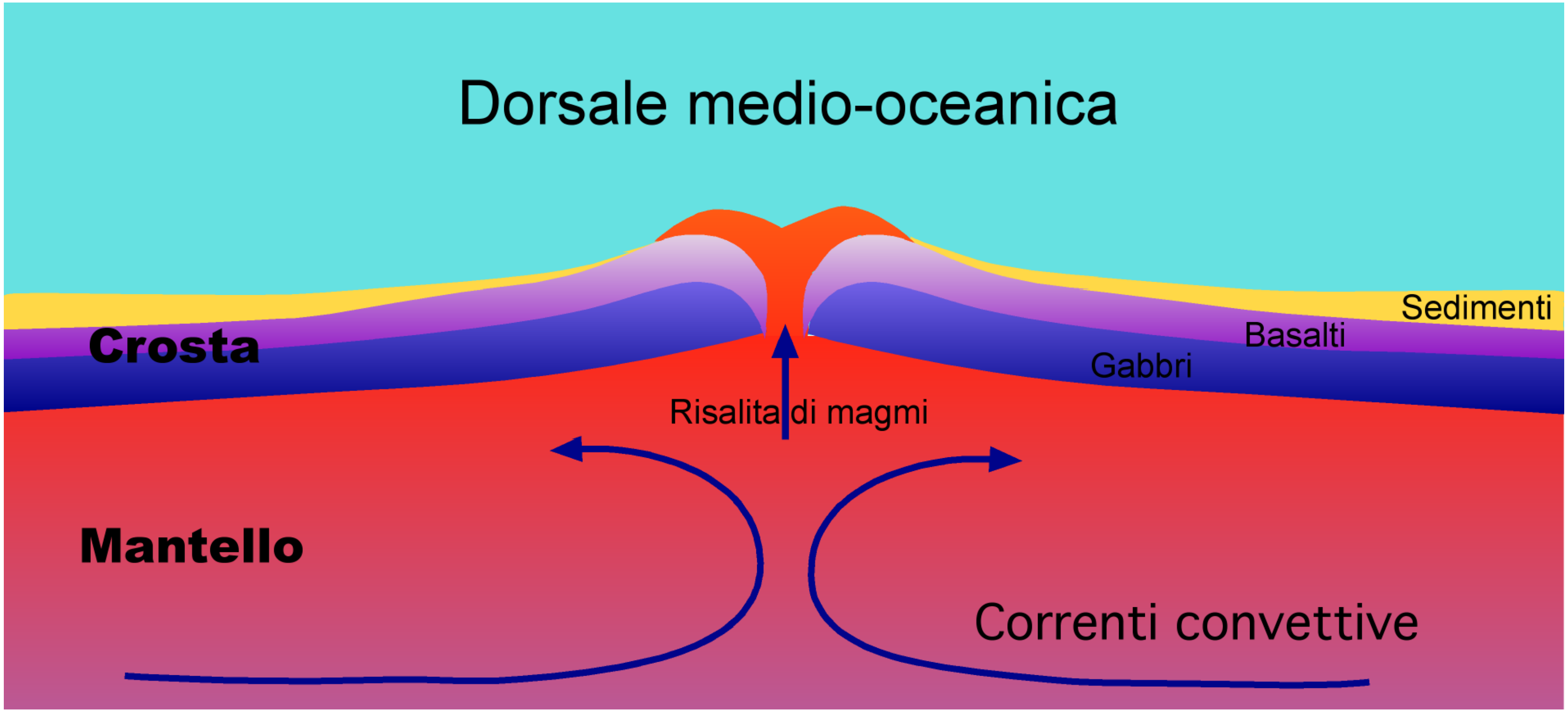
Triple junction

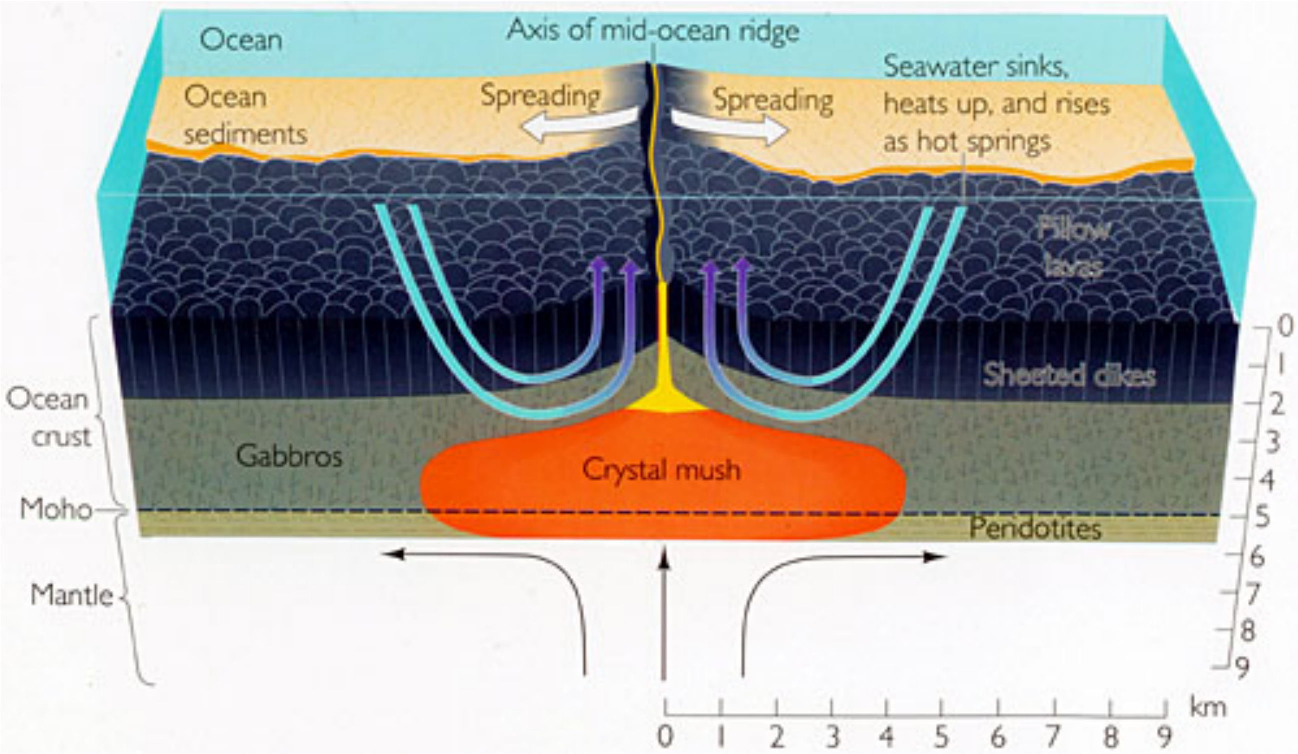


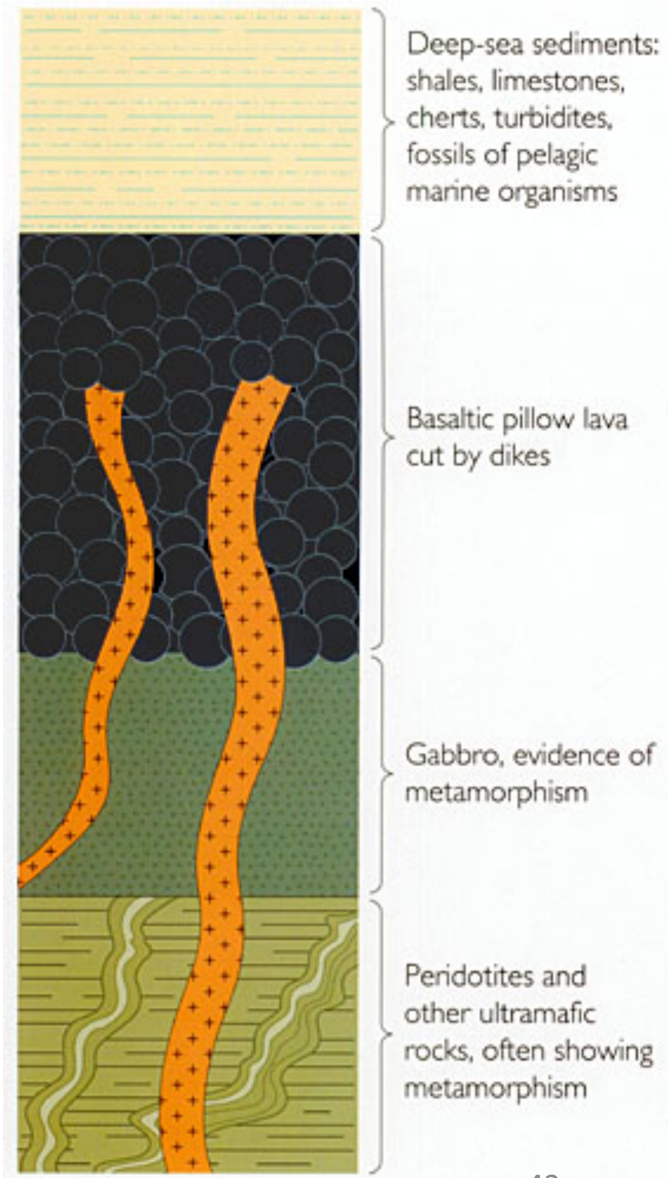




MACQUARIE TRIPLE JUNCTION


Dorsale medio-oceanica
Sedimenti
Basalti
Gabbri
Crosta
Risalita di magmi
Mantello
Correnti convettive





Oceanic plates thin crust (MOHO at about 6 km)
Oceanic plates thicken as they cool (boundary between convecting and non-convecting mantle deepens)
Colder (older) plates sink (subduction)
Examples: Pacific, Nazca, Cocos, Phillipine
On-land examples of ocean crust: ophiolites
- Oceanic crust emplaced upon continents
- Thickness of 8-10 km
- Ophiolite stratigraphy same worldwide => same processes operate worldwide

The compositions of materials erupted at the mid-ocean ridges are tholeiitic basalts called **m**id-**o**cean **r**idge **b**asalts (MORB).

Magnetic Susceptibility

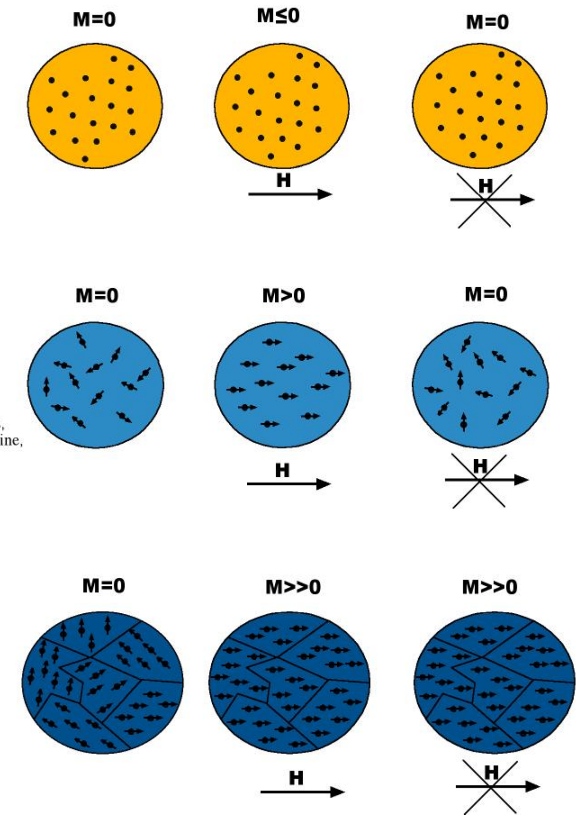
$$K = \frac{M}{H}$$

K = magnetic susceptibility
M = induced magnetization in the material
H = applied magnetic field

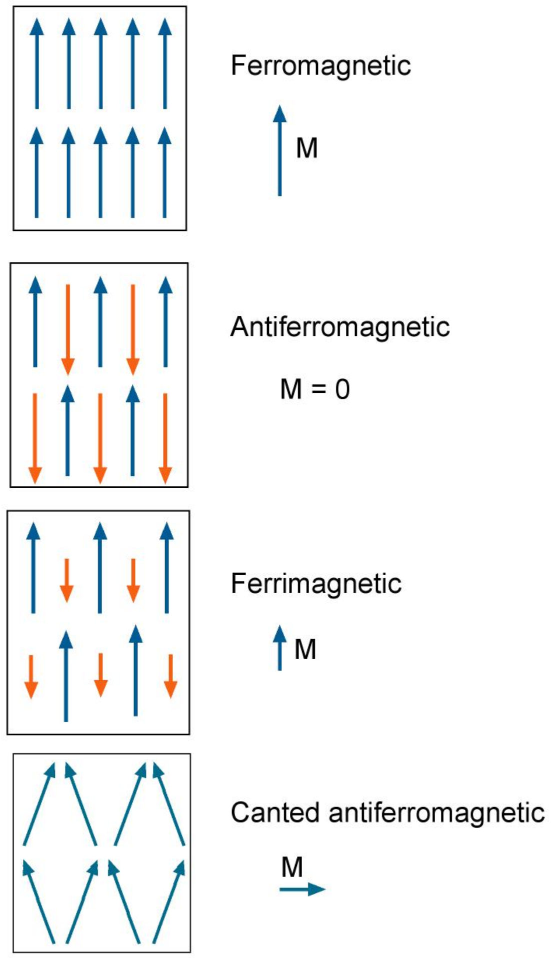
DIAMAGNETIC
weak negative susceptibility
(water, organic matter, quartz, feldspars, calcium carbonate)

PARAMAGNETIC
weak positive susceptibility
(many Fe-containg minerals and salts, eg. biotite, muscovite, pyroxene, olivine, ferrous sulfate)

FERROMAGNETIC
strong positive susceptibility
(pure iron like magnetite and ematite, nickel, chromium)

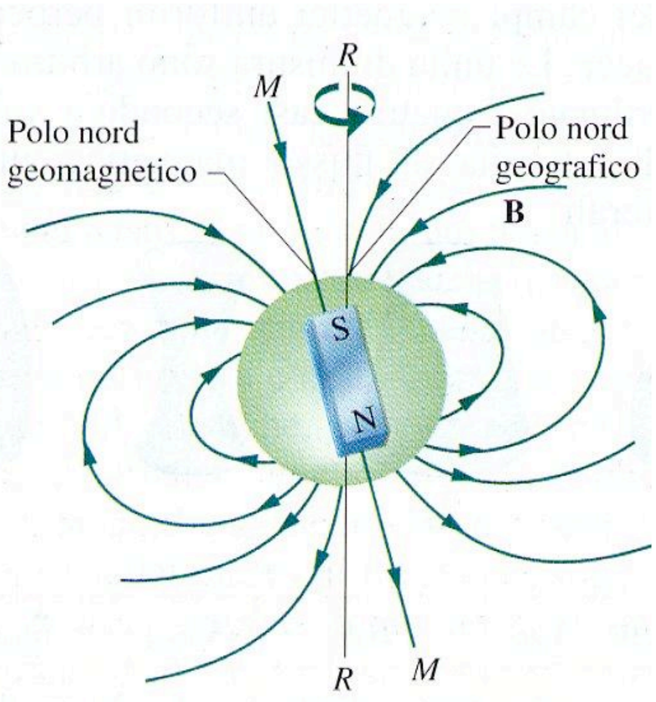


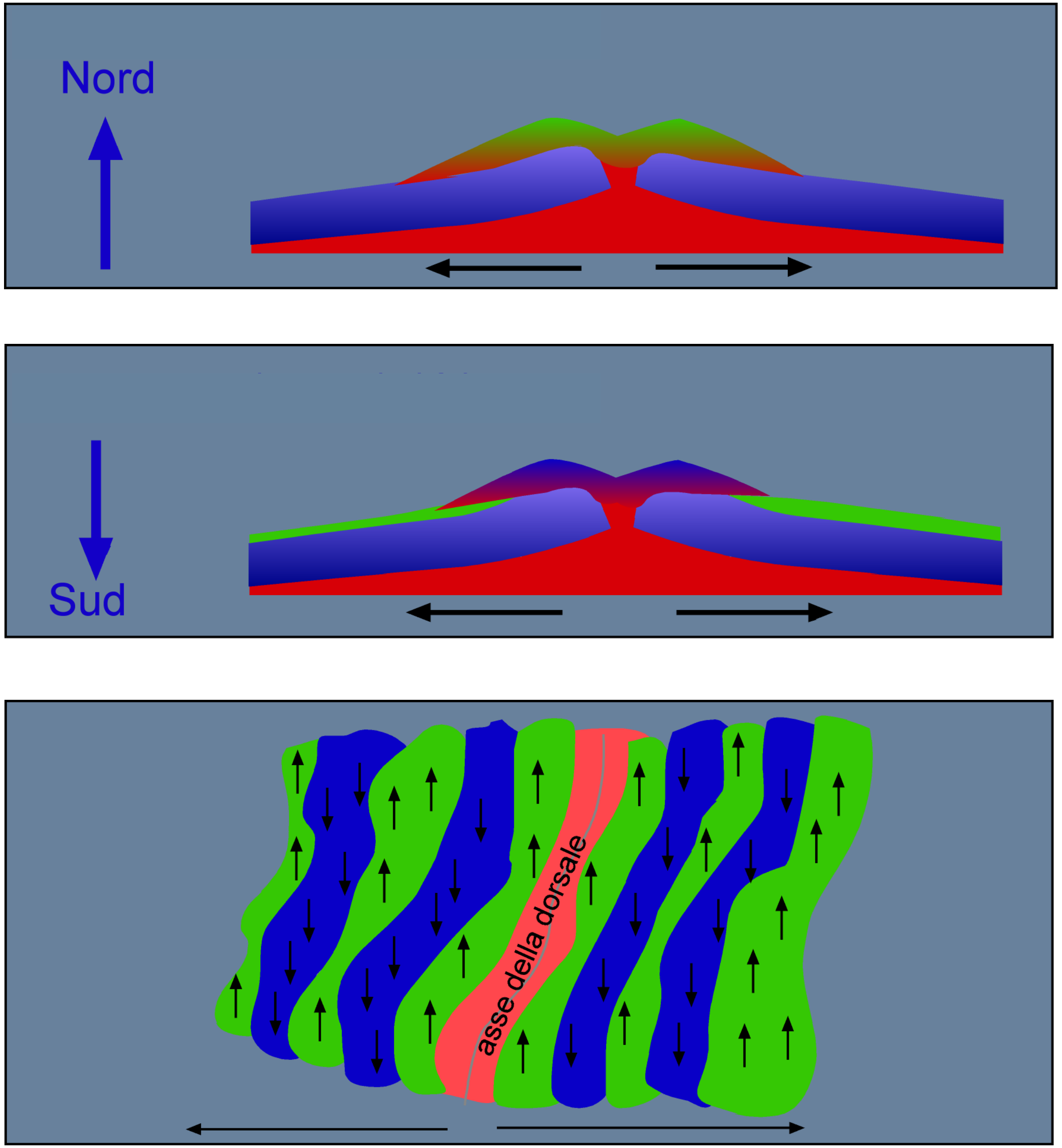
Magnetic spin coupling in material with permanent remanent magnetization



(modified after Piper, 1989)

Present magnetic filed

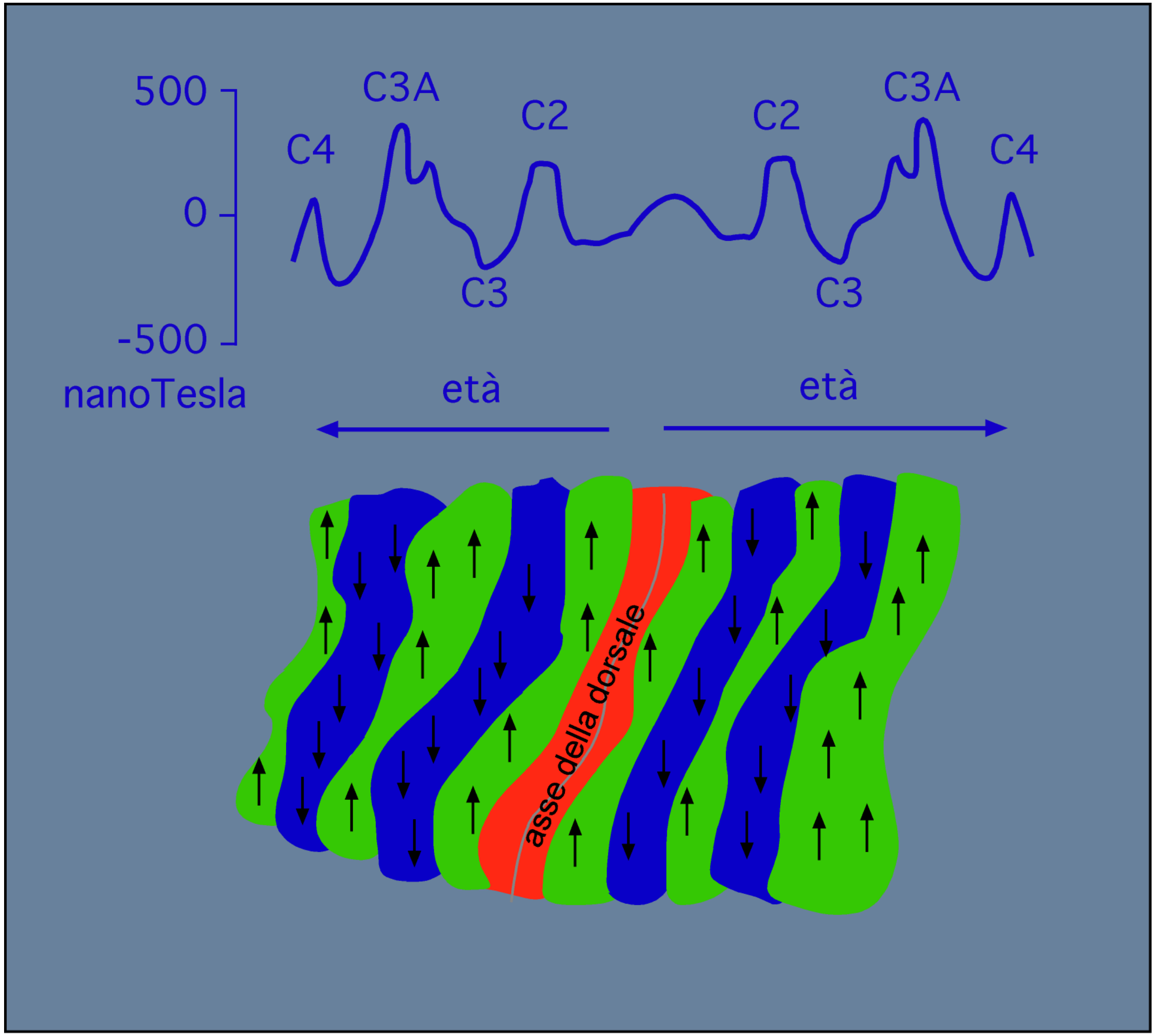




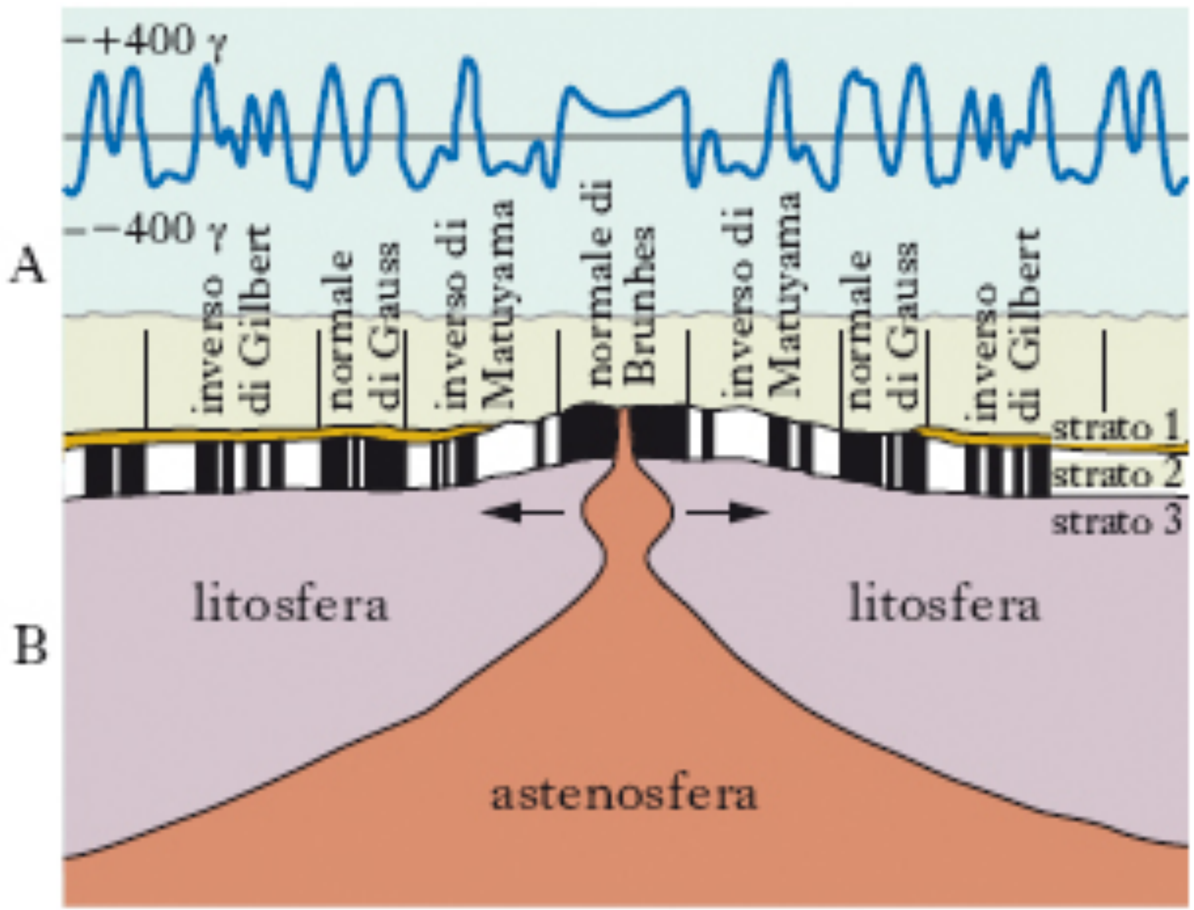
Instruments to measured the earth magnetic field in the ocean:

- magnetometer

- gradiometer composed by two magnetometers to filter time variation in the magnetic field

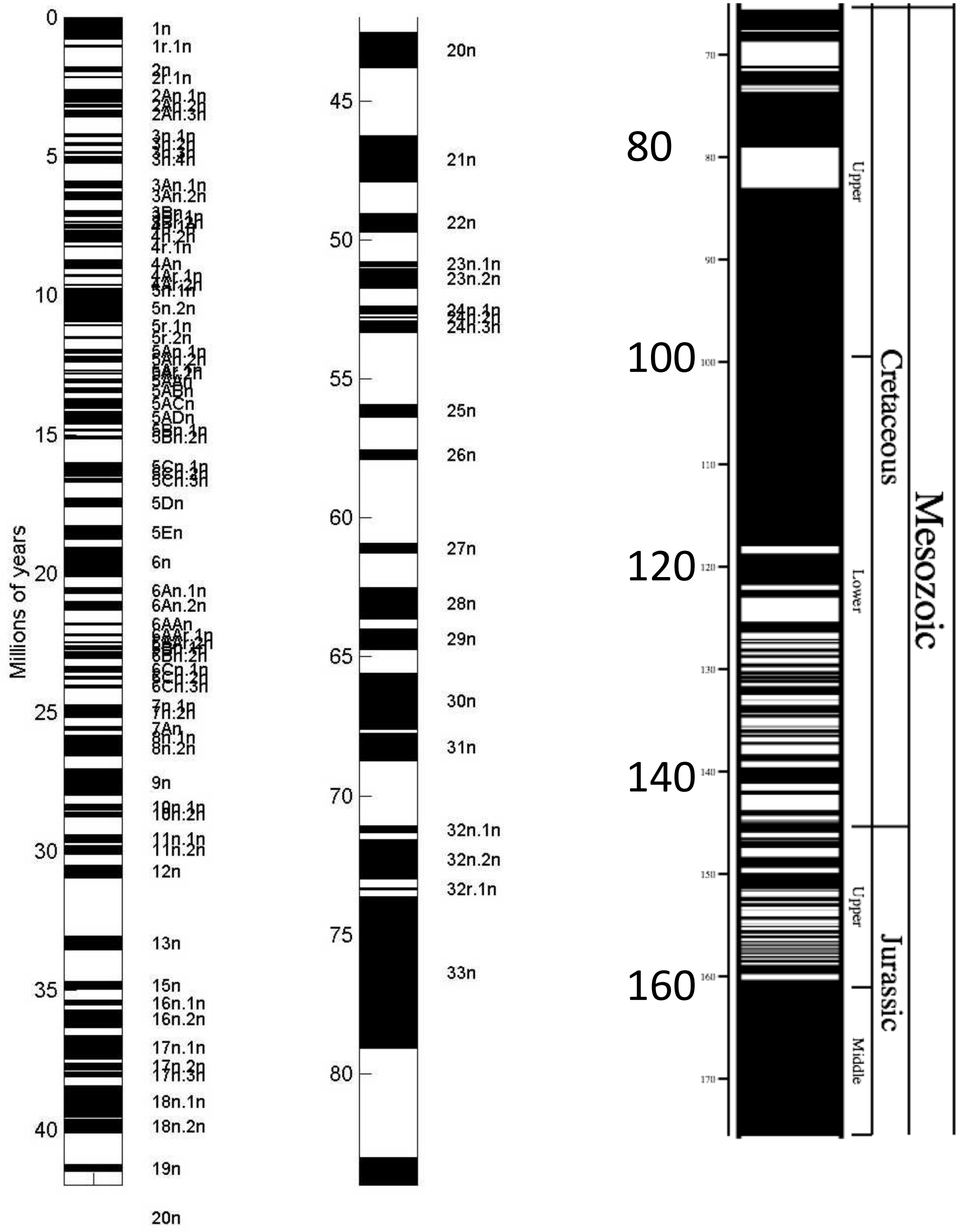


The magnetic anomalies are numbered as C*n* (Chrone *n*) or A*n* *(*Anomaly *n)*
(C1 or A1 is the youngest and C23 or A23 is older).

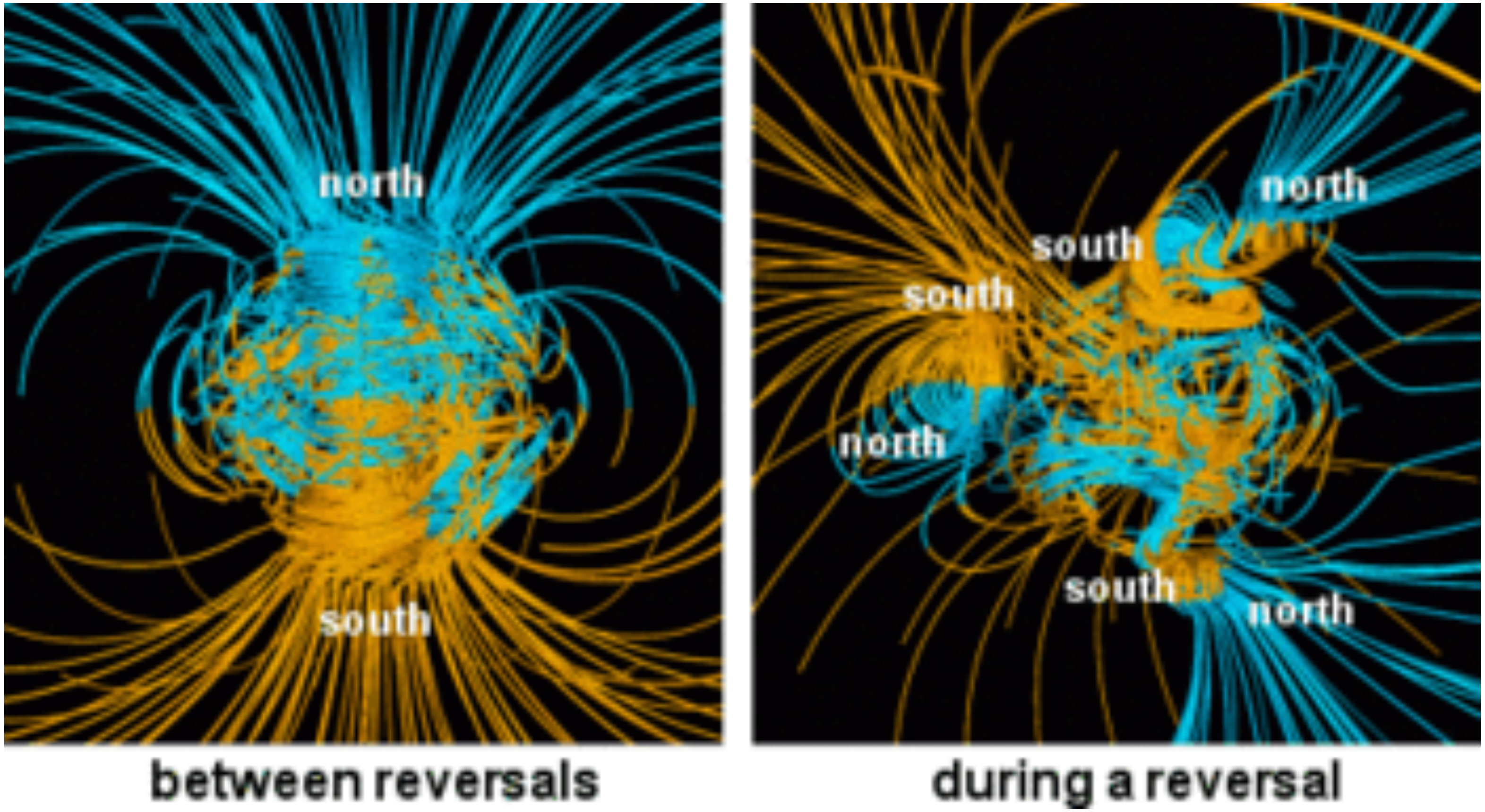


1 - sedimenti non magnetici
2 - colate e strato di basalto a cuscini (altamente magnetico: in nero, polarita normale; in bianco, polarita inversa)
3 - crosta oceanica a gabbri (debolmente magnetica)

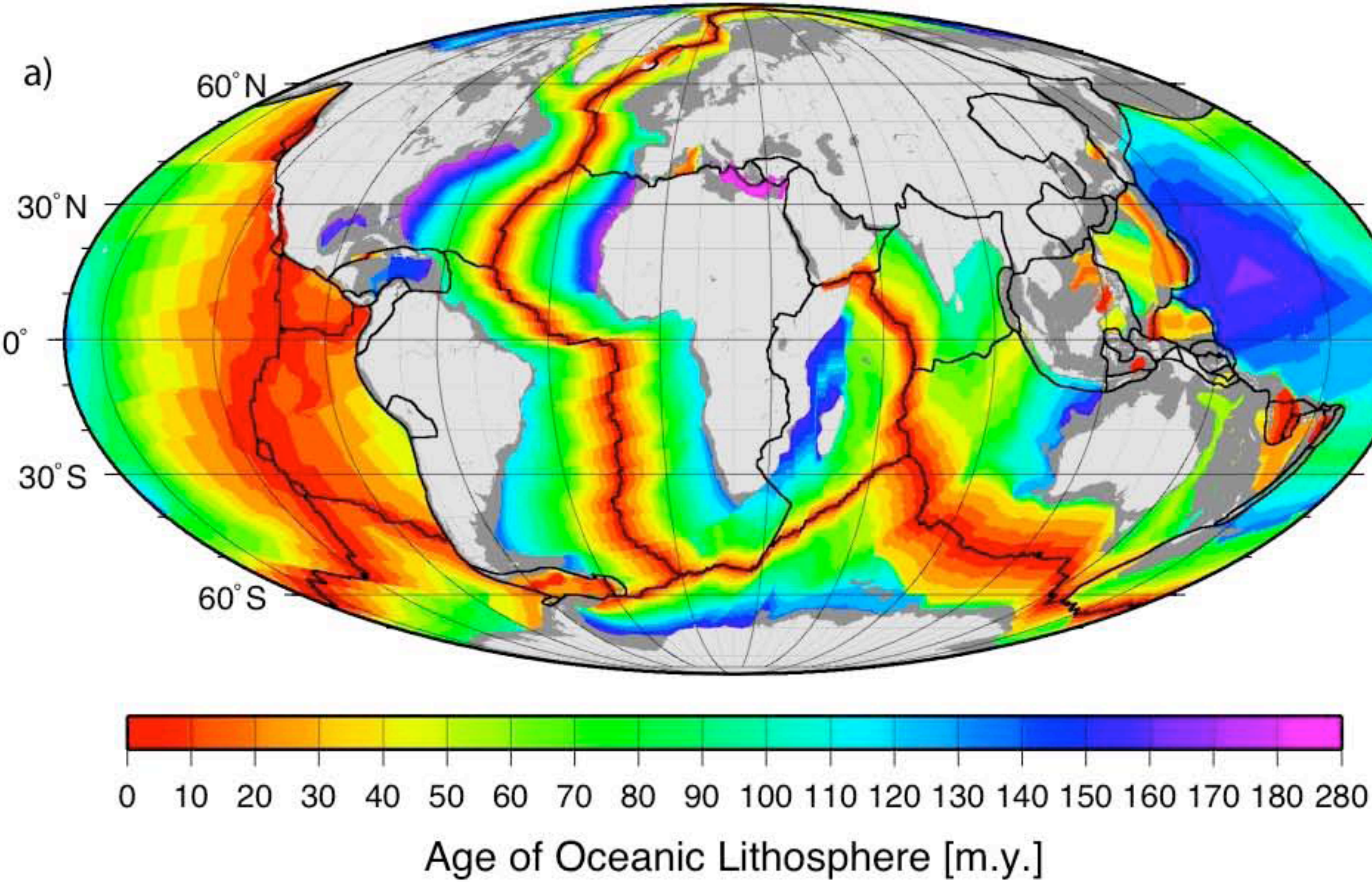
Geomagnetic Polarity Time Scale (GPTS)



Cande & Kent 1995



NASA computer simulation using the model of Glatzmaier and Roberts.
The tubes represent magnetic field lines blue when the field points towards the center and yellow when away. The rotation axis of the Earth is centered and vertical. The dense clusters of lines are within the Earth's core.



From Muller et al., 2008

Stato termico dei ridge e piane abissali

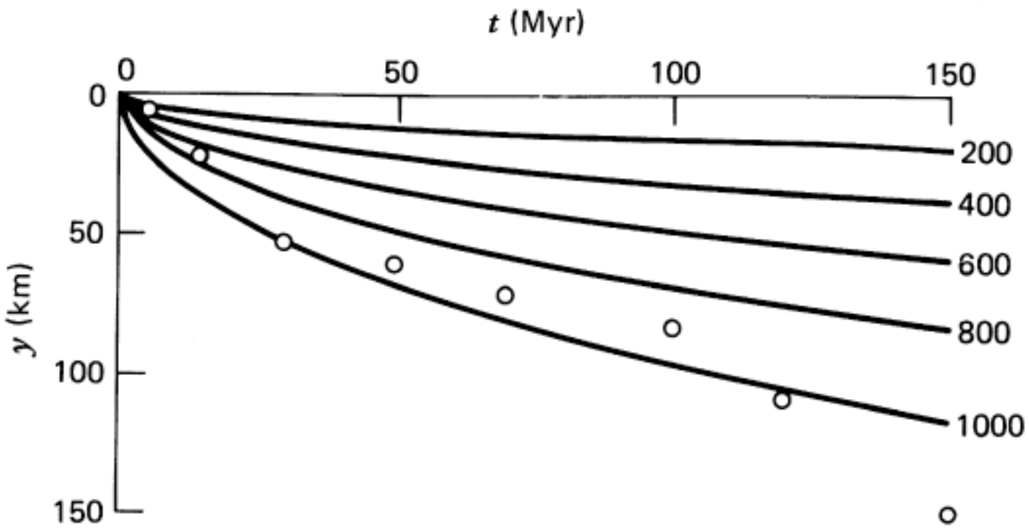
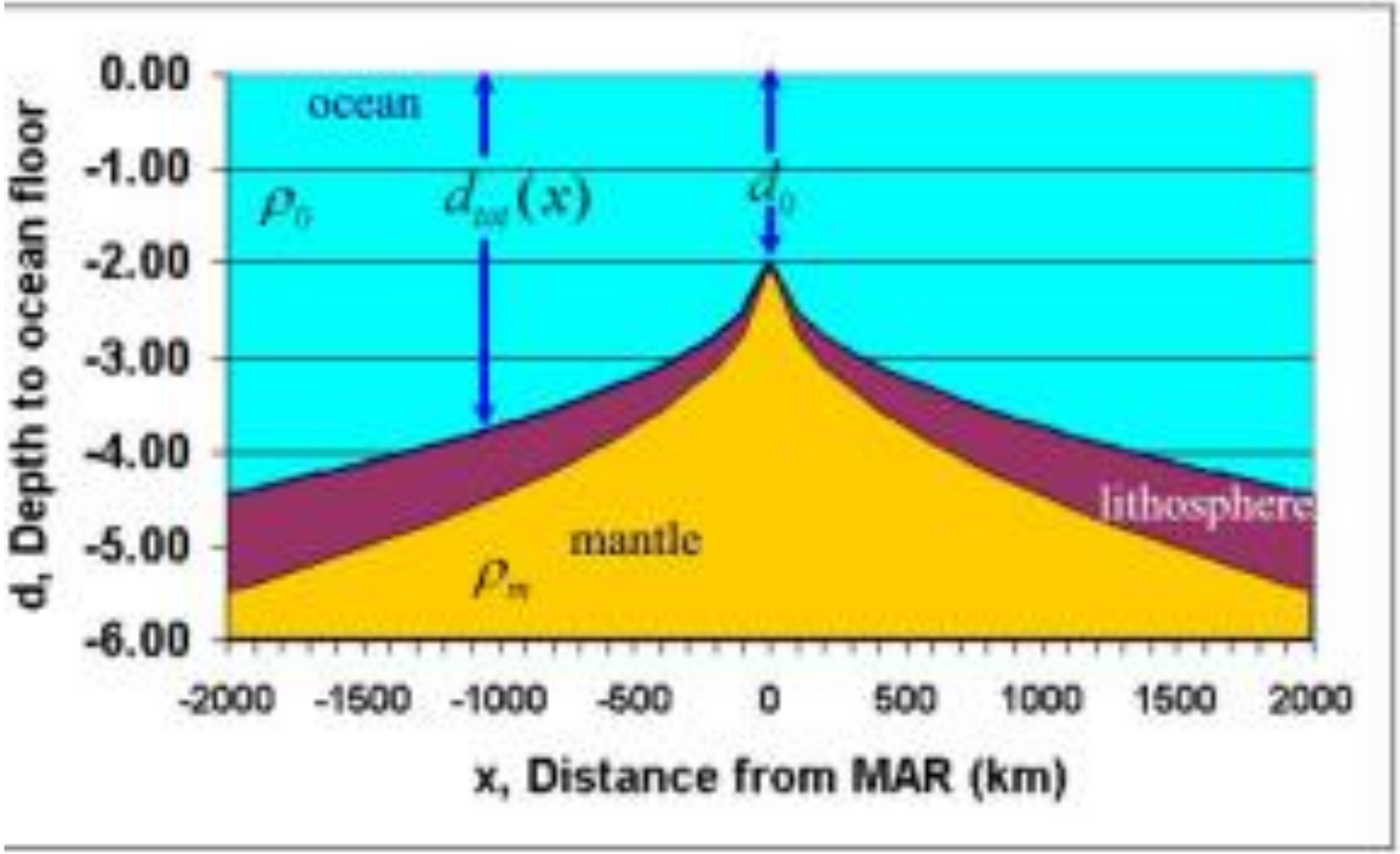
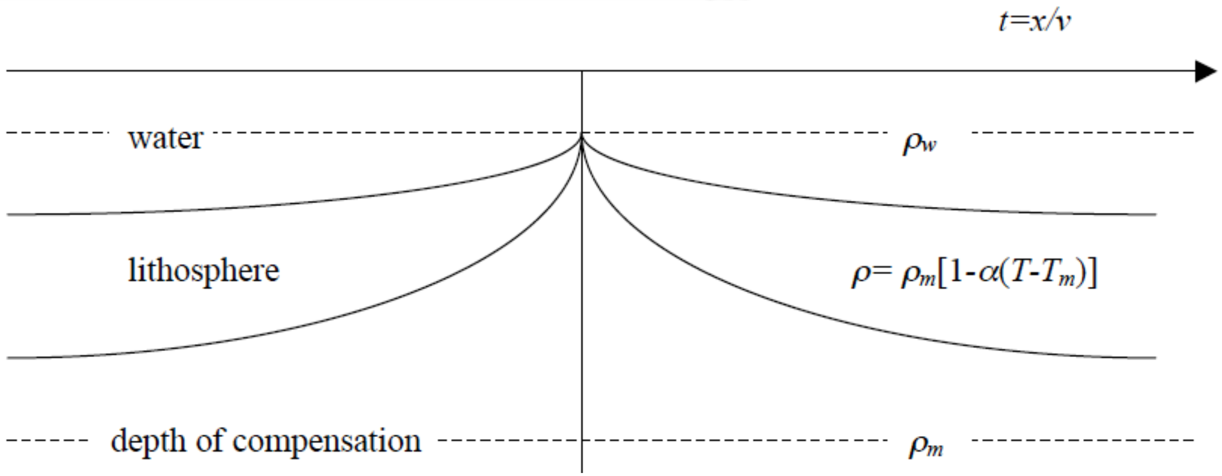


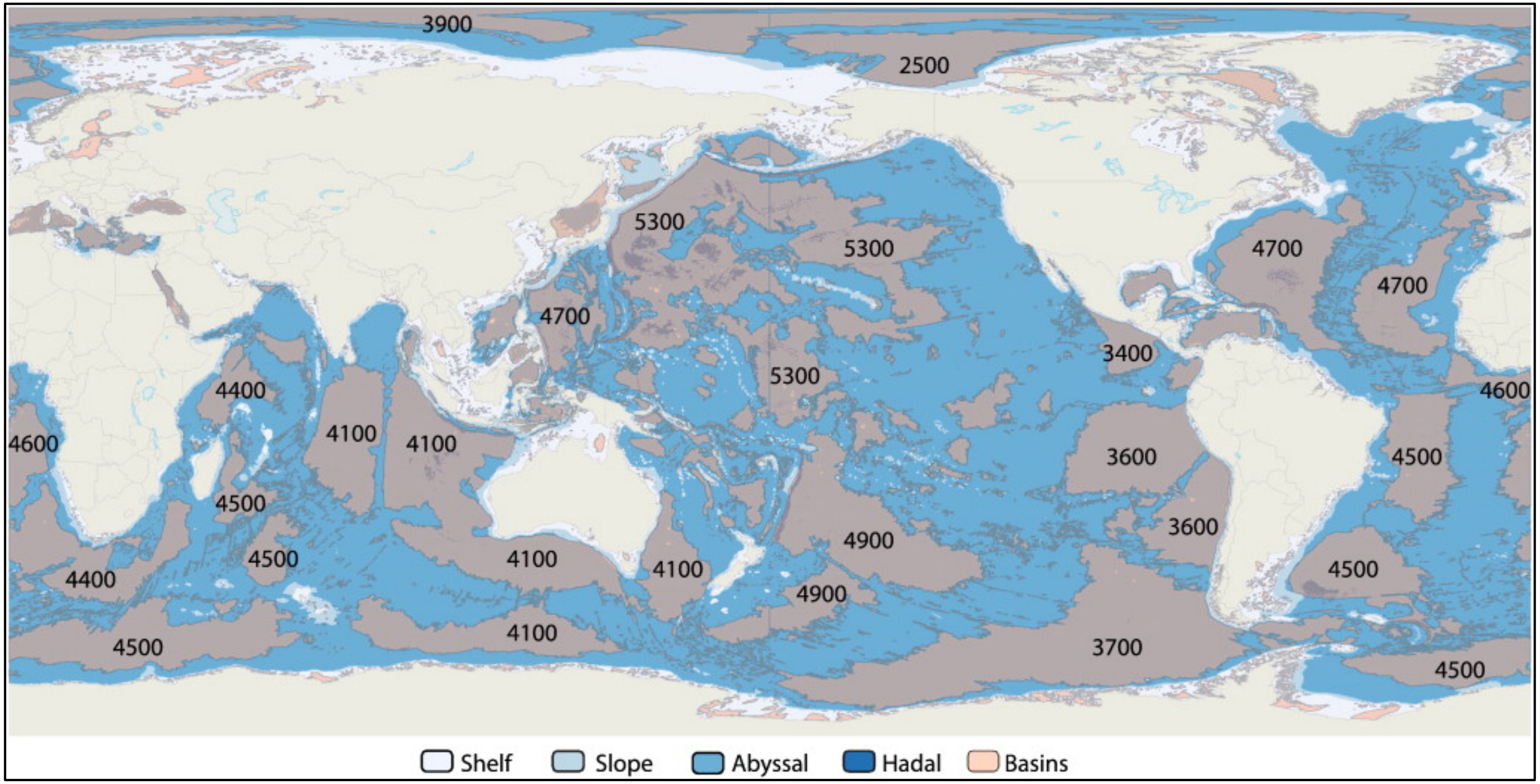
Figure 4-24 The solid lines are isotherms, $T - T_s$ (°K), in the oceanic lithosphere from Equation (4-125). The data points are the thicknesses of the oceanic lithosphere in the Pacific determined from studies of Rayleigh wave dispersion data. (From A. R. Leeds, L. Knopoff, and E. G. Kausel, Variations of upper mantle structure under the Pacific Ocean, *Science*, **186**, 141–143, 1974.)



Cooling of oceanic crust



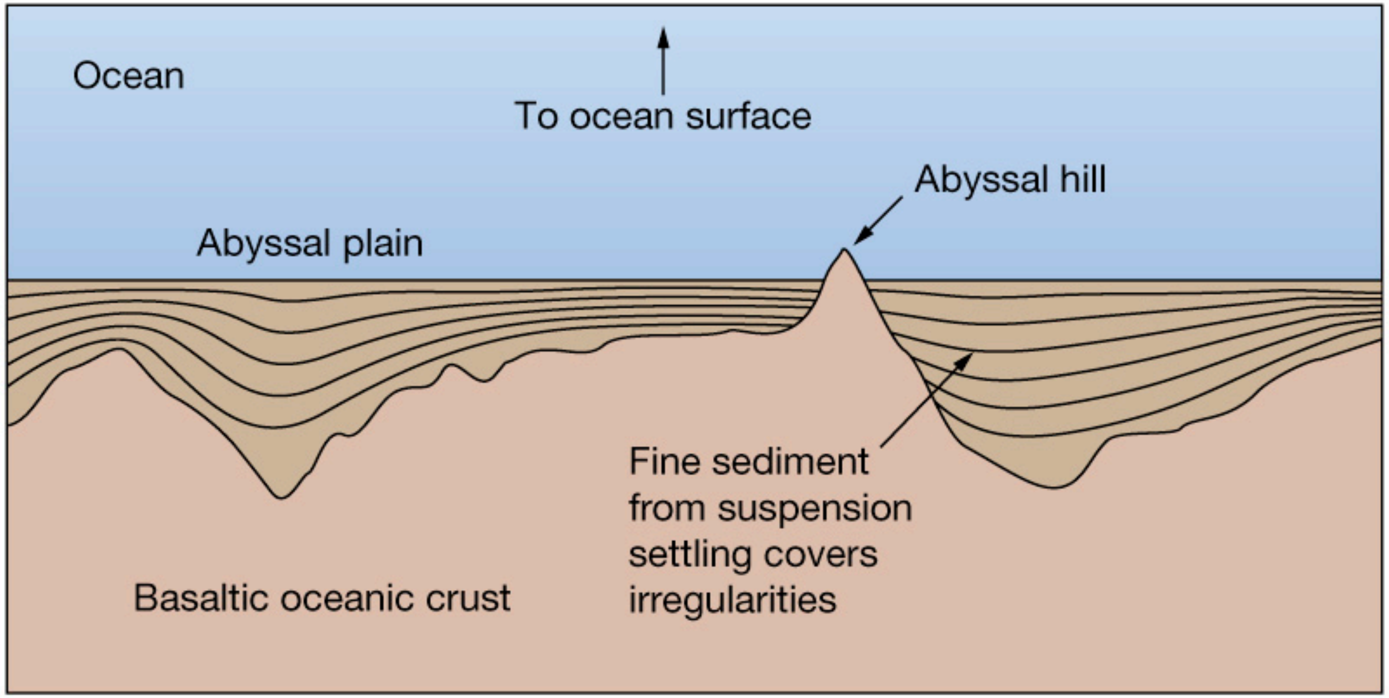
Basins in the oceans



The numbers indicate contour depths of major ocean basins based on the most shallow, closed, bathymetric contour that defines the basin outline, illustrating that the deepest basins are located in the northwest Pacific.

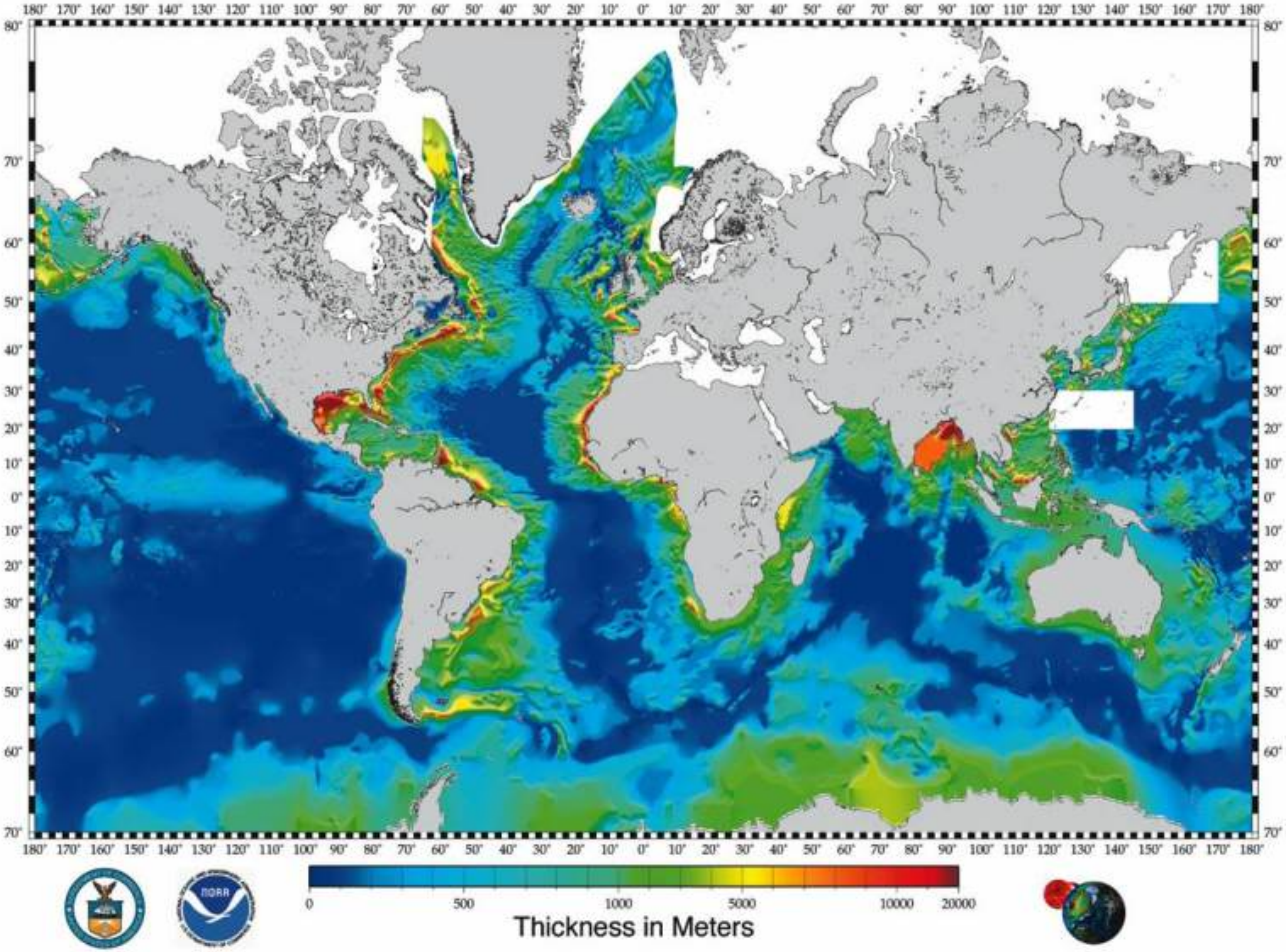
Harris, Macmillan-Lawler, Rupp, Baker, 2014. **Geomorphology of the oceans.** Marine Geology, 352, 2014, 4–24. http://dx.doi.org/10.1016/j.margeo.2014.01.011

Abyssal Plain



Result from the blanketing of the oceanic crust by fine-grained sediments, mainly clay and silt from turbidity currents and from pelagic sediments.
Metallic nodules are common in some areas of the plains, with varying concentrations of metals, including manganese, iron, nickel, cobalt, and copper.

Total Sediment Thickness of the World's Oceans & Marginal Seas



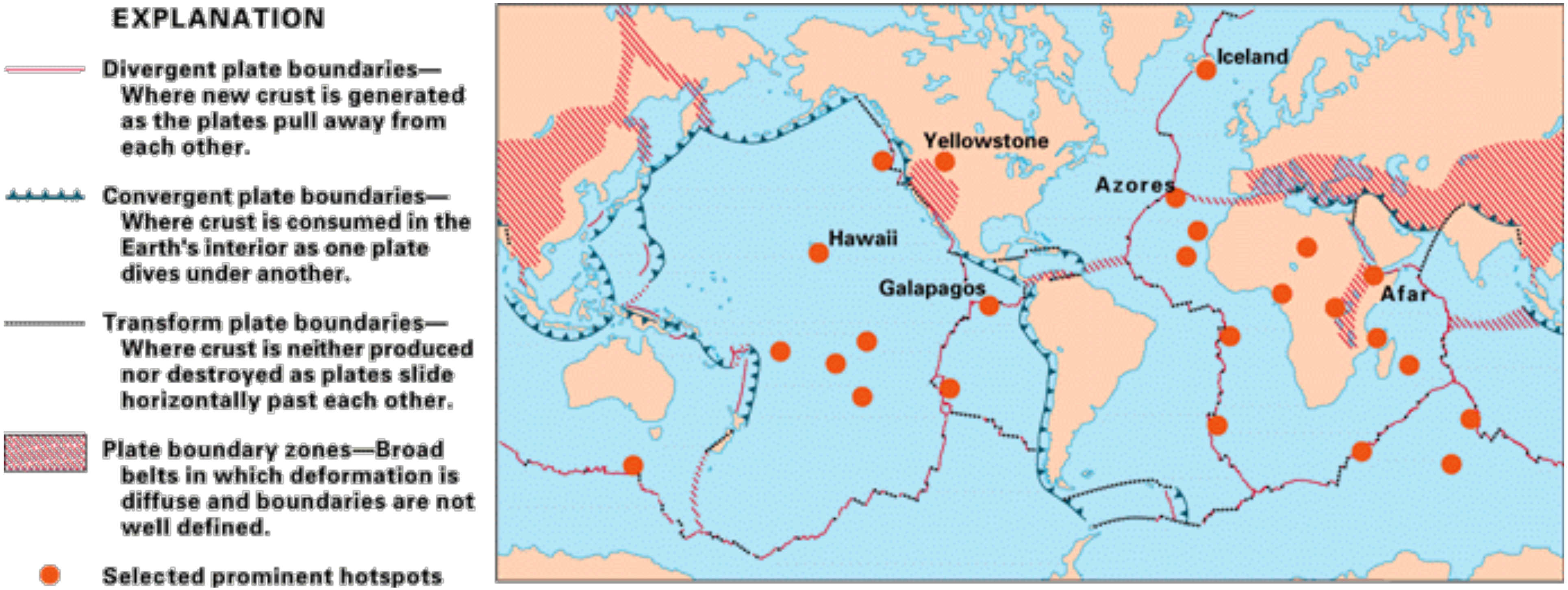
A digital total sediment thickness database for the world's oceans and marginal seas is being compiled by the National Geophysical Data Center (NGDC) ,Marine Geology & Geophysics Division. The data are gridded with a spacing of 5 arc-minutes by 5 arc-minutes. Sediment thickness data were compiled from three principle sources: previously published isopach maps; ocean drilling results, both ODP and DSDP; and seismic reflection profiles archived at NGDC as well as seismic data and isopach maps available as part of the IOC's Geological/Geophysical Atlas of the Pacific (GAPA) project.

The distribution of sediments in the oceans is controlled by five primary factors:
1) Age of the underlying crust
2) Tectonic history of the ocean crust
3) Structural trends in basement
4) Nature and location of sediment sources, and
5) The nature of the sedimentary processes delivering sediments to depocenters

The data values are in meters and represent the depth to acoustic basement. It should be noted that acoustic basement may not actually represent the base of the sediments. These data are intended to provide a minimum value for the thickness of the sediment in a particular geographic region.

http://www.ngdc.noaa.gov/mgg/sedthick/sedthick.html

HOT SPOT



Hotspots are places where molten rock from the earth's mantle is erupting at the surface. They are in the middle of the plate.

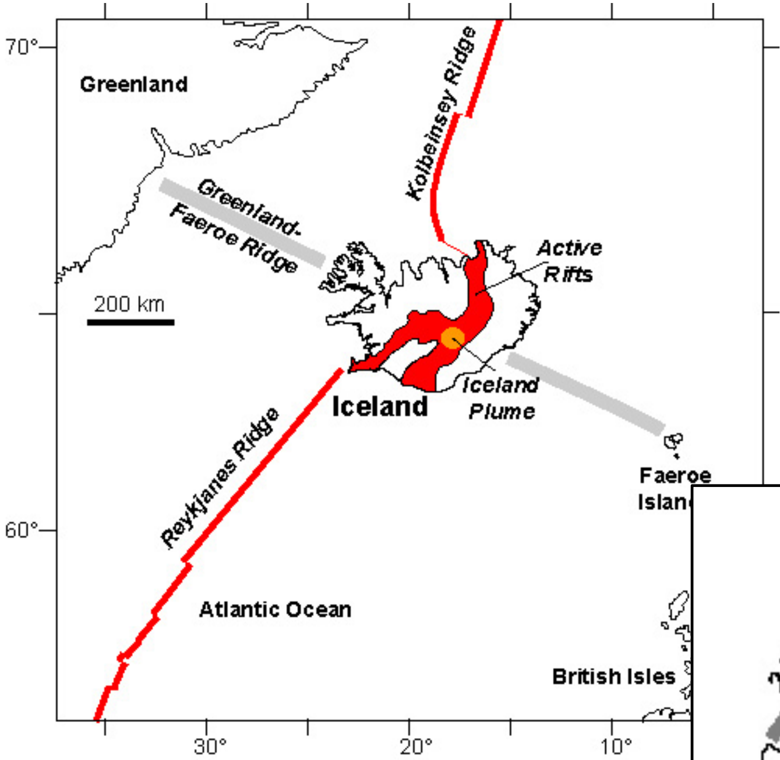
Two hypothesis:

a) the hotspots move relative to the earth;

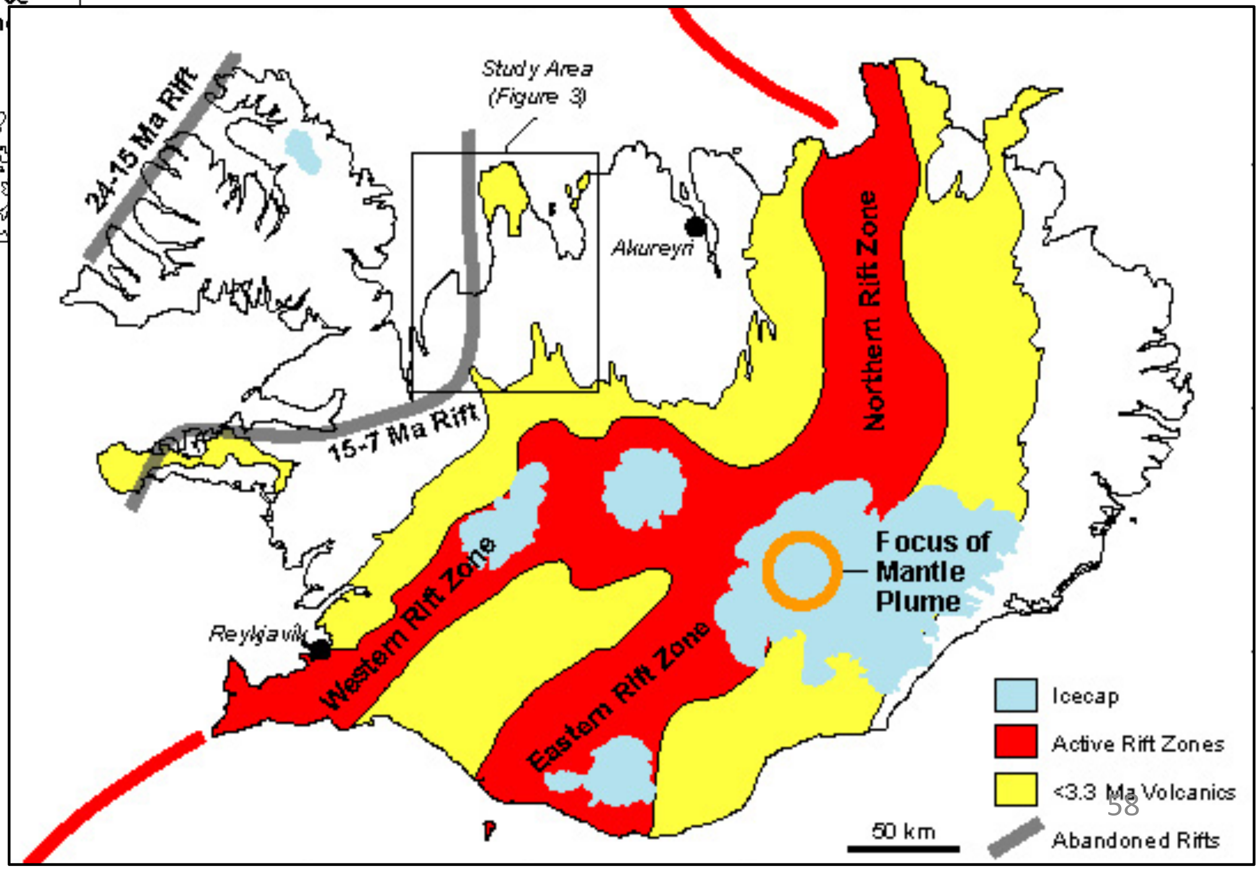
b) the hotspots are fixed to the earth.

ICELAND HOT SPOT

- 20 million years old
- some of the most active volcanoes in the world are located in Iceland
- is situated on a hotspot

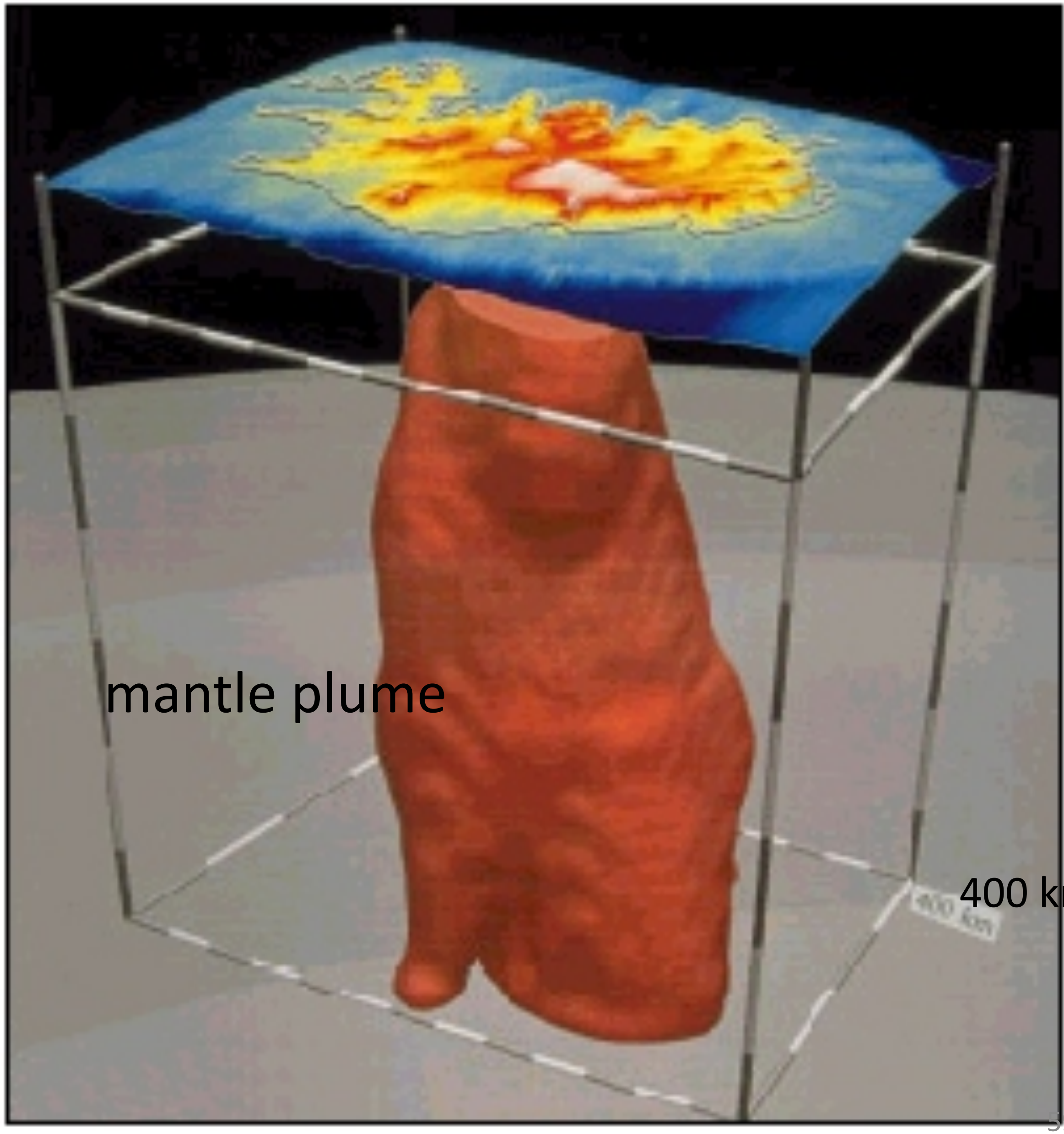


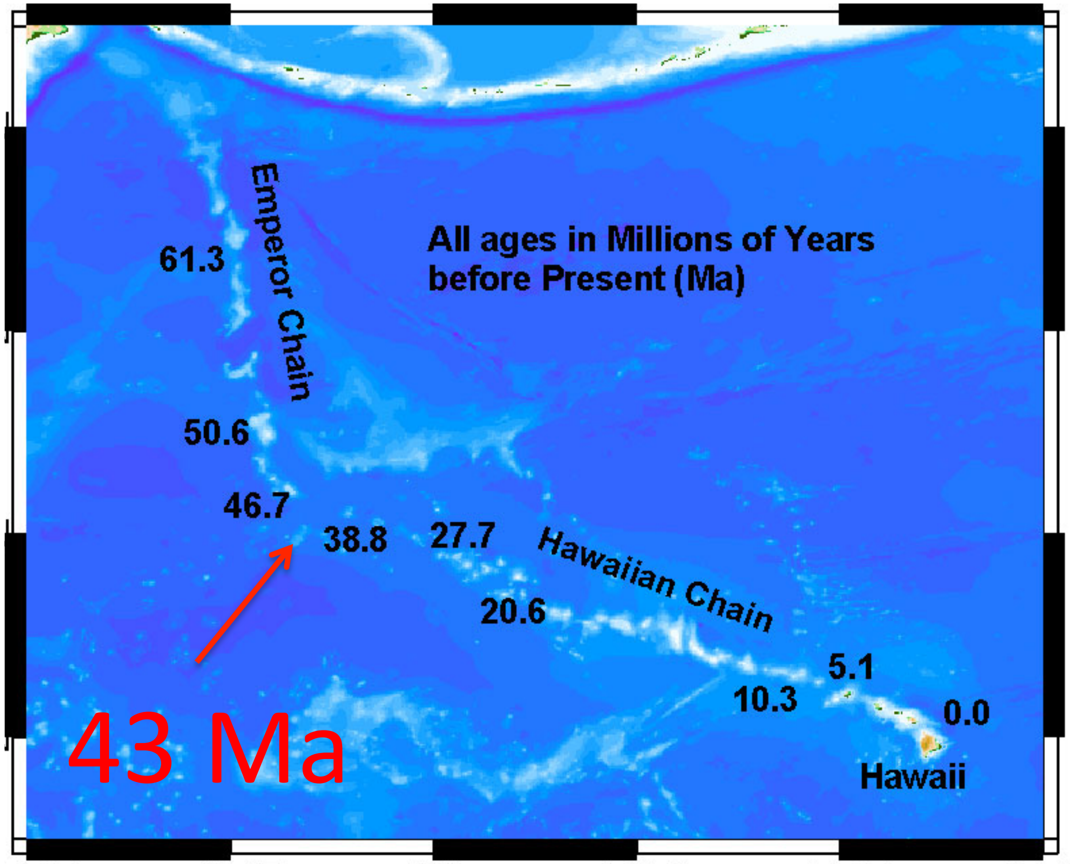
A detailed map of Iceland lying in the middle of the Atlantic Ocean. It shows the mid Atlantic ridge cutting through Iceland along with the location of its hotspot.
Image taken from
[Iceland Keck]



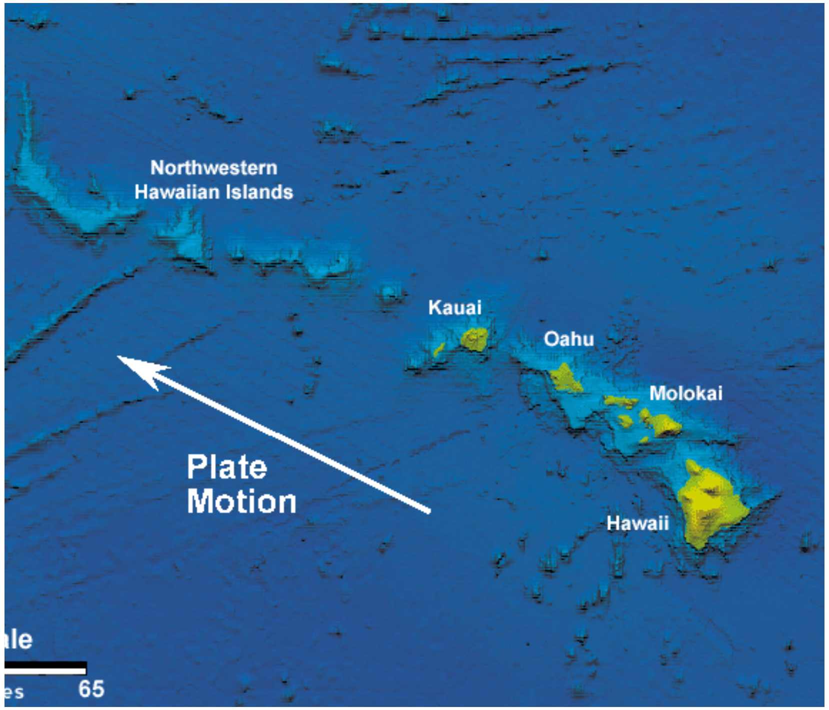
ICELAND HOT SPOT
(or mantle plume)

The starting plume head, **hundreds of degrees hotter than normal mantle**, spreads sideways, incorporates surrounding mantle, and buoyantly uplifts a region roughly 1000 km in diameter to produce a **topographic bulge about 1 km high**. (Image by D. Müller, University of Sydney).





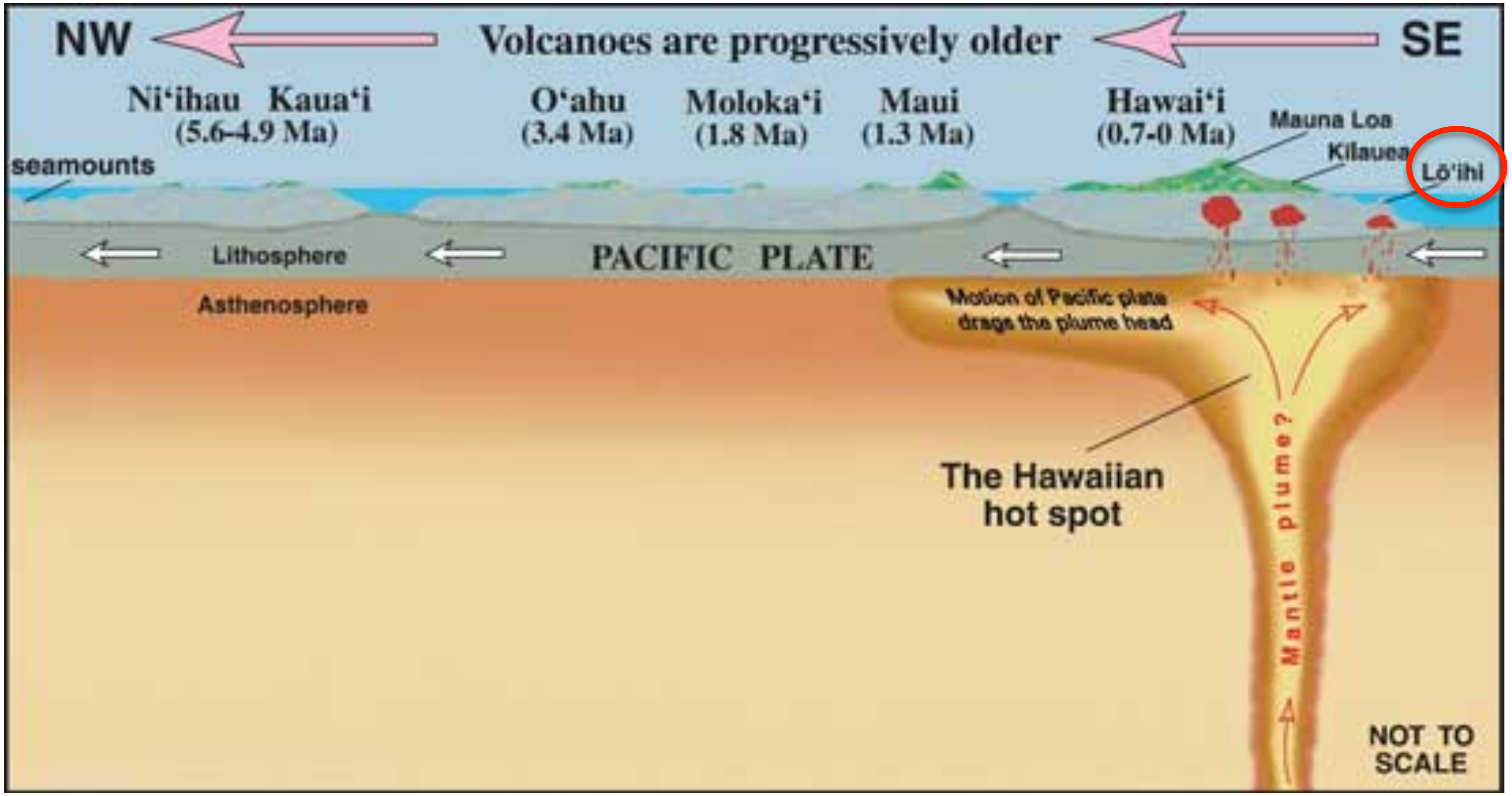
HAWAII HOT SPOT



The Hawaiian Ridge-Emperor Seamounts chain:

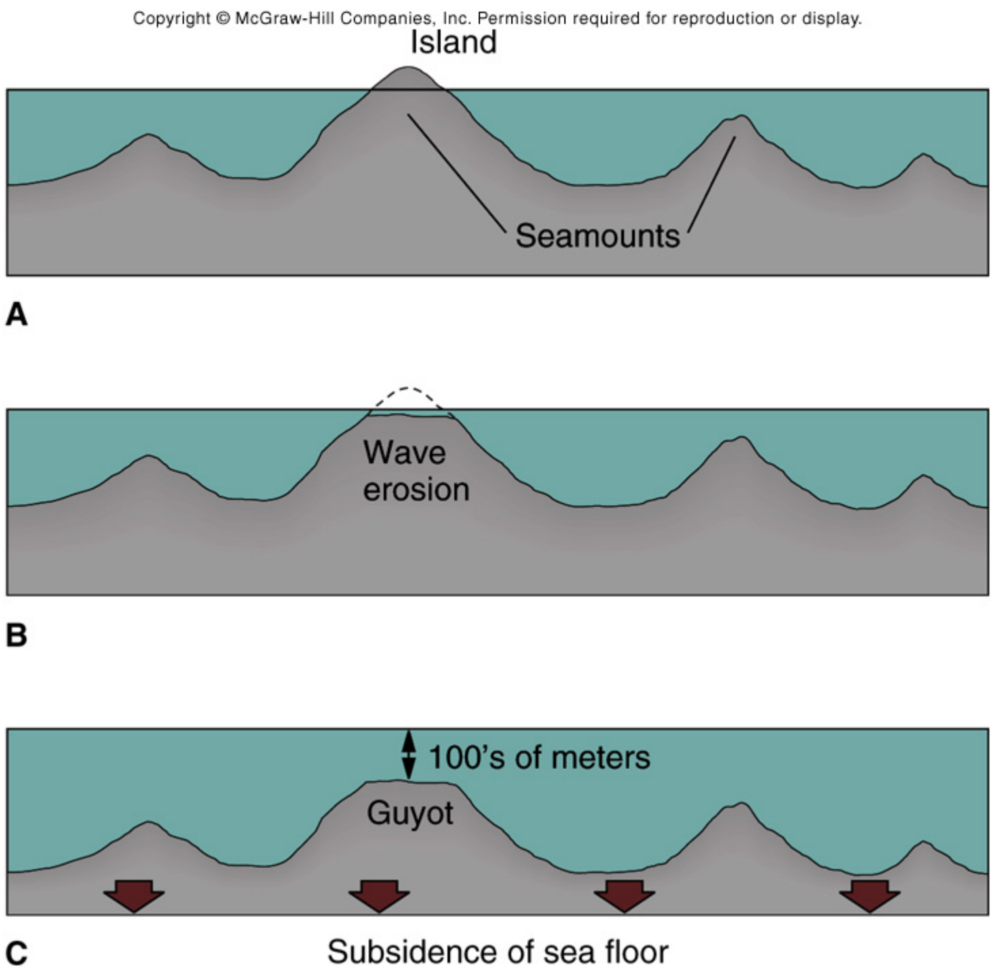
- extends some 6,000 km,
- composed by 80 volcanoes
- started 70 Ma ago, and sharp bend indicates change of motion at 43 Ma, possibly due to India-Asia collision
- is stationary

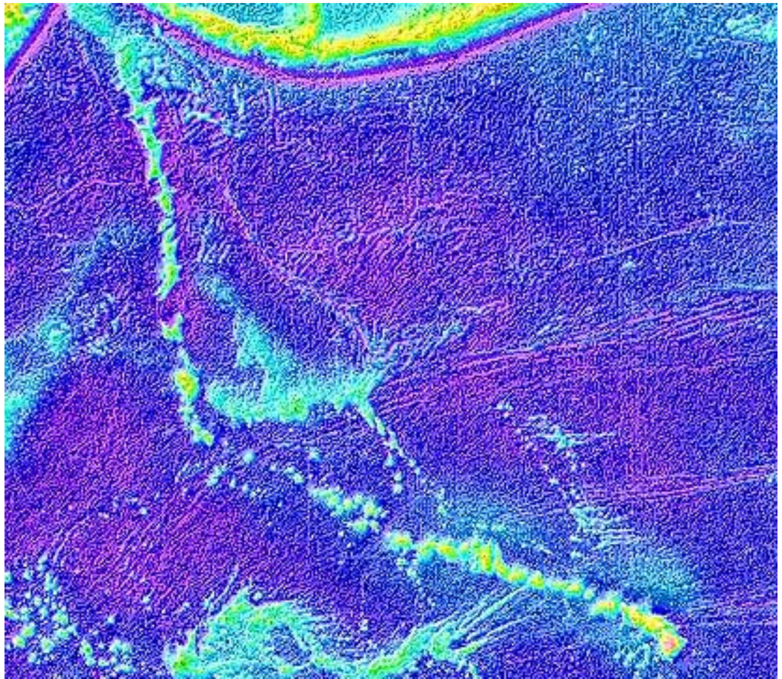
HAWAII HOT SPOT

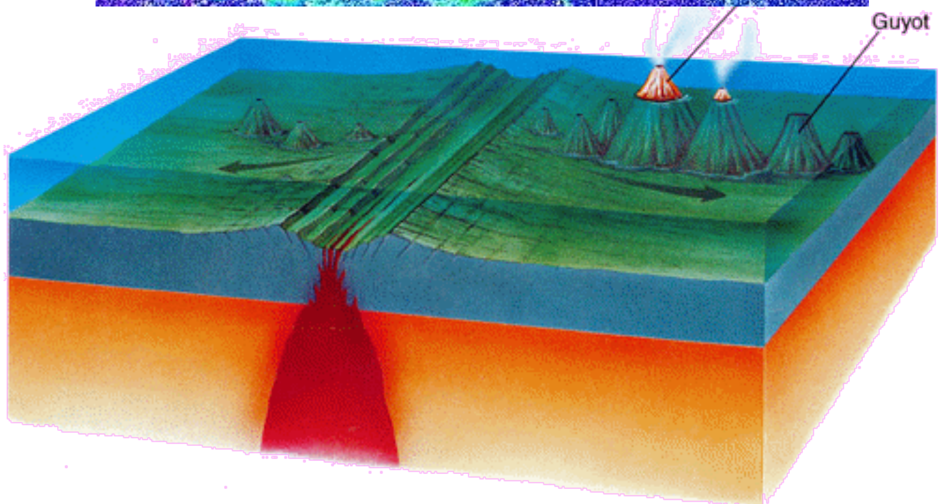


As the Pacific Plate continues to move west-northwest, the Island of Hawaii will be carried beyond the hotspot by plate motion, setting the stage for the formation of a new volcanic island in its place. In fact, this process may be under way. **Loihi Seamount**, an active submarine volcano, **is forming about 35 km off the southern coast of Hawaii**. Loihi already has risen about 3 km above the ocean floor to within 1 km of the ocean surface. According to the hotspot theory, assuming Loihi continues to grow, it will become the next island in the Hawaiian chain. In the geologic future, Loihi may eventually become fused with the Island of Hawaii, which itself is composed of five volcanoes knitted together-Kohala, Mauna Kea, Hualalai, Mauna Loa, and Kilauea.

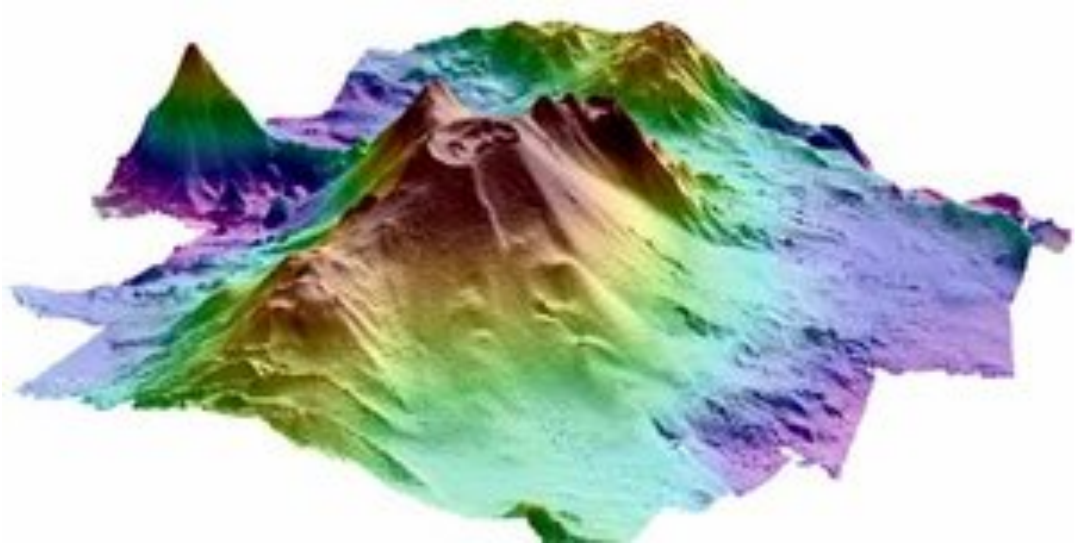
Morphological Features
Seamounts, volcanic island and guyots



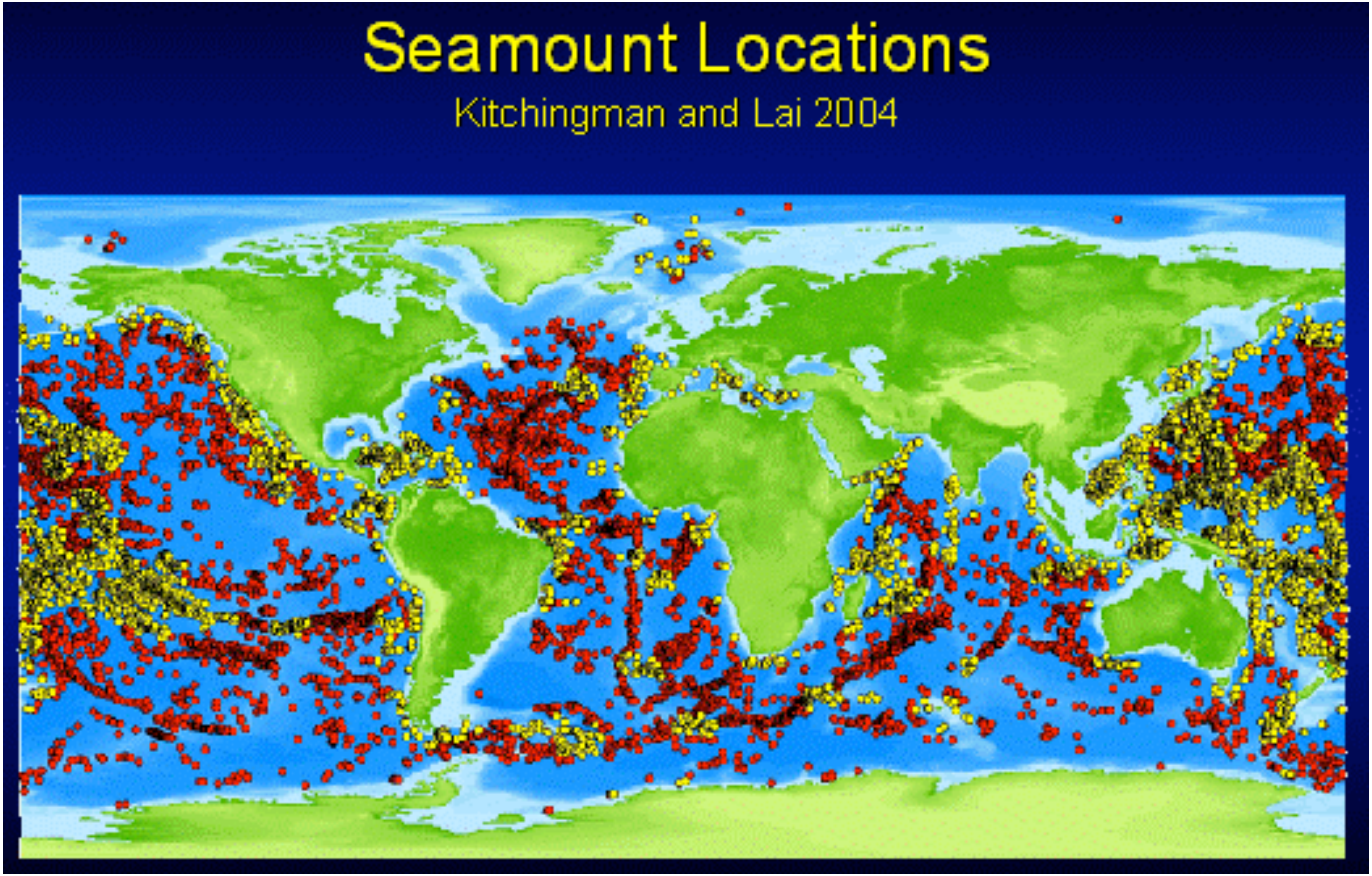




SEAMOUNT

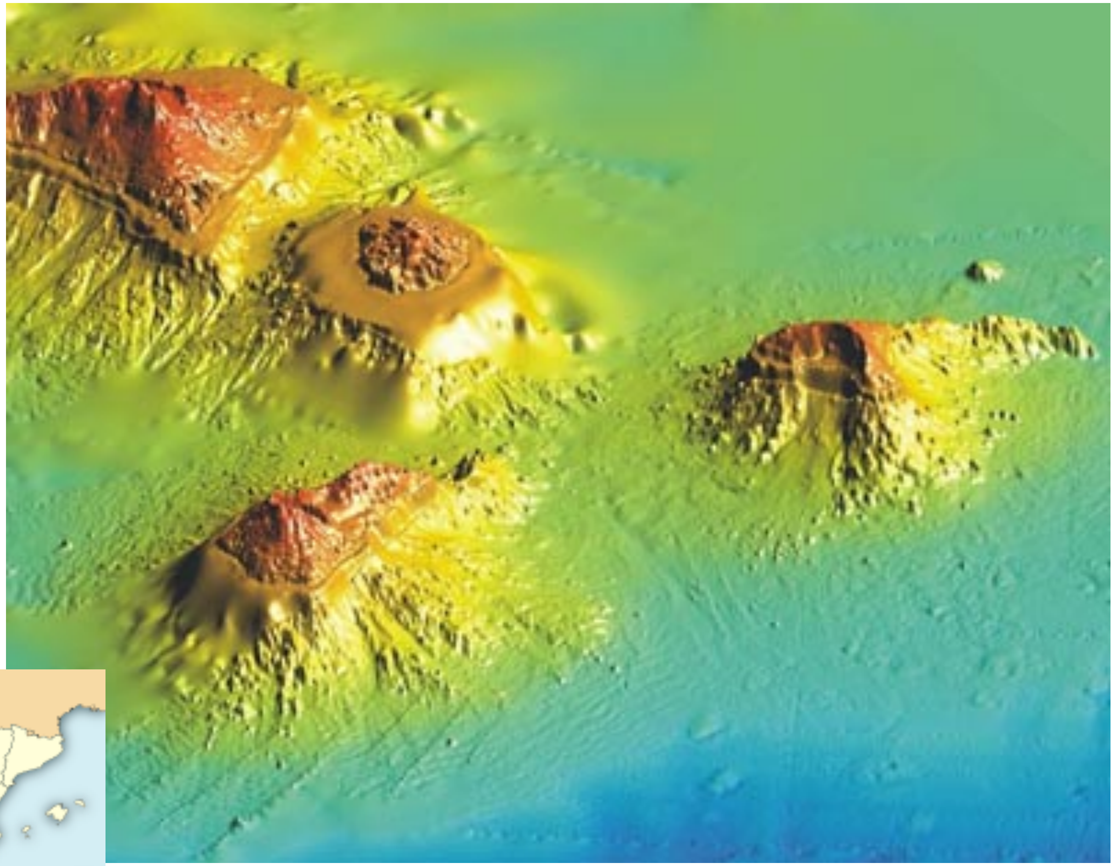


Seamounts: undersea mountains rising from the bottom of the sea with a minimum elevation of 1,000 meters, that do not break the water's surface.
Seamounts are usually isolated and cone-shaped, are mostly volcanic and therefore found on oceanic crust, formed near mid-oceanic ridges, hotspot and island-arc convergent settings.
A seamount tall enough to break the sea surface is called an oceanic island, e.g., the islands of Hawaii, the Azores and Bermuda.



about 60.000 seamounts

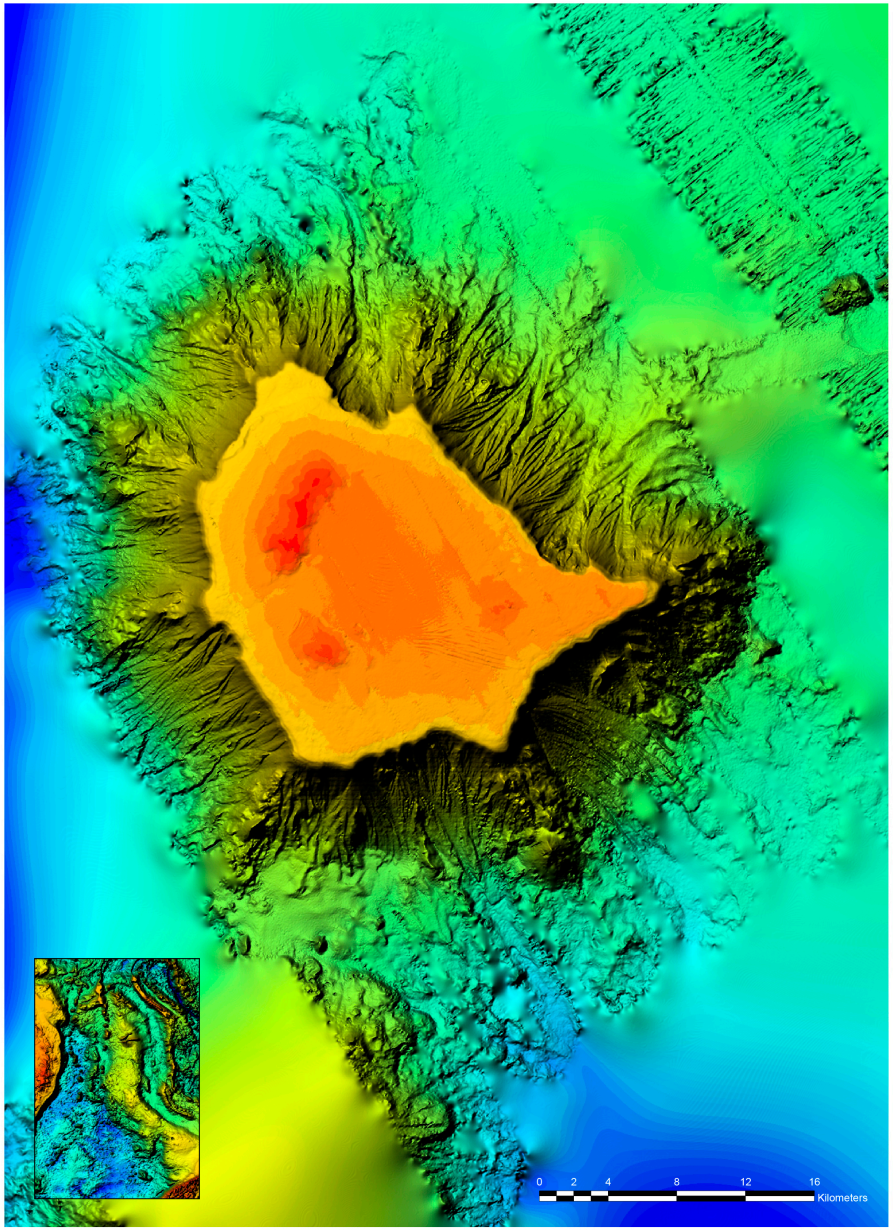
Volcanic Island



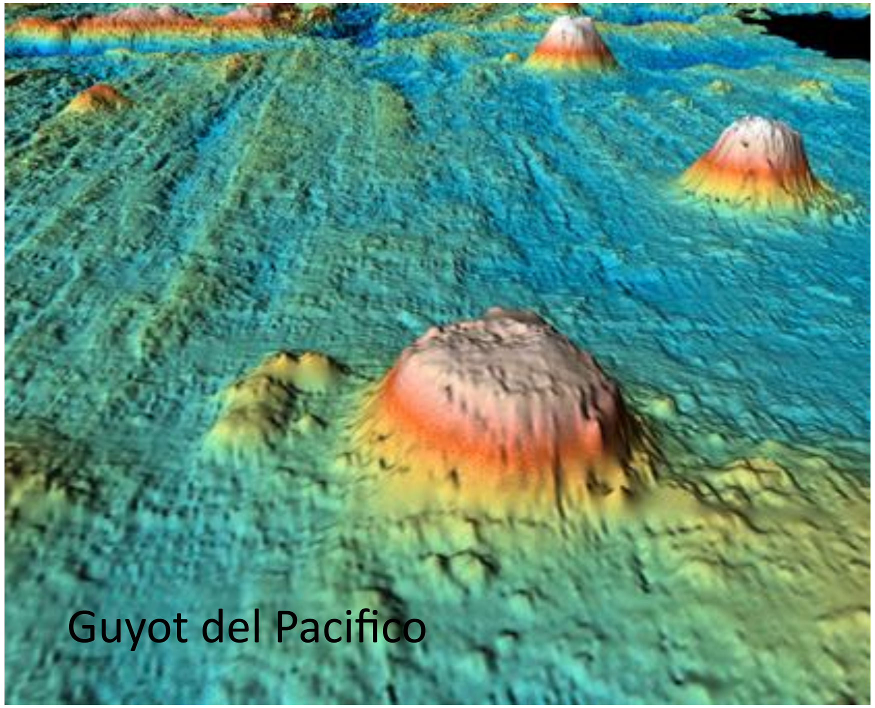
Isole canarie

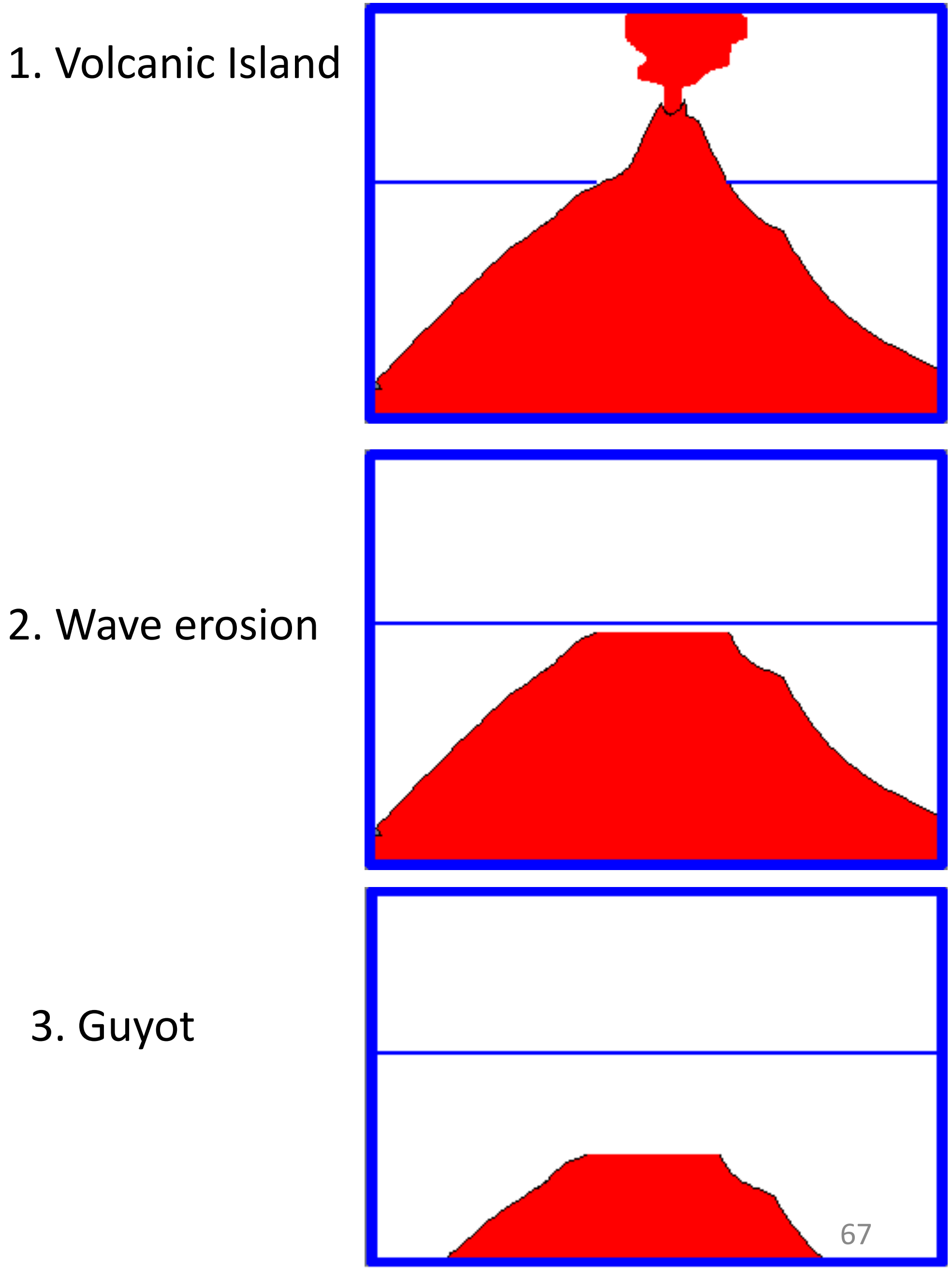
Gifford Guyot

Faust-Capel basins reconnaisance survey (Tan0713)

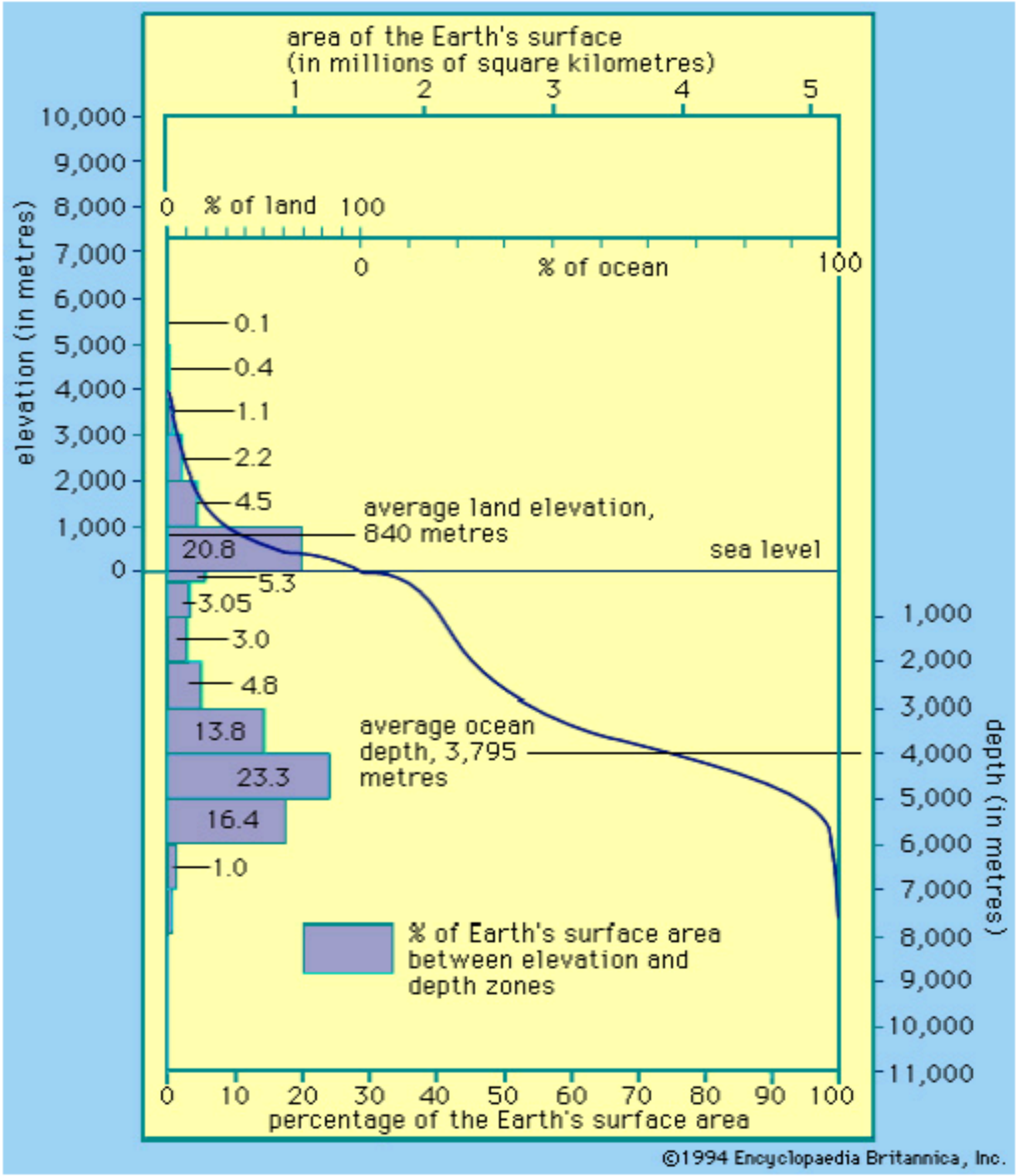


GUYOT

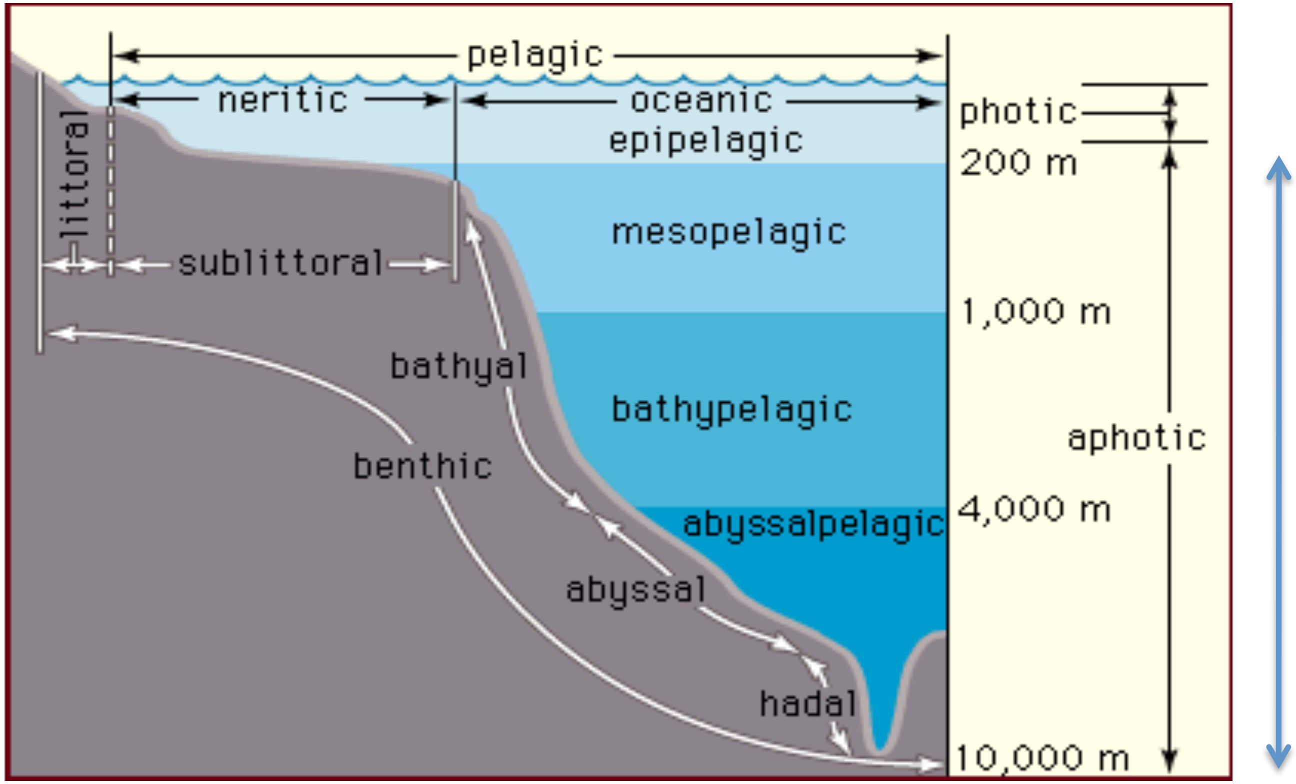




The classification


area of the Earth's surface
(in millions of square kilometres)
1
2
3
4
5
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
elevation (in metres)
0 % of land 100
0 % of ocean 100
0.1
0.4
1.1
2.2
4.5
20.8
average land elevation,
840 metres
sea level
5.3
3.05
3.0
4.8
13.8
23.3
16.4
1.0
average ocean
depth, 3,795
metres
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
10,000
11,000
depth (in metres)
% of Earth's surface area
between elevation and
depth zones
0 10 20 30 40 50 60 70 80 90 100
percentage of the Earth's surface area
©1994 Encyclopaedia Britannica, Inc.

Classification of the Marine Zones



Temperature

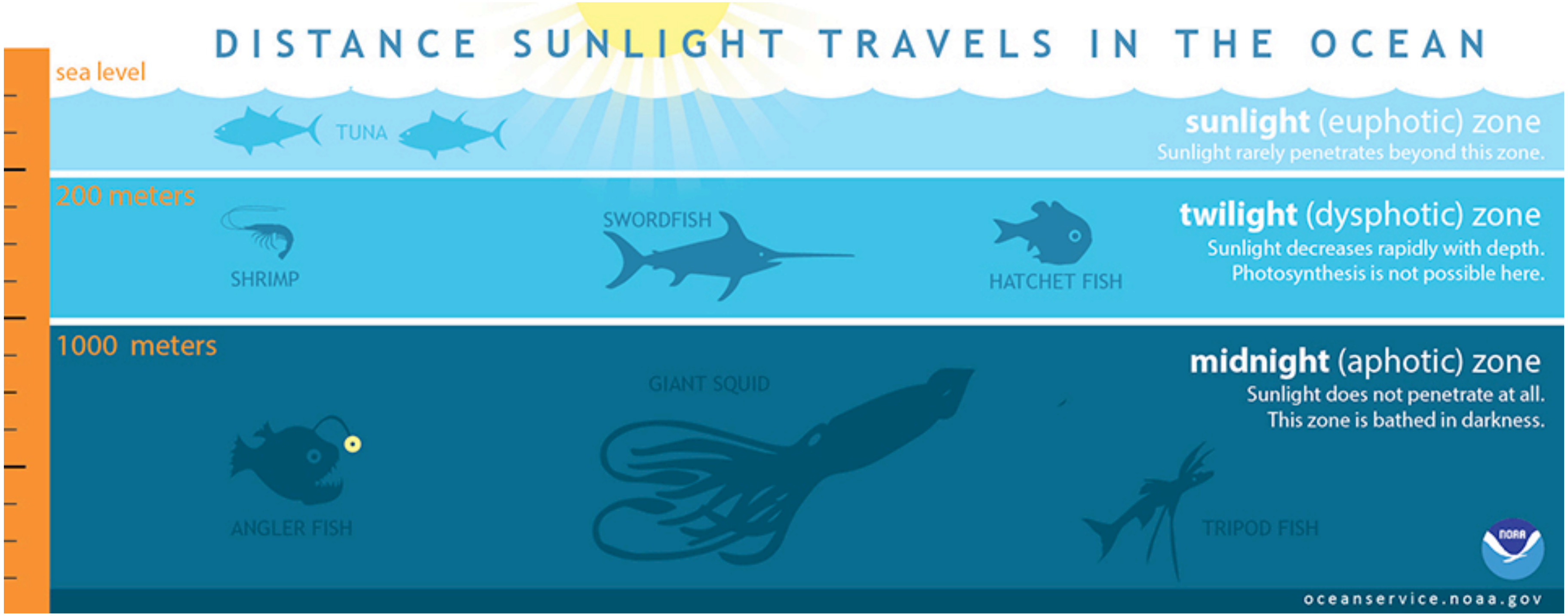
T= 12° C
at about 700-1000 m depth
in the tropic

T= 4° C
at about 4000 m depth
in the tropic

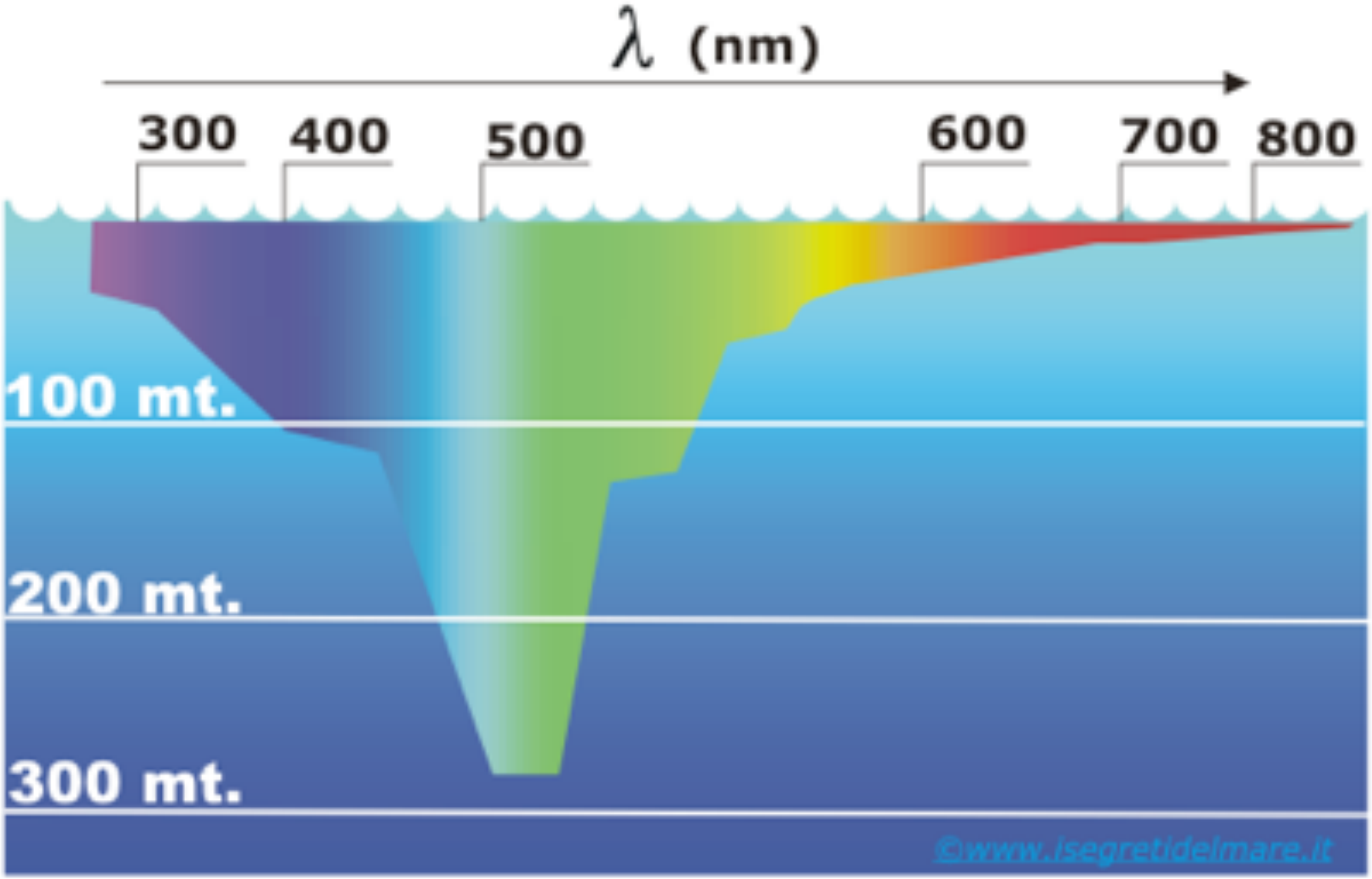
Environmental classification:
- Littoral
- sublittoral
- bathyal
- abyssal
- hadal

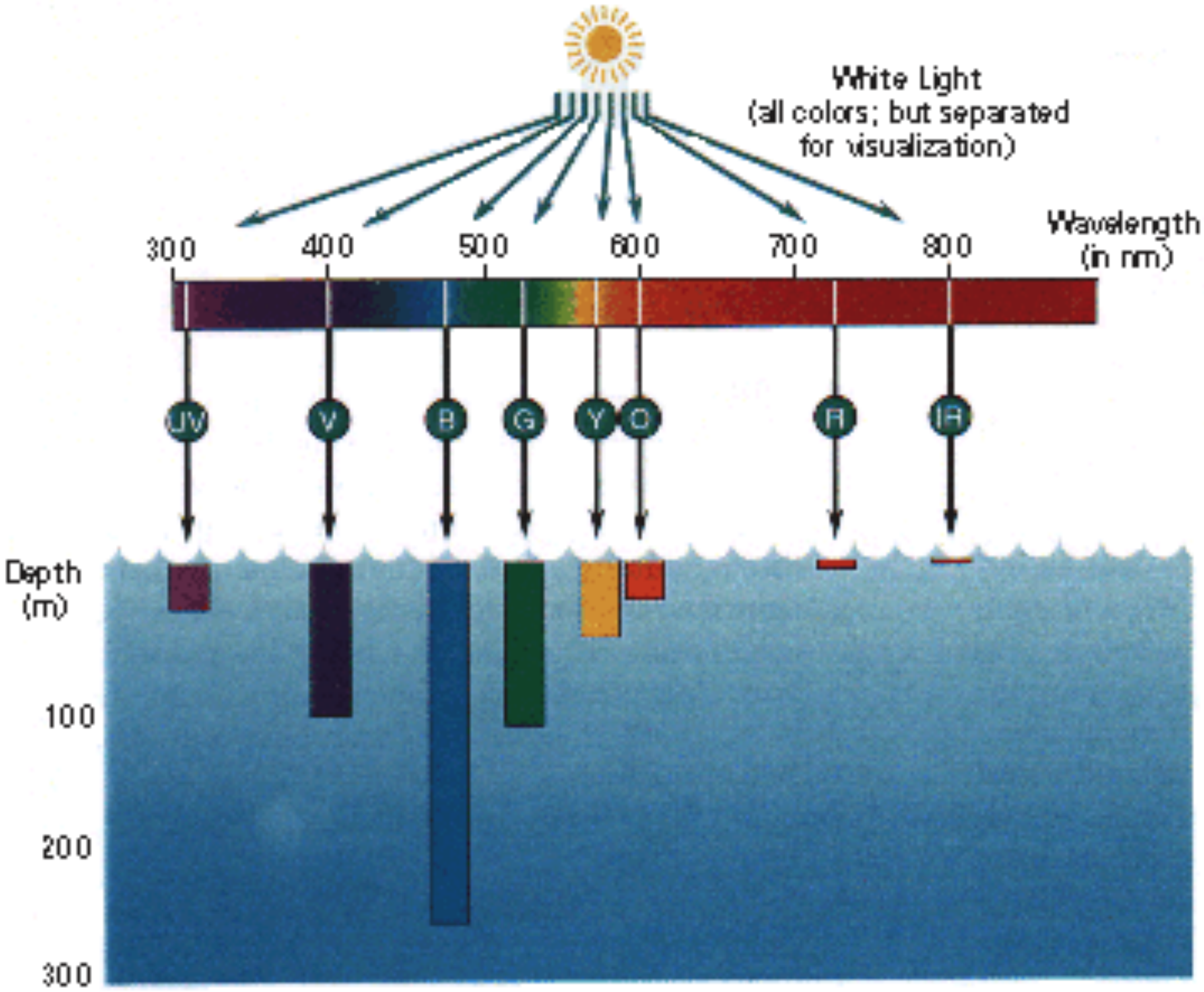
Light classification:
- photic
- aphotic

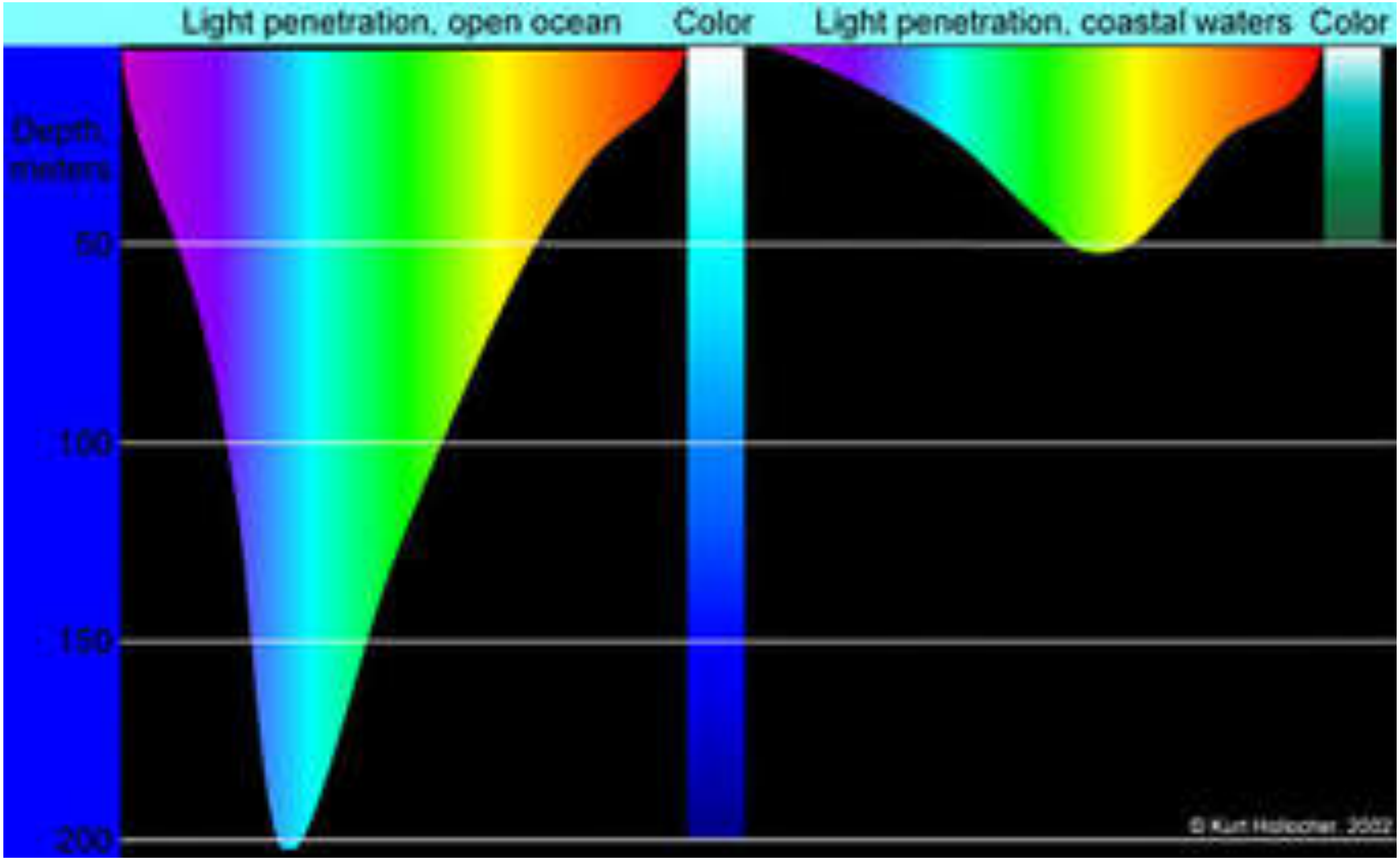
Pelagic:
- neritic
- oceanic:
  - epipelagic (photic zone)
  - mesopelagic (down to T=12°C)
  - bathypelagic (12°C < T > 4°C)
  - abyssalpelagic
  - hadalpelagic



Such a miniscule amount of light penetrates beyond a depth of 200 meters that photosynthesis is no longer possible.


λ (nm)
300
400
500
600
700
800
100 mt.
200 mt.
300 mt.
©www.isegretidelmare.it


White Light
(all colors; but separated for visualization)
Wavelength
(in nm)
300
400
500
600
700
800
UV
V
B
G
Y
O
R
IR
Depth
(m)
100
200
300


Light penetration, open ocean
Color
Light penetration, coastal waters
Color
Depth, meters
50
100
150
200
© Kurt Hollocher, 2002

Ancient Oceans

The origin of the water of the ocean

The water of the paleo-oceans formed on Earth 3.8 billion years ago (the Earth is 4.5 b years old) by two sources:

- outgassing whereby gases are released from molten rock in the mantle of the planet by volcanic activity;

- bombardment by comets and meterorites bringing with them gases which contributed to the Earth's atmosphere (some meteorites are formed by 20% of water).

Some of the gases in the new atmosphere were methane (CH_4), ammonia (NH_3), water vapor (H_2O), and carbon dioxide (CO_2).

The water on Earth stayed in gaseous form until the planet's surface cooled below 100°C.

At this time, 3.8 billion years ago, water condensed into rain and poured onto the land. Water collected in low lying areas which gradually became the primitive oceans.

At 3.5 billions years ago, the first photosynthetic organisms appeared, and they produced oxigen that enreached the primitive atmosphere.

The geochemical cycles had their beginnings here, with minerals entering the oceans from the land and sky and minerals leaving the oceans through tectonic activity and by evaporation/deposition processes.

These cycles were well established about 1 billion years ago.

Since then the chemically composition of the oceans has remained constant.

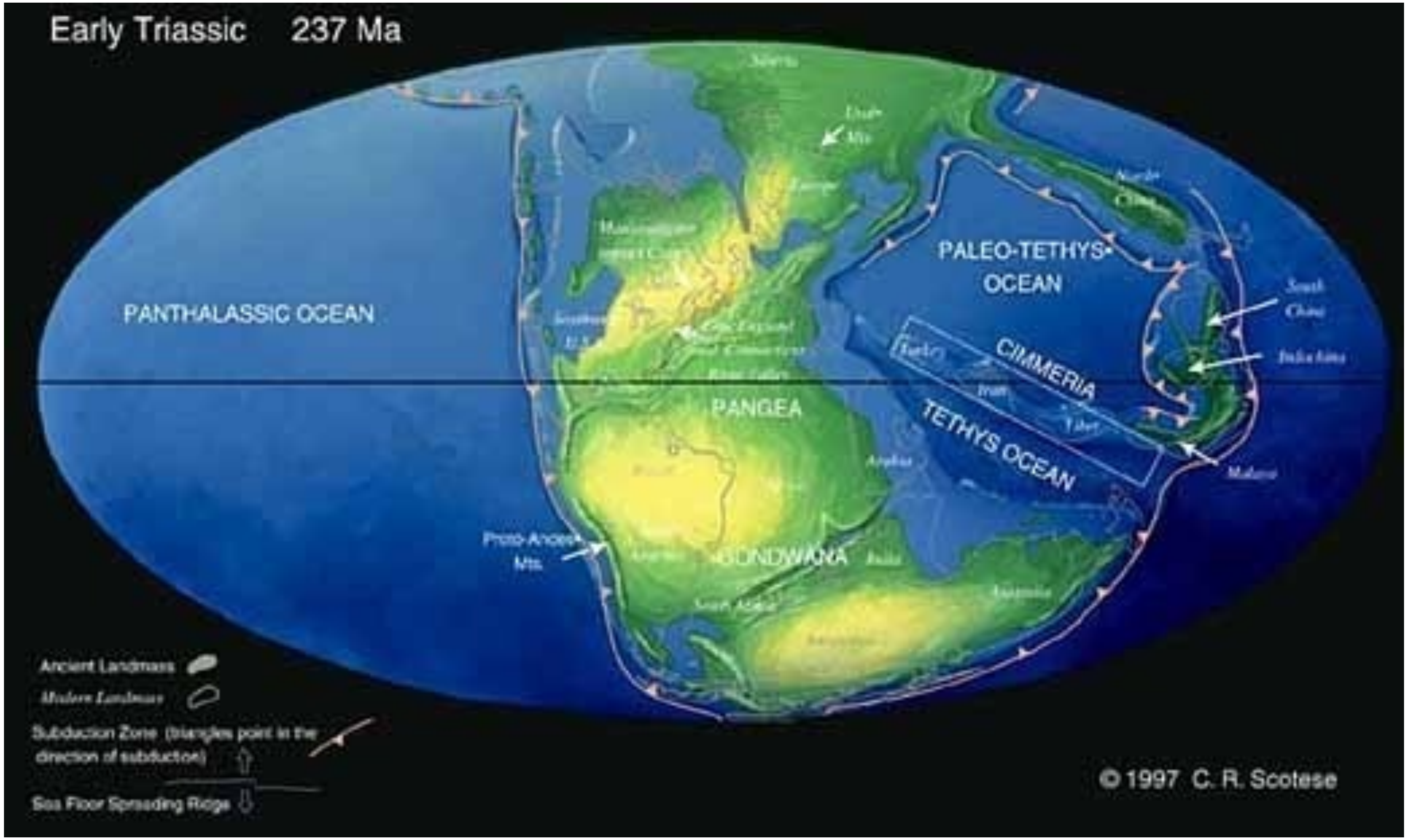
The **Giapeto Ocean**, between the Laurentua and Baltica continents

- formed in the Cambrian, about 510 milion years ago,

- disappear in the Devonian, about 400 milion years ago.

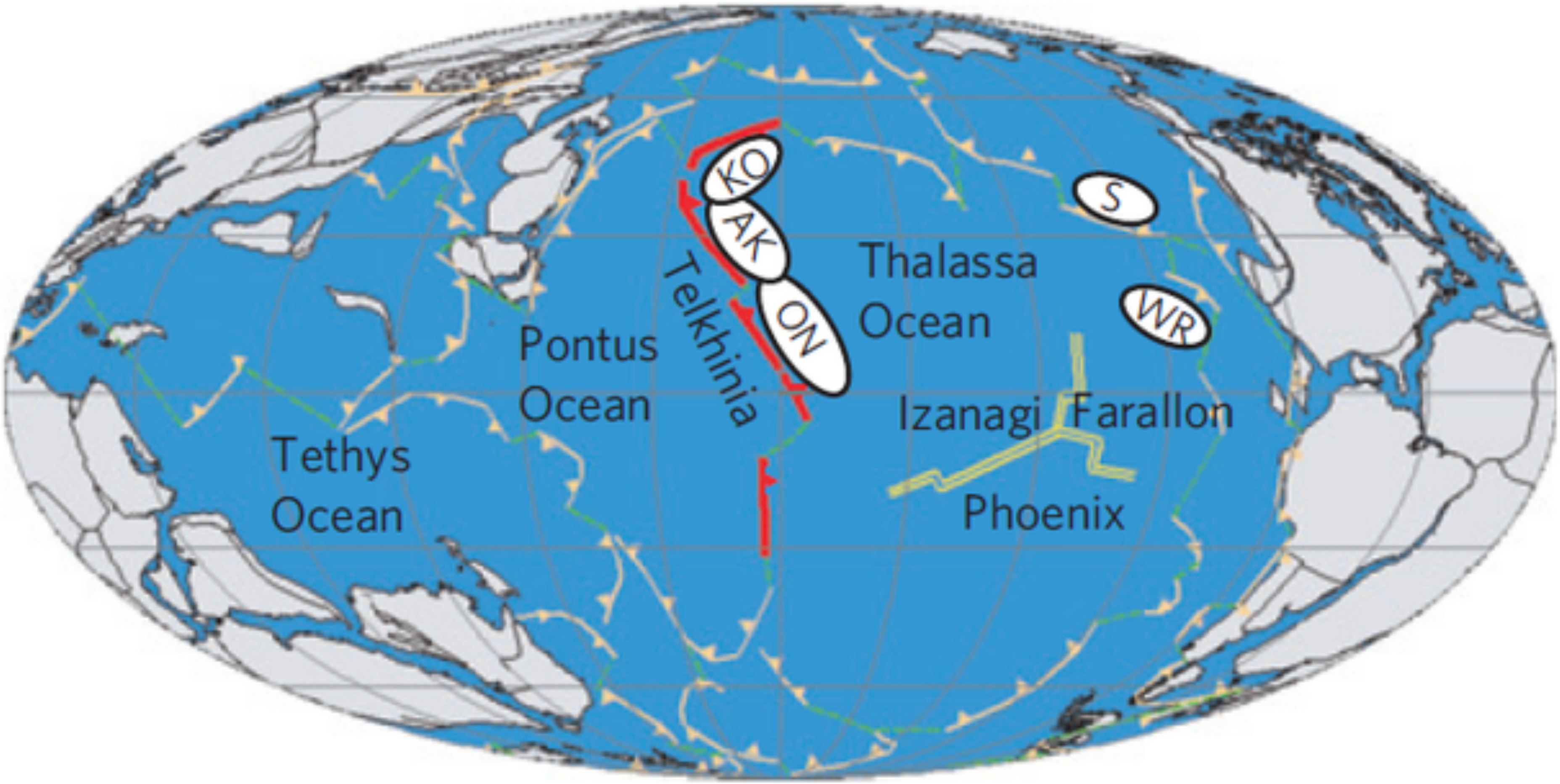
Panthalassa

Παν pan, tutto + θάλασσα thálassa, mare



Panthalassa

Παν pan, tutto + θάλασσα thálassa, mare

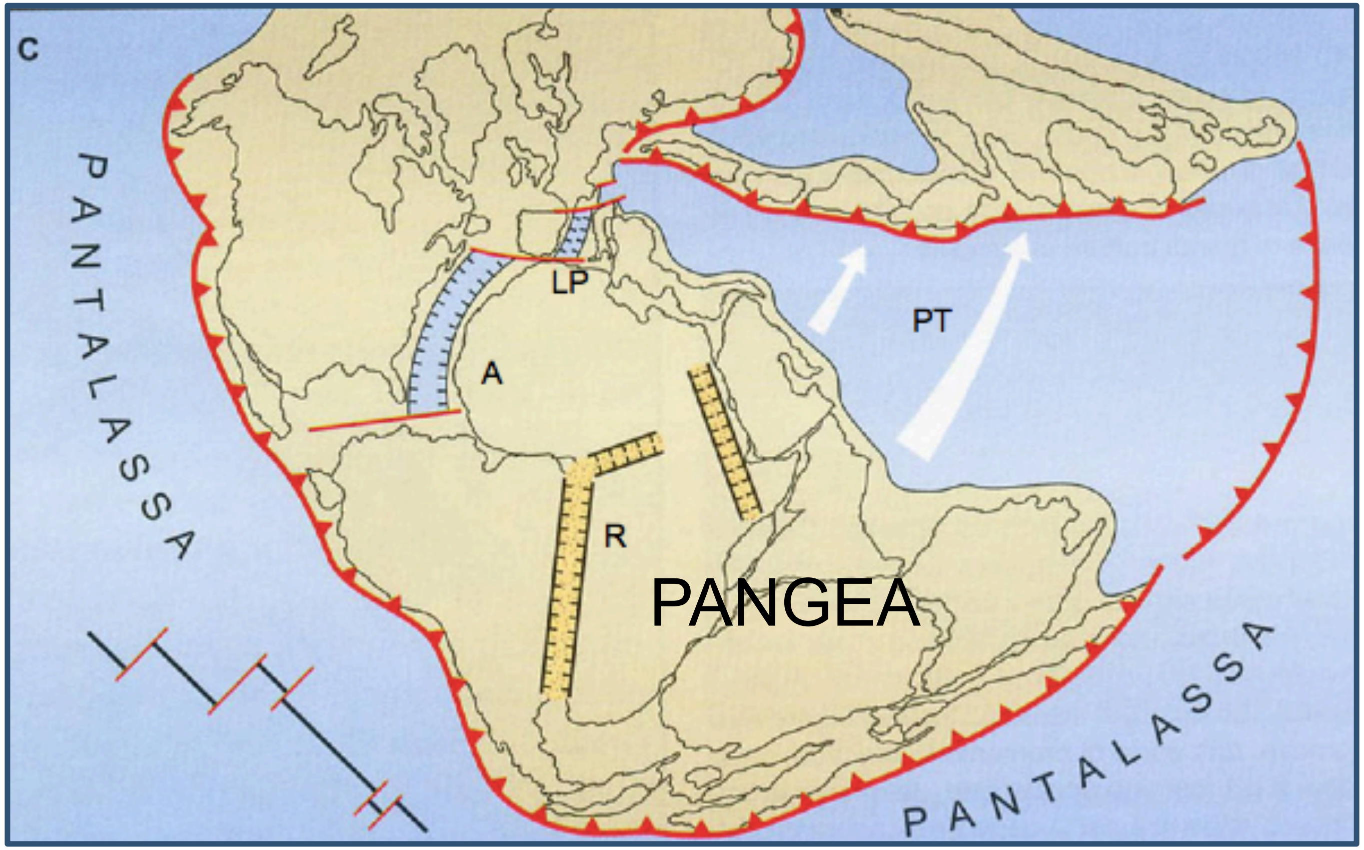


Van der Meer et alii, 2012, Nature Geoscience

Gli oceani nel passato

Map courtesy of CR Scotese, PALEOMAP Project

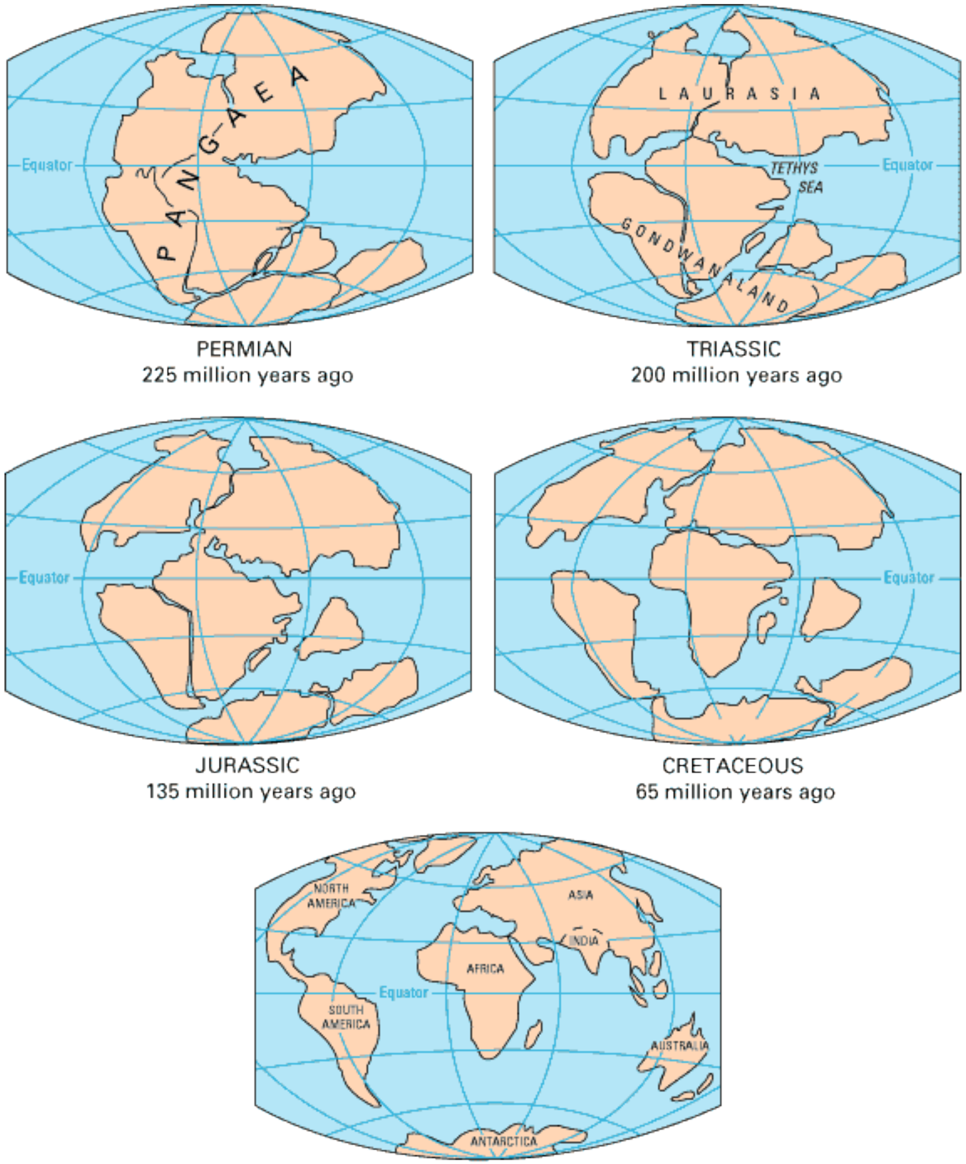
ATLANTIC OCEAN: initial stage



Fragmentation of the Pangea (Late Giurassic):

- Opening of the Central Atlantic (A) and the Ligurian-Piedemont Basin (LP – western Tethys)
- Continental rifting of the future Southern Atlantic (R)
- Subduction of the Paleo Tethys (PT) in the Permo-Triassic

The break up of Pangaea



PERMIAN 225 million years ago

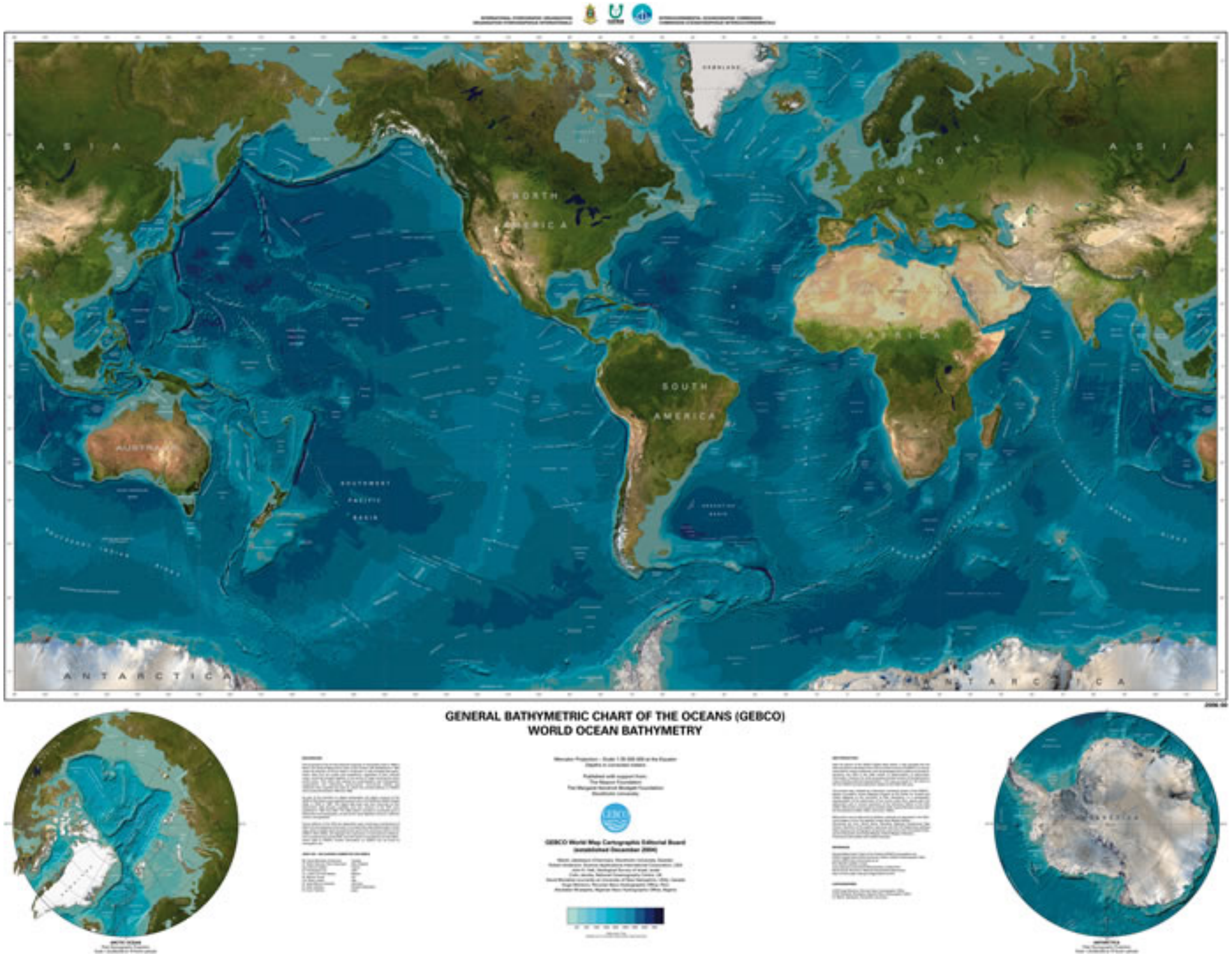
TRIASSIC 200 million years ago

JURASSIC 135 million years ago

CRETACEOUS 65 million years ago

PRESENT DAY

General Bathymetric Chart of the Oceans - GEBCO
http://www.gebco.net



International Hydrographic Organization

It is the inter-governmental organisation representing the hydrographic community. It enjoys observer status at the UN where it is the recognised competent authority on hydrographic surveying and nautical charting.

Functions

- The principal work undertaken by the IHO is:
- To bring about a close and permanent association between national hydrographic offices.
- To study matters relating to hydrography and allied sciences and techniques.
- To further the exchange of nautical charts and documents between hydrographic officers of member governments.
- To tender guidance and advice upon request, in particular to countries engaged in setting up or expanding their hydrographic service.
- To encourage coordination of hydrographic surveys with relevant oceanographic activities.
- To extend and facilitate the application of oceanographic knowledge for the benefit of navigators.
- To cooperate with international organizations and scientific institutions which have related objectives.
- The IHO develops hydrographic and nautical charting standards to be agreed upon by its Member States. All Member States then follow those standards in their surveys, nautical charts, and publications. The almost universal use of the standards means that the products and services from the world's hydrographic and oceanographic offices are increasingly consistent and recognisable for all seafarers and for other users. Much has been done in the field of standardisation since the Bureau (now the IHO) was founded.

Web sites

http://www.oceanleadership.org/

Paleomagnetism
http://www.minerva.unito.it/SIS/Paleomagnetismo/paleo4.htm

Plate tectonic
http://www.ucl.ac.uk/EarthSci/people/lidunka/GEOL2014/Geophysics1-%20Plate%20tectonics/PLATE%20TECTONICS.htm

Woods Hole Oceanographic Institution
http://www.whoi.edu/main/ocean-topics

NOAA National Geophysical Data Center
http://www.ngdc.noaa.gov

Ocean gravity
http://topex.ucsd.edu/grav_outreach/index.html#natlanticano

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Philip Kearey, Keith A. Klepeis, Frederick J. Vine
2009, Wiley-Blackwell