UNIVERSITÀ
DEGLI STUDI
DI PADOVA

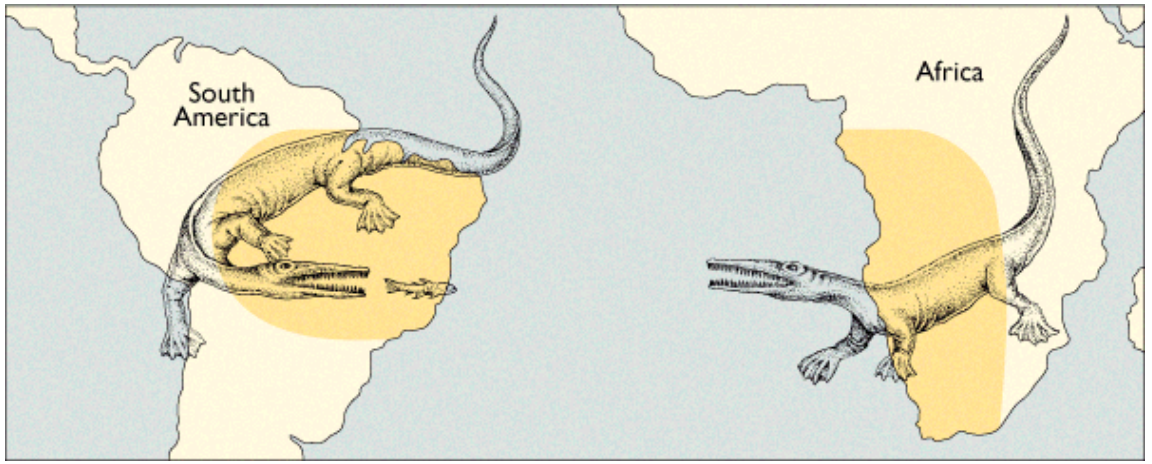
Tettonica delle Placche

Tettonica delle placche: teoria attraverso la quale spiegare la ***dinamica della Terra***.

Spiega i ***fenomeni che interessano la crosta terrestre*** quali:

- attività sismica,
- orogenesi,
- distribuzione dei vulcani,
- variazioni del chimismo delle rocce magmatiche,
- formazione di strutture come fosse oceaniche e archi insulari,
- distribuzione geografica di faune e flore fossili nelle ere geologiche.

Questo modello ha parzialmente inglobato la precedente teoria della ***deriva dei continenti***, di A. Wegener.



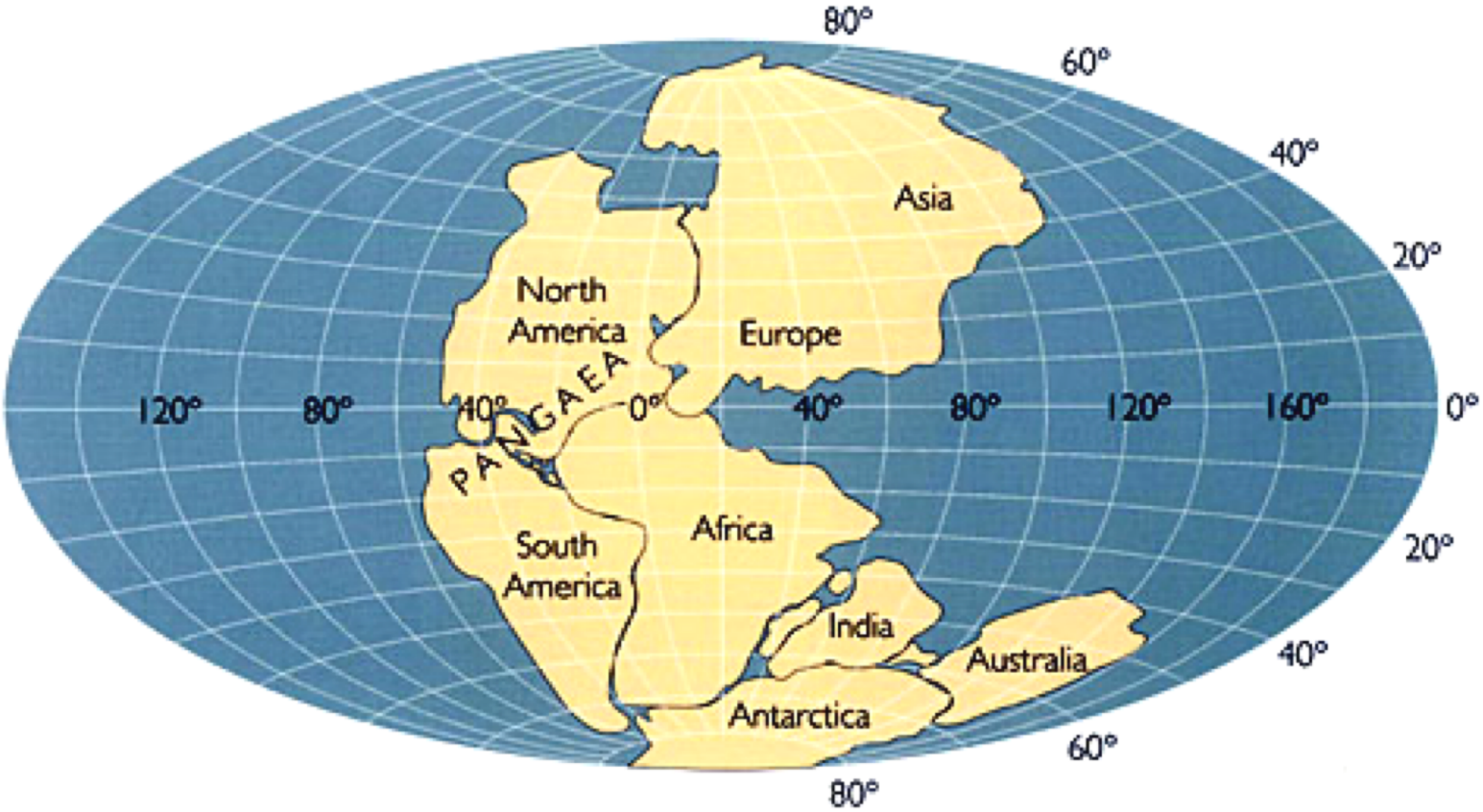
1915: Alfred Wegener nota la similitudine tra **rocce**, **strutture** e **fossili** di America Meridionale e Africa

⇒ vecchio "supercontinente" **Pangea** che si è fratturato in continenti più piccoli, che sono poi andati alla deriva

Il margine atlantico

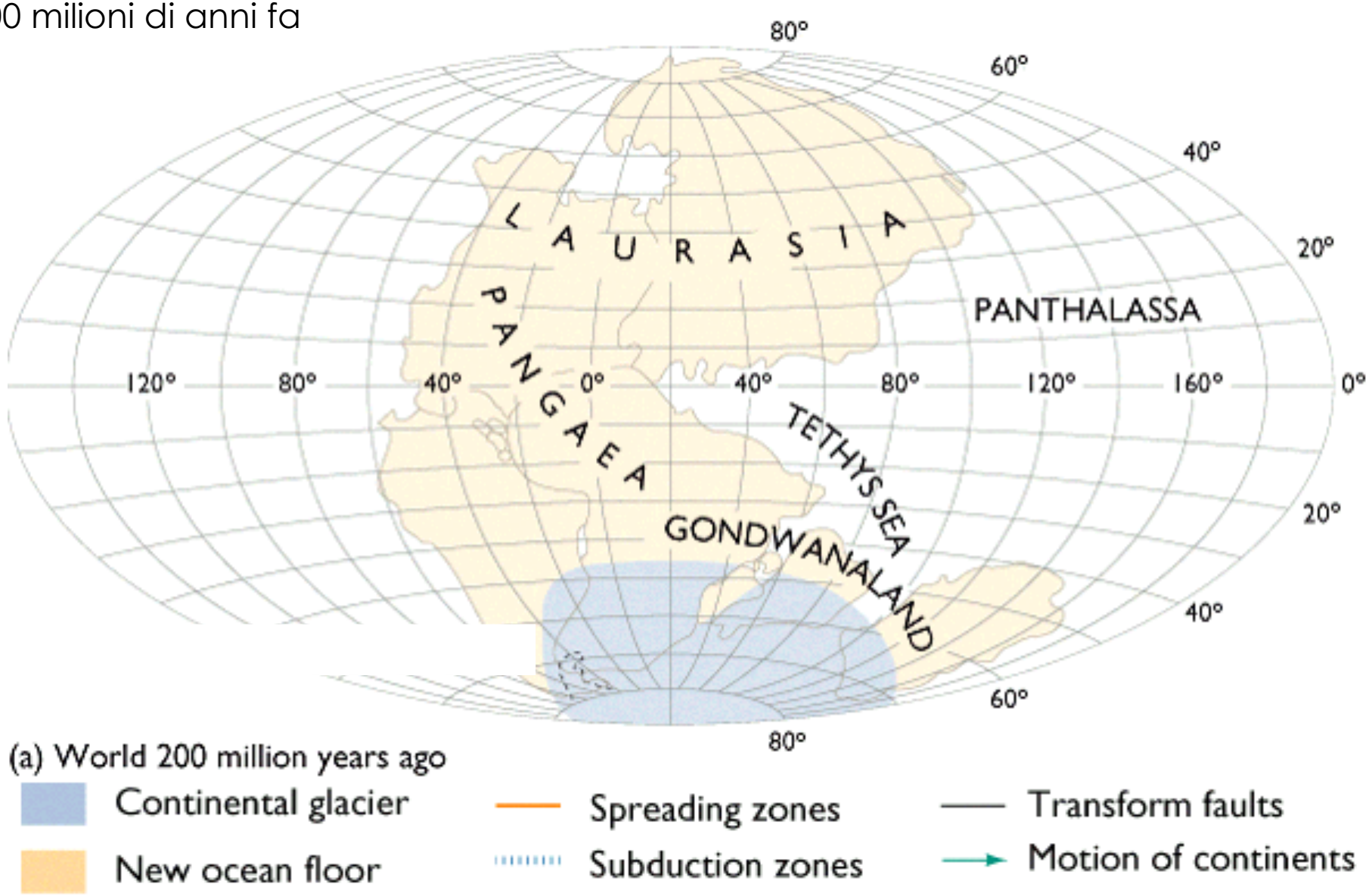
Evidenze

- **Strutture**, cratoni, geometrie
- **Rocce sedimentarie** (tipo e età)
- **Fossili** (diversi prima dell'accrezione, simili durante, e differenti dopo la separazione)
- Similitudini **paleoclimatiche** (glaciale)
- Evidenze della **scissione** (bacini di rift, vulcanismo CAMP)

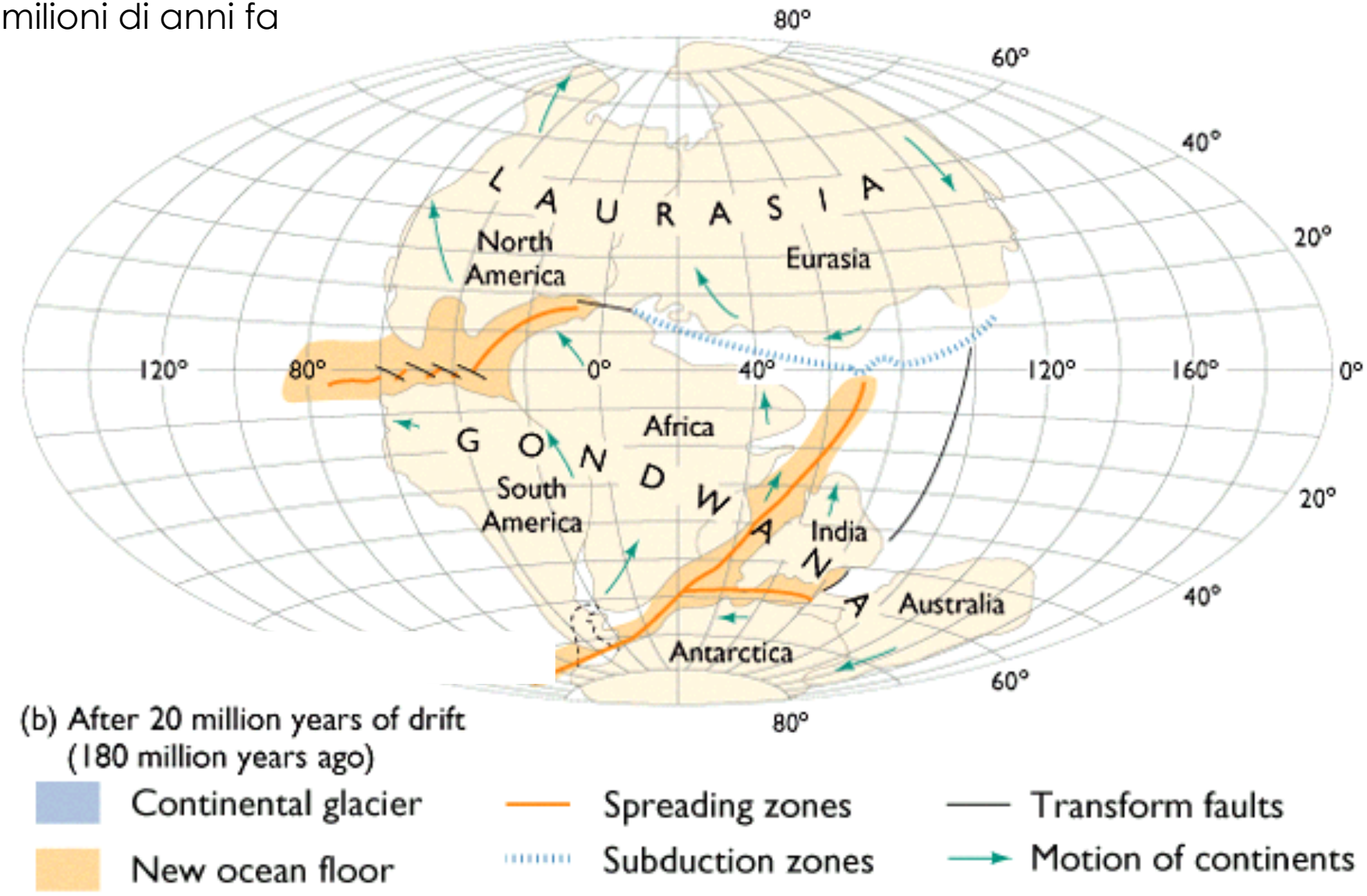


Nel Permiano (circa 225 Ma) i contineneti erano uniti a formare la **Pangea**, circondata dal **Mare della Panatalssa**

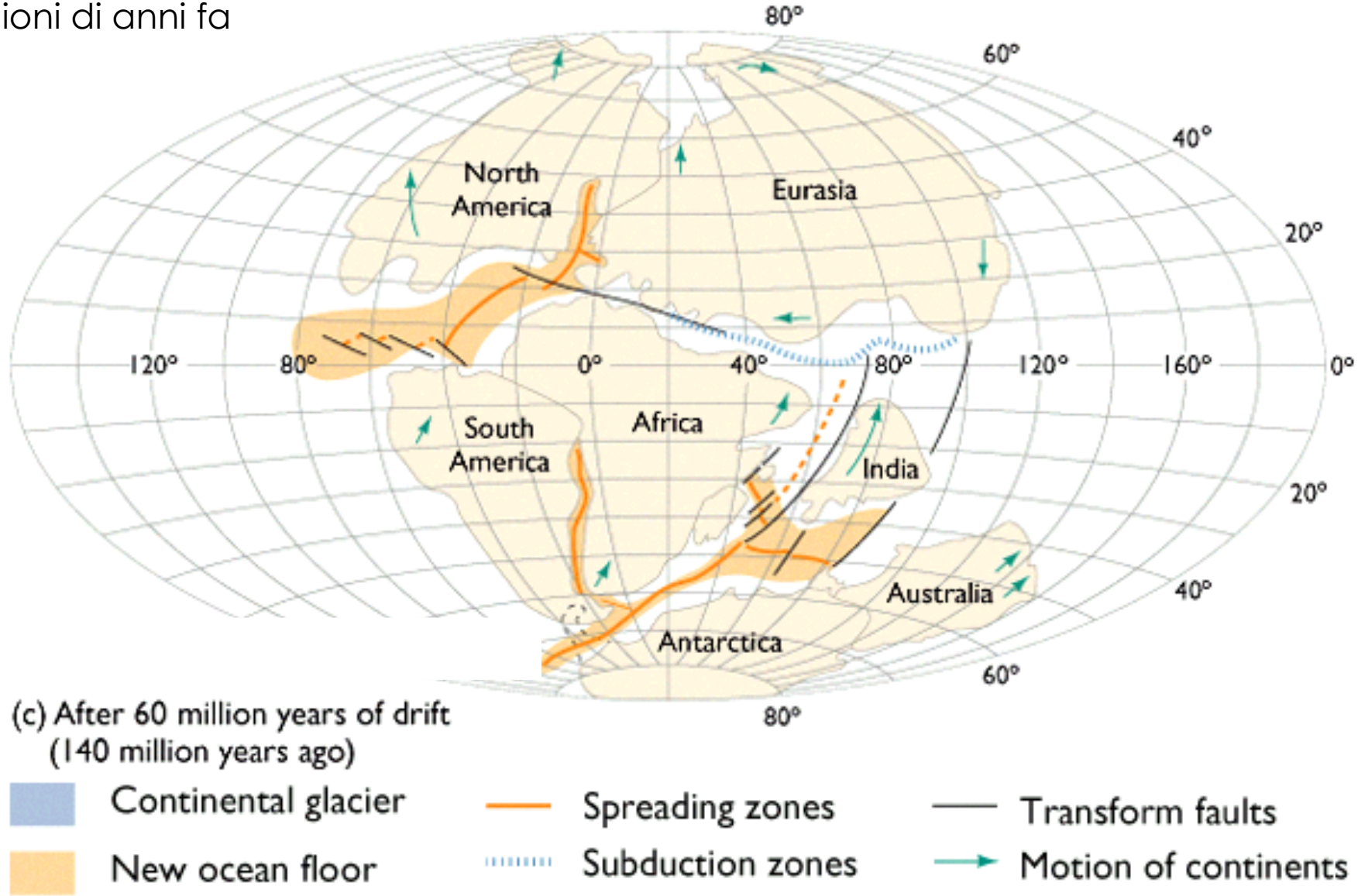
200 milioni di anni fa



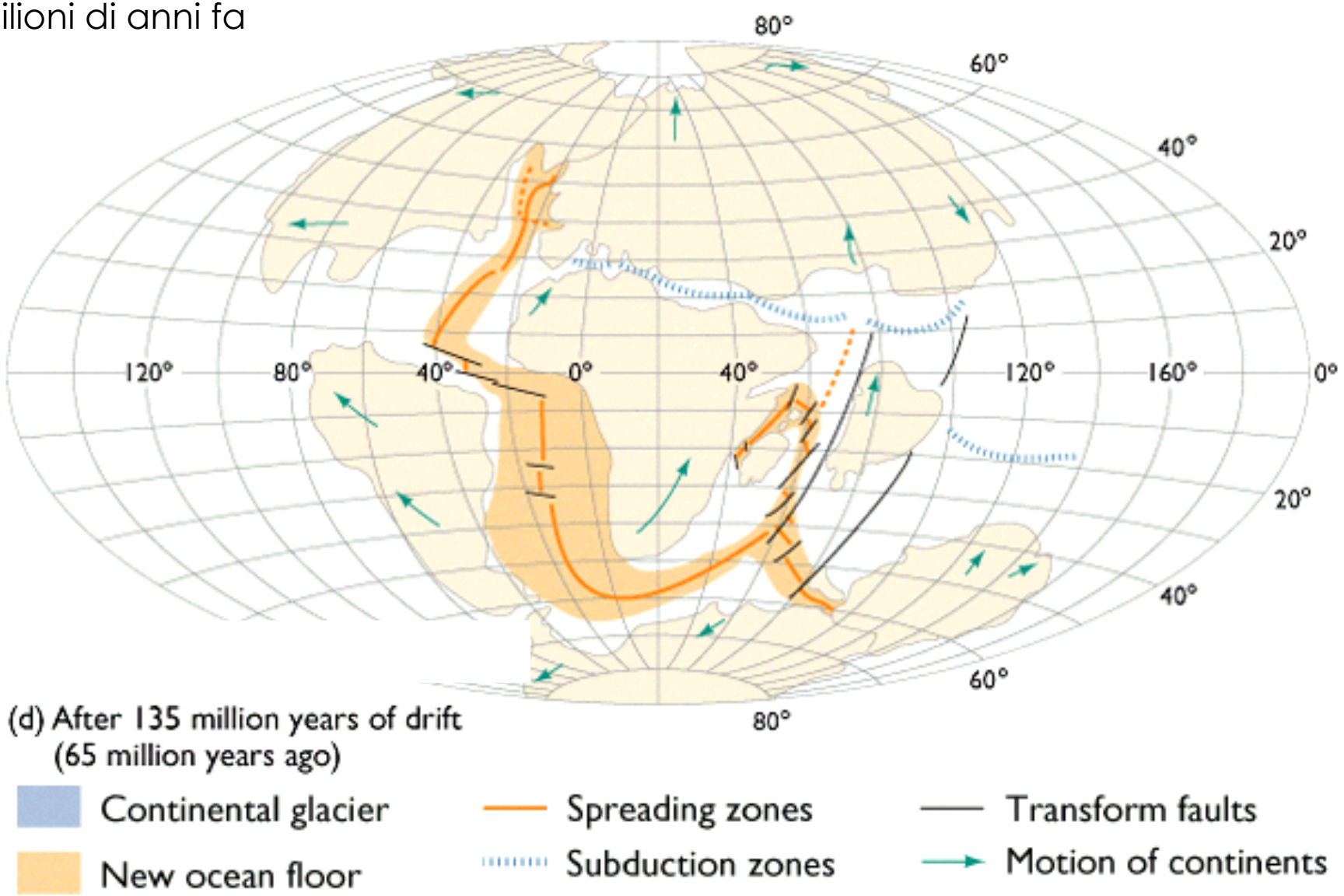
180 milioni di anni fa



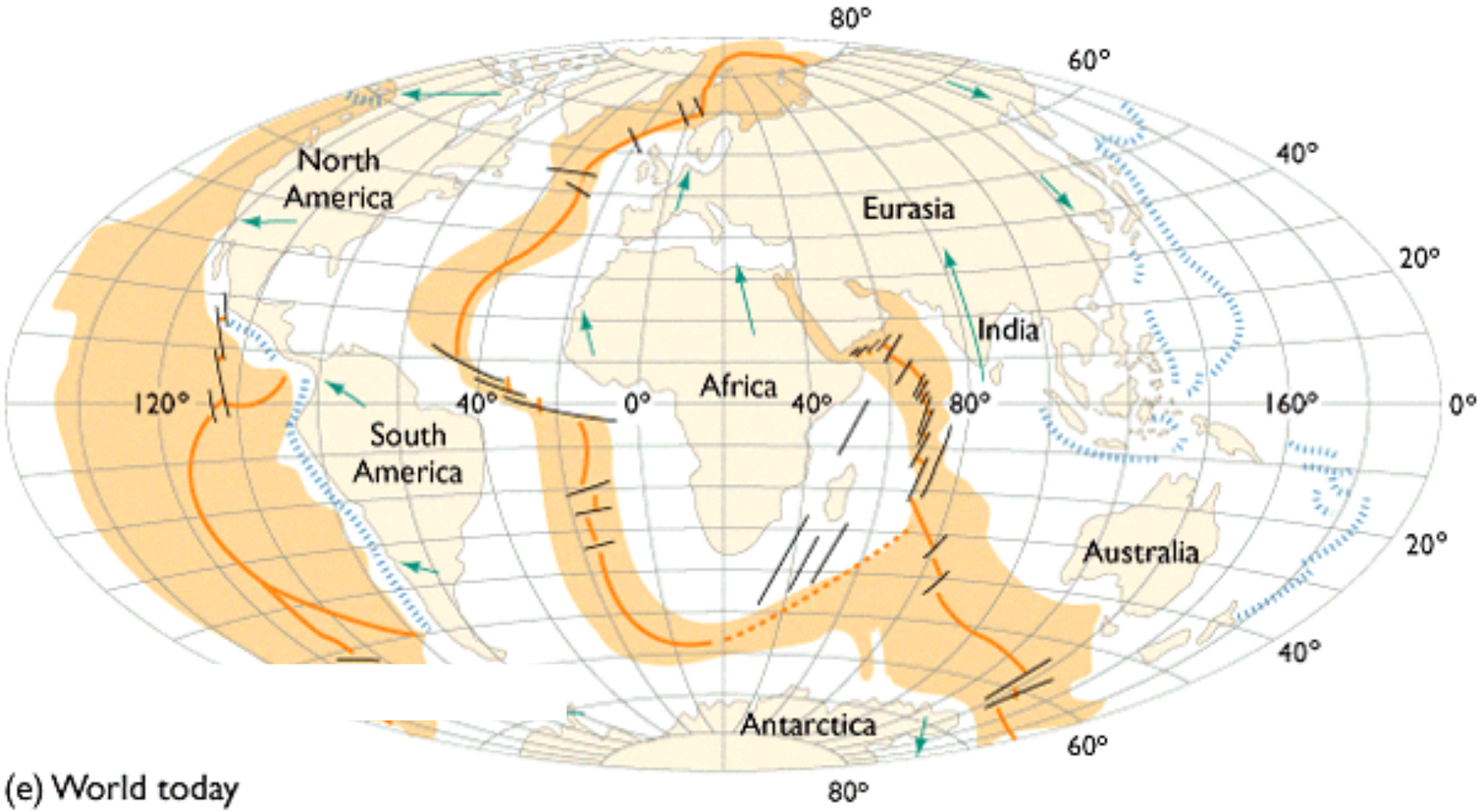
140 milioni di anni fa

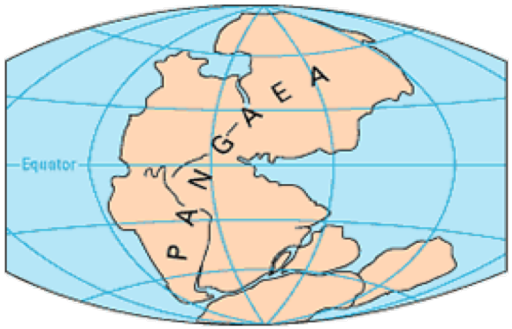


65 milioni di anni fa



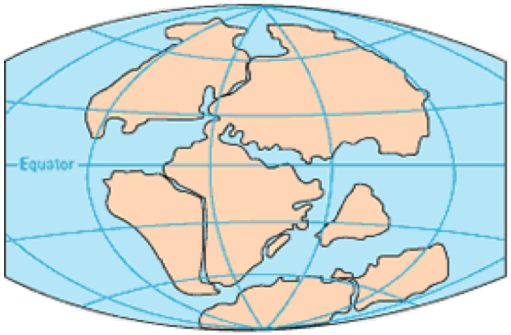
Oggi


80°
60°
40°
20°
0°
20°
40°
60°
80°
120°
40°
0°
40°
80°
160°
North America
Eurasia
India
Africa
South America
Australia
Antarctica
(e) World today
Continental glacier
New ocean floor
Spreading zones
Subduction zones
Transform faults
Motion of continents

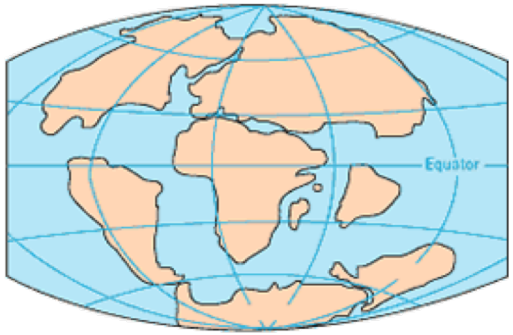


Permiano (225 Ma)

Triassico (200 Ma)



Giurassico (135 Ma)



Cretaceo (65 Ma)

PRESENT DAY

Cretaceo: separazione America meridionale e Africa

America settentrionale ed Europa mantengono un punto di contatto fino al Quaternario

Durante la deriva delle Americhe, ad occidente si forma la Cordigliera delle Ande per compressione

Una vasta area a nord dell'India si era corrugata verso nord (Himalaya).

Australia e Nuova Guinea si staccano dall'Antartide nell'Eocene e si spostano verso Nord.

Quali sono le forze motrici?

Wegener era molto incerto sulle forze che determinavano il movimento dei continenti.
"Il Newton della deriva non è ancora apparso. E' probabile che la soluzione completa del problema delle forze motrici sia ancora lontana.."

Ipotizza due possibili componenti:
- la forza di fuga dai poli: spiega movimento dei continenti verso Equatore

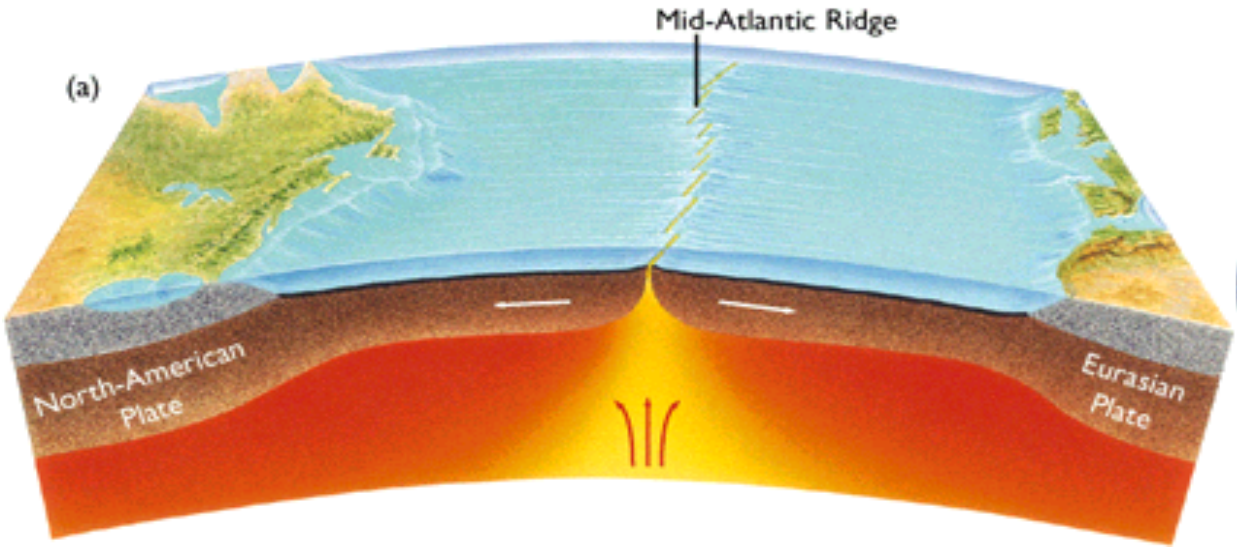
- la forza di "marea": per spiegare la deriva verso Ovest dei continenti americani.

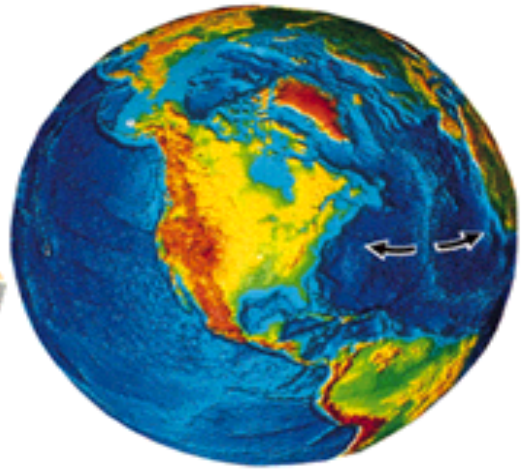
L'ipotesi di Holmes: tettonica delle placche

Teoria secondo al quale sul lato frontale delle placche si formassero montagne, mentre sul lato arretrato si formasse l'oceano.

Questo concetto era vicino a quello attuale con margini convergenti e divergenti.

Malgrado la sua ipotesi offrisse effettivamente la prima spiegazione per il movimento delle placche, Holmes la formulò come pura speculazione in attesa di conferma.





Nuove evidenze (1960)

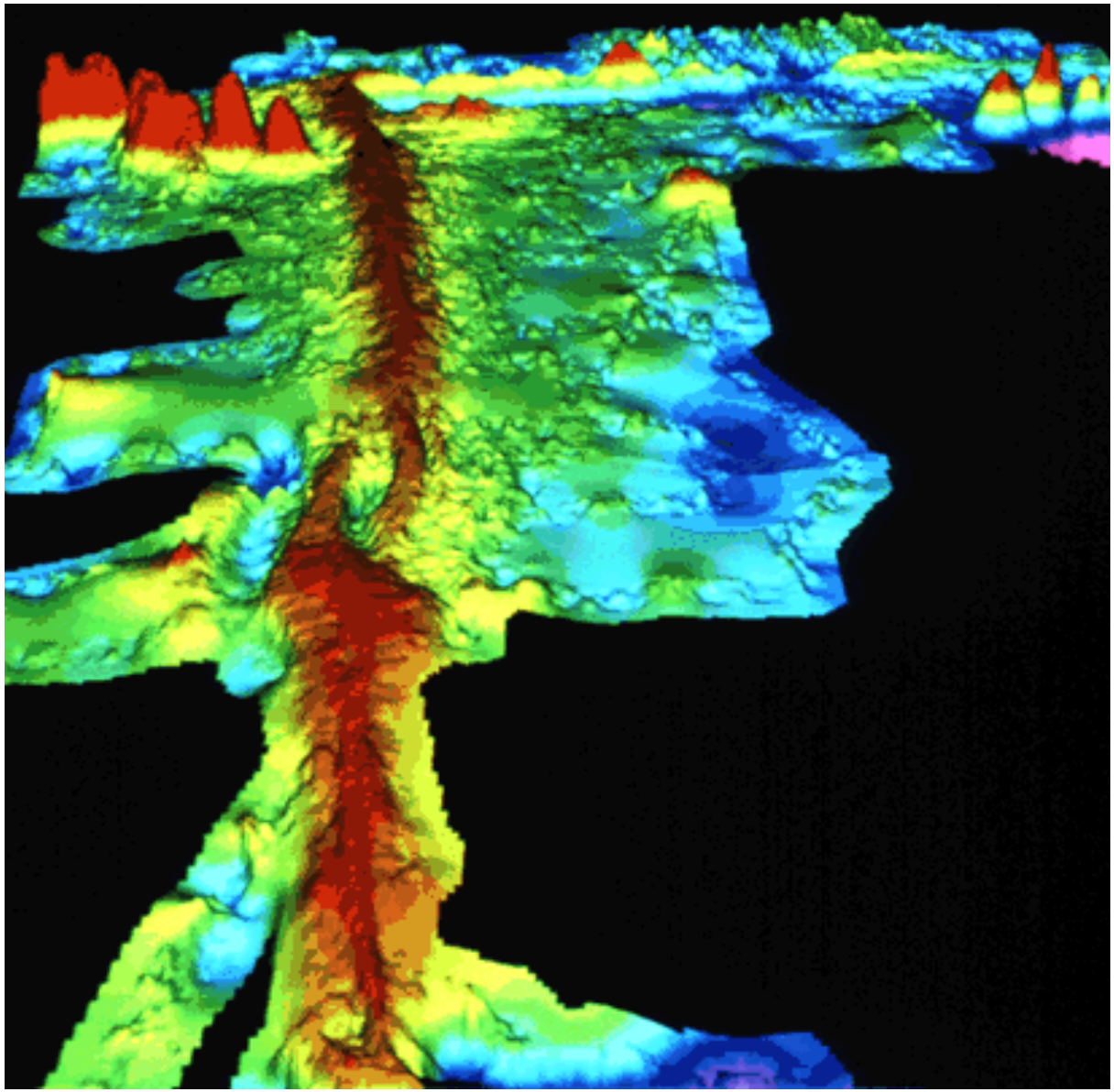
provenivano dal fondale oceanico…

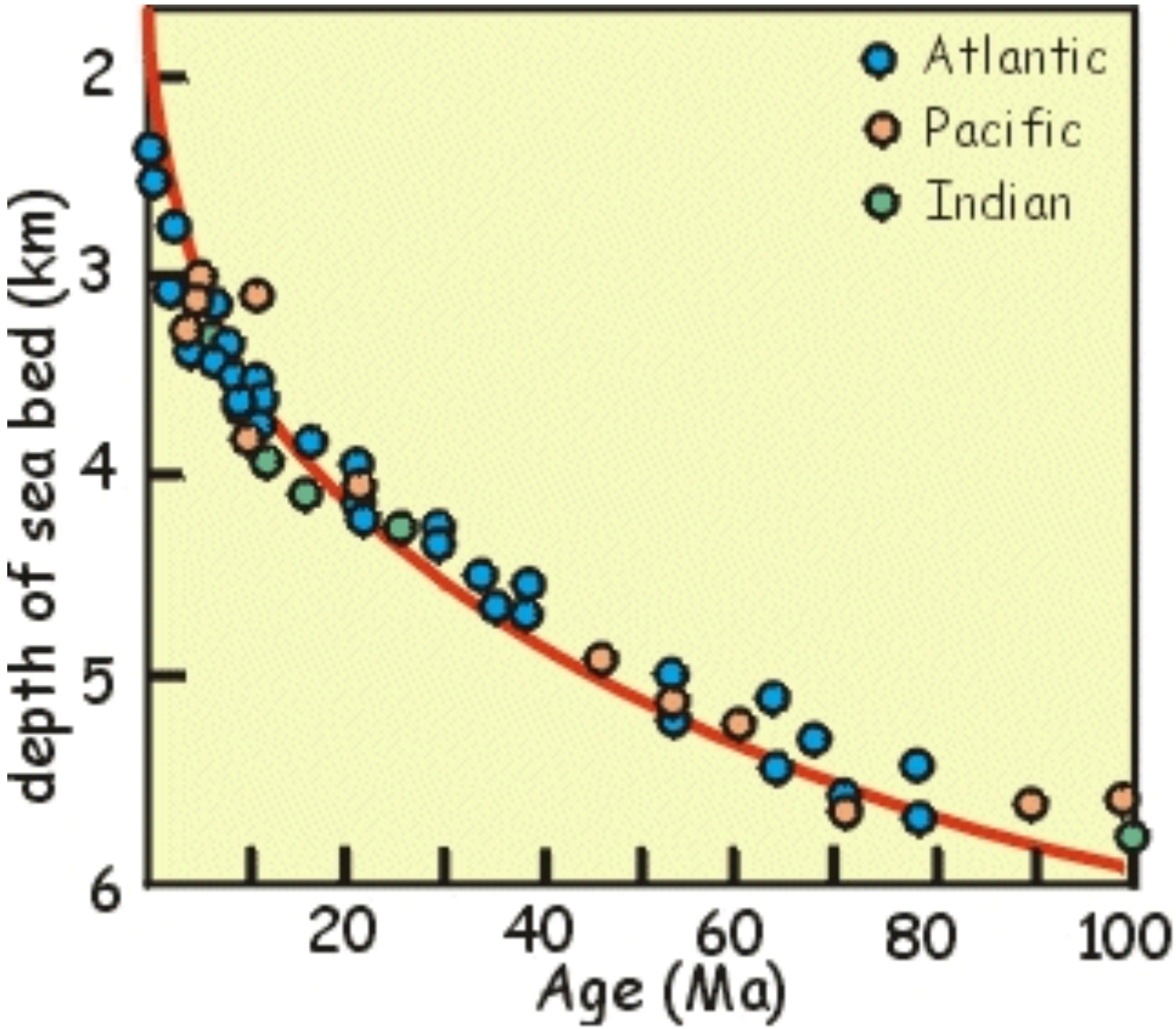
Una ***mappatura sistematica del fondale oceanico dell'Atlantico*** mise in evidenza una catena montuosa (*dorsale*) medio-oceanica con una valle centrale (*rift valley*) dislocata da faglie trasformi laterali.

Harry Hess e Robert Dietz suggerirono quindi che il fondale oceanico si stesse separando lungo il rift della catena medio-oceanica (*Seafloor Spreading, espansione del fondale oceanico*)

Deep-Sea Drilling Project (DSDP)

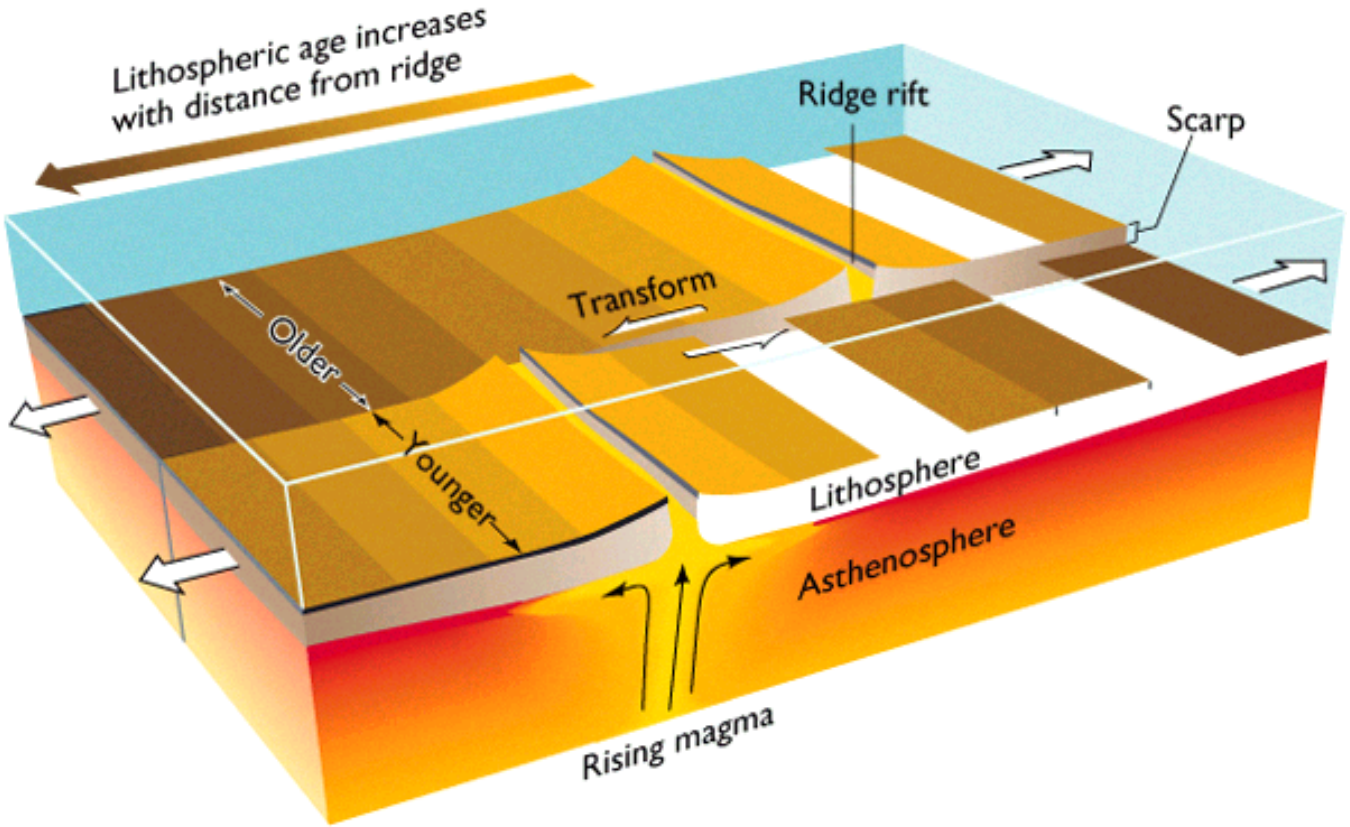
Ocean Drilling Project (ODP)




Atlantic
Pacific
Indian
depth of sea bed (km)
2
3
4
5
6
20
40
60
80
100
Age (Ma)

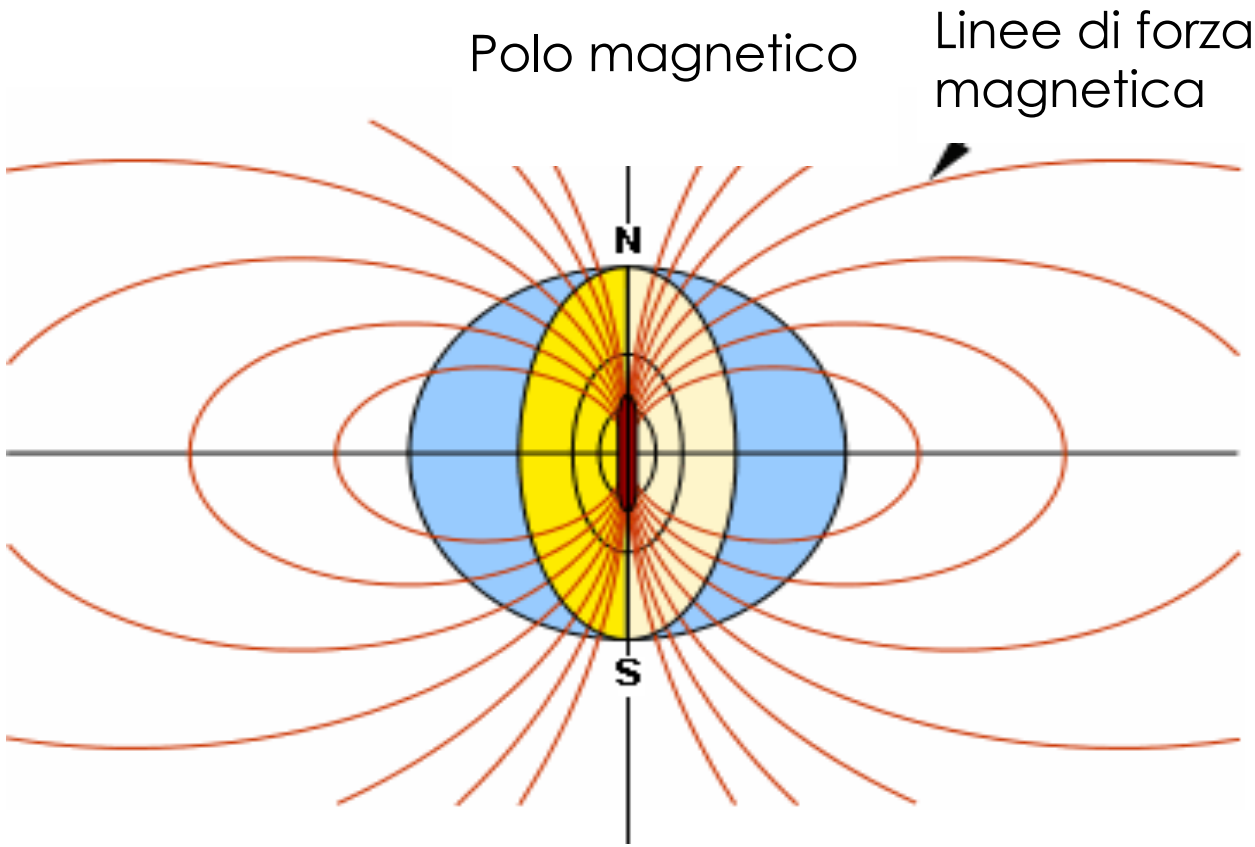
Anomalie magnetiche e trascorrenza

1967: J.T. Wilson incorporò il concetto delle ***anomalie magnetiche*** registrate nei fondali oceanici e la ***trascorrenza laterale*** delle dorsali medio oceaniche lungo le faglie trasformi in un elegante modello che ulteriormente confermava l'espansione dei fondali oceanici.

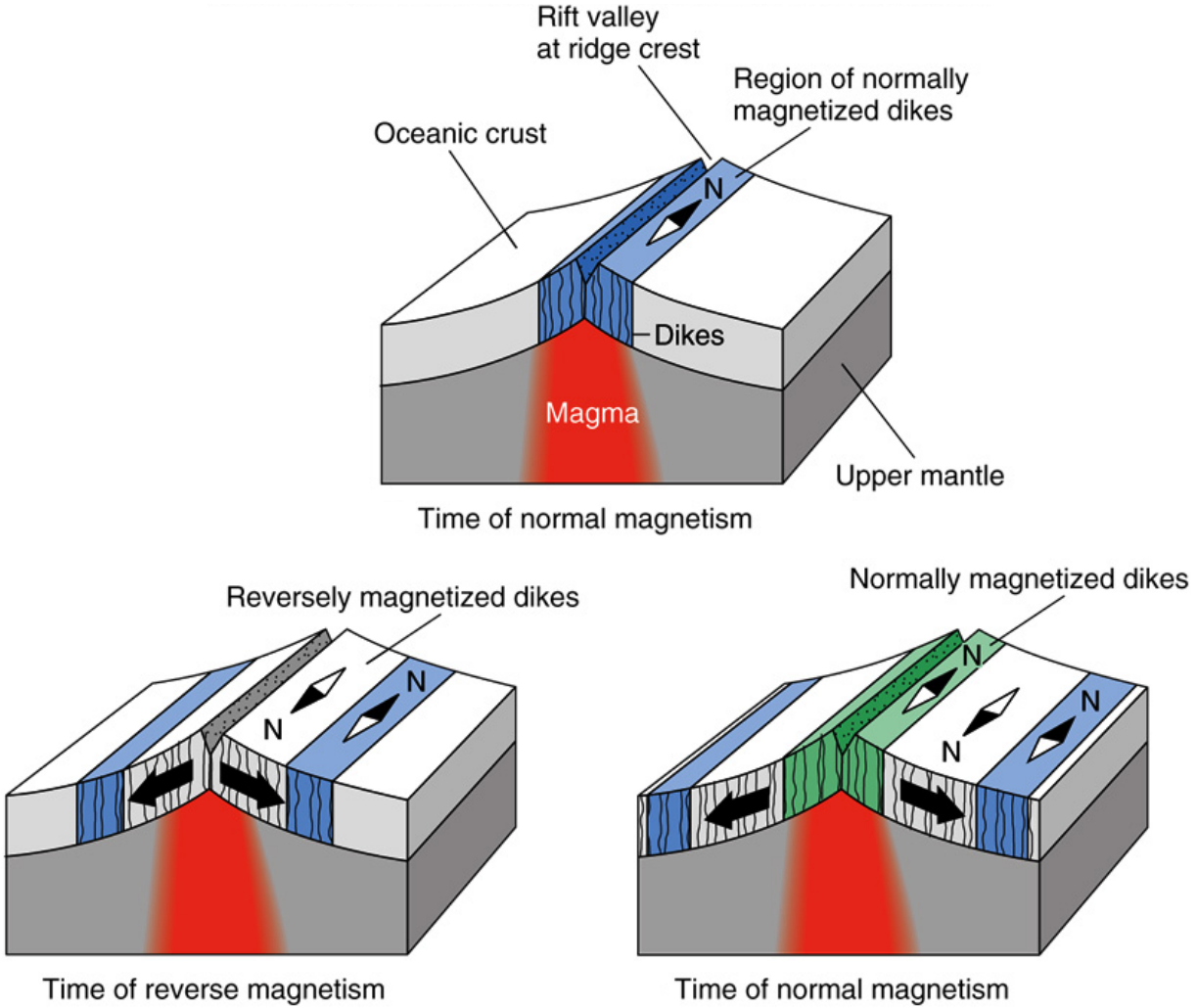


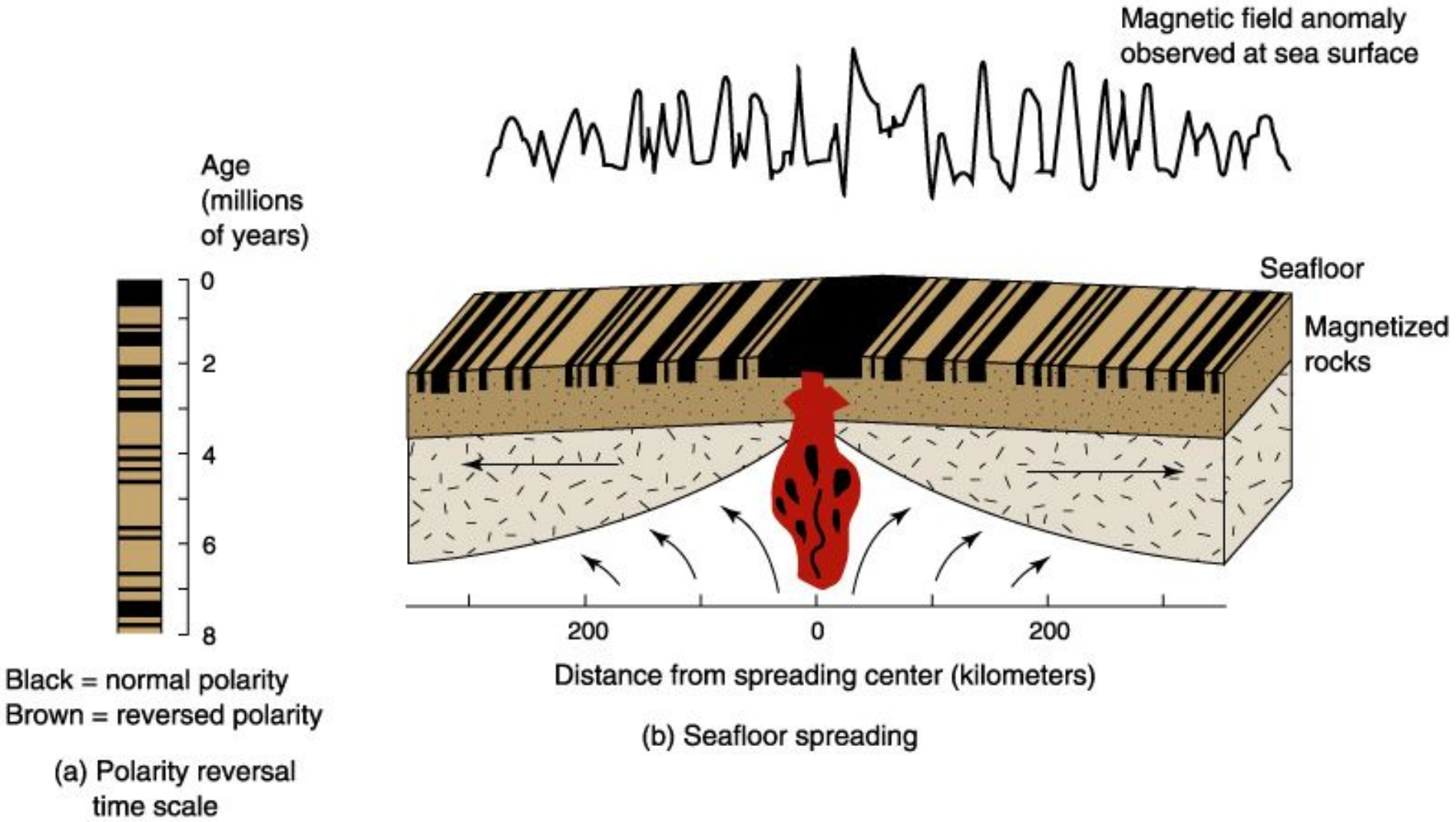
Le inversioni magnetiche

Nel tempo il campo magnetico terreste varia la sua polarità
Le rocce registrano, quando si formano, il campo magnetico terrestre



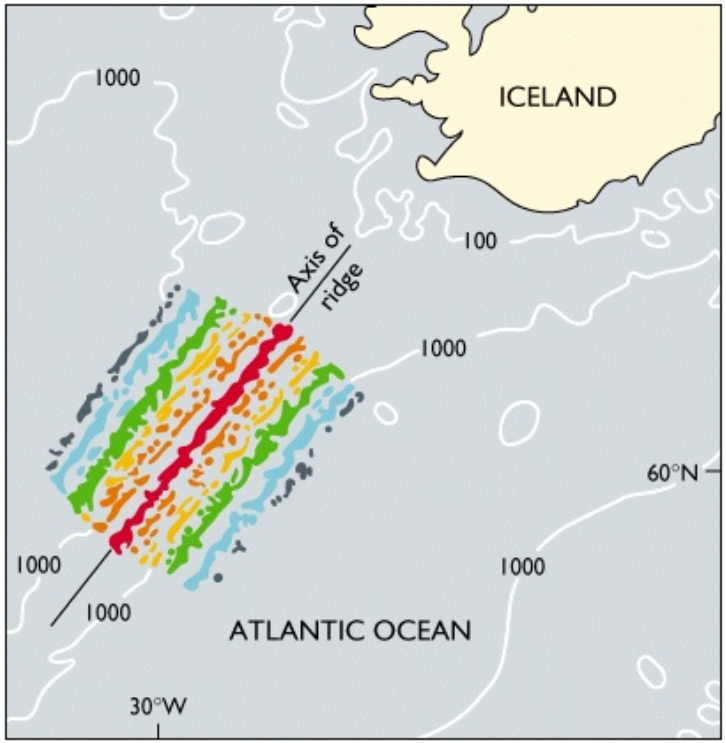
Le inversioni magnetiche

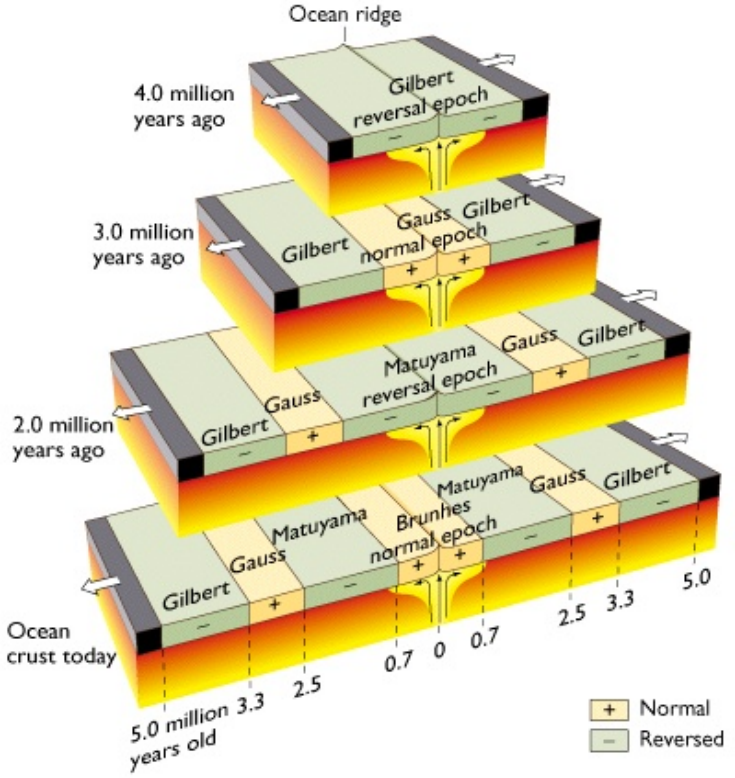



Age
(millions
of years)
0
2
4
6
8
Black = normal polarity
Brown = reversed polarity
(a) Polarity reversal
time scale
Magnetic field anomaly
observed at sea surface
Seafloor
Magnetized
rocks
200
0
200
Distance from spreading center (kilometers)
(b) Seafloor spreading

Lineazione magnetica dei fondi oceanici

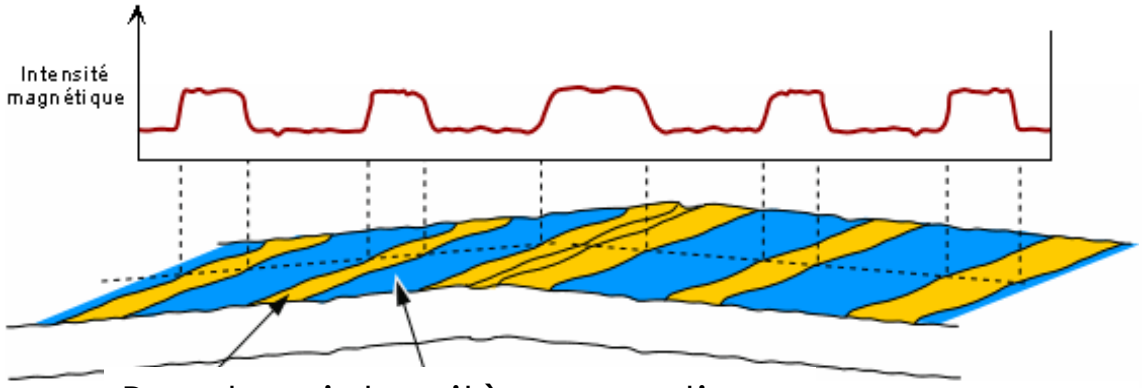
Quando la crosta oceanica si forma, essa acquisisce il campo magnetrico vigenete in quel momento. Il pattren di inversione magnetica, desunto da studi magnetostrtigrafici, può essere letto come una lineazione simmetrica attorno alla dorsale mediooceanica, a dimostare l'apertura degli oceani e la loro velocità di espansione.



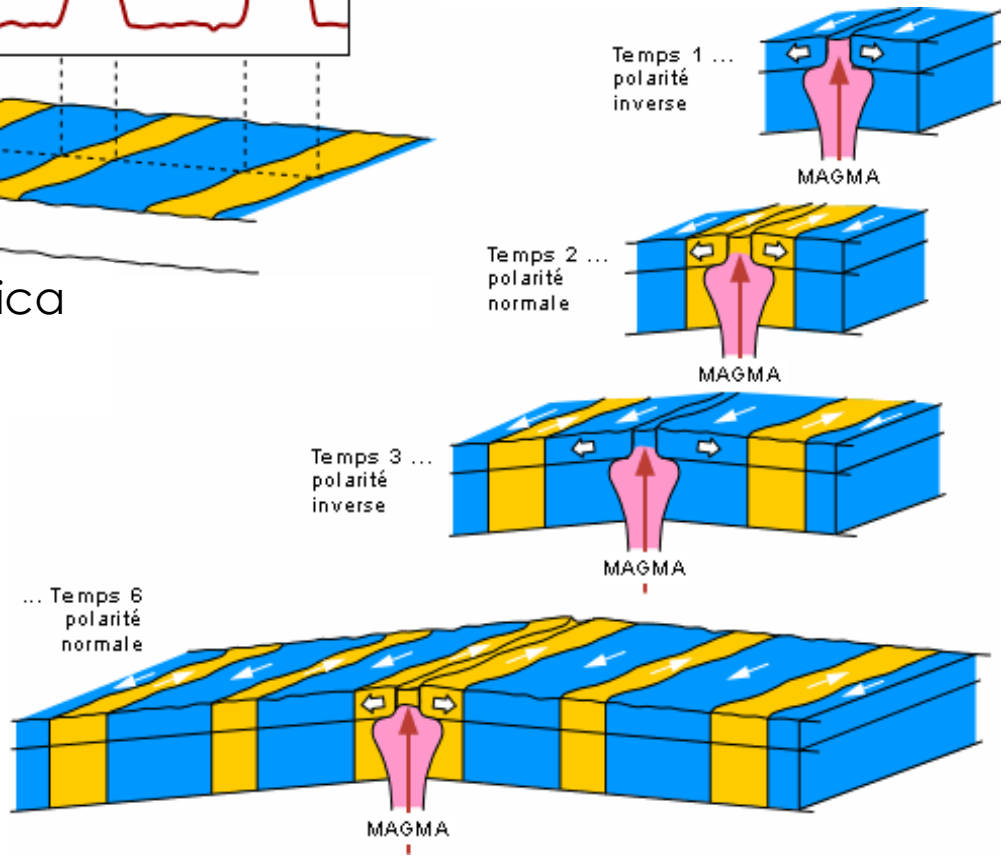


Le variazioni magnetiche dei fondi oceanici

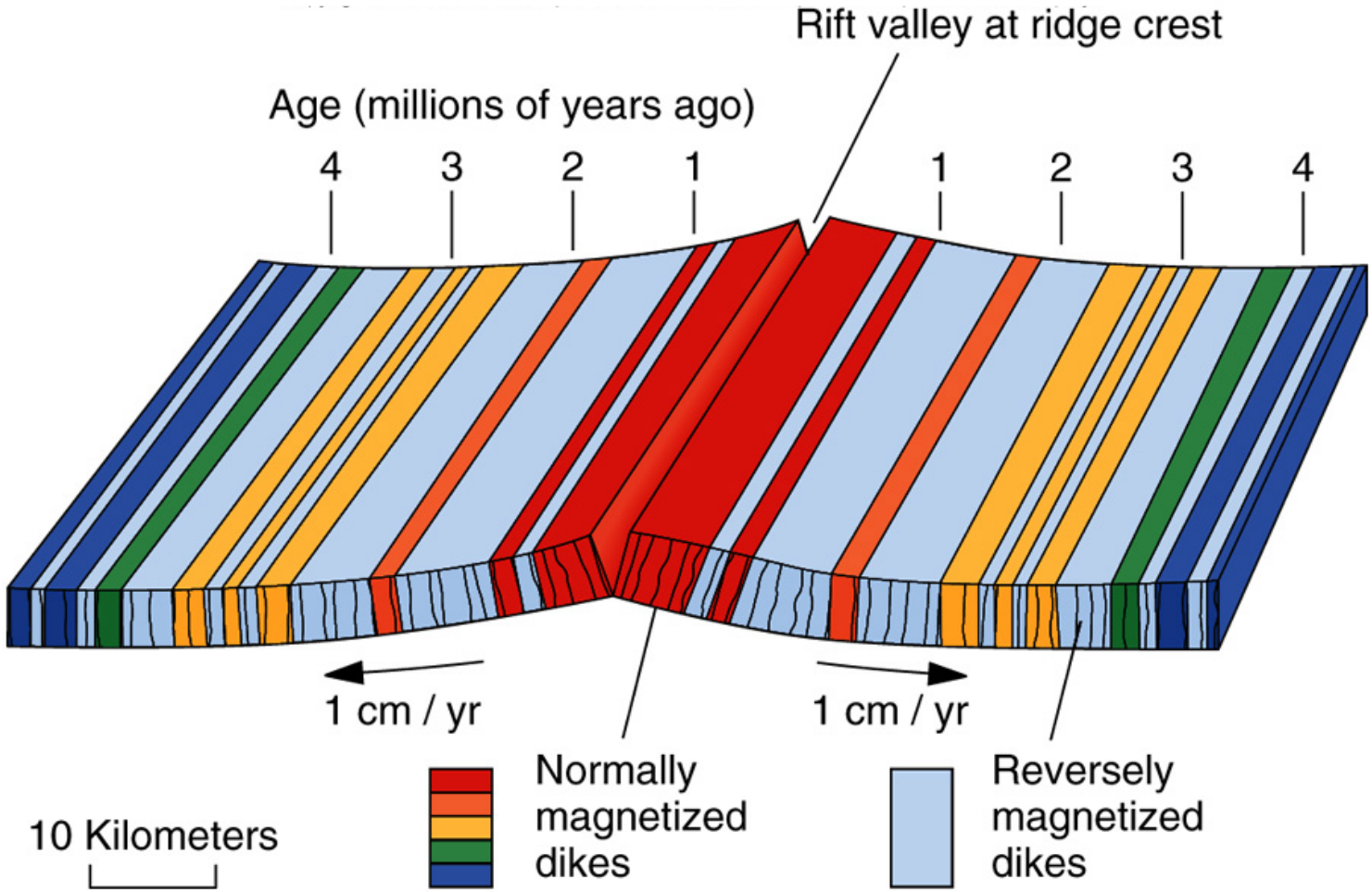
Intensità magnetica



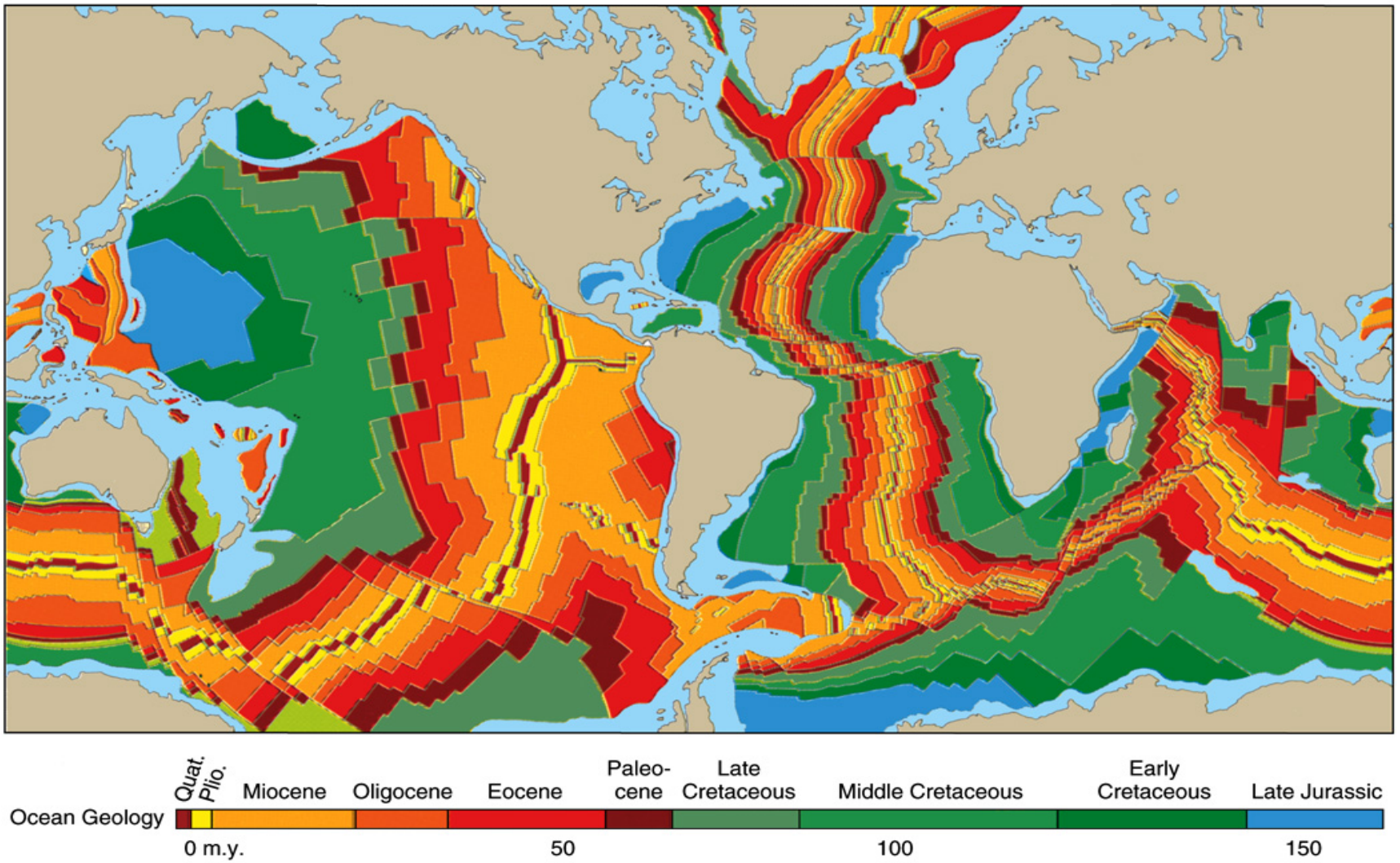
Bande a intensità magnetica diversa



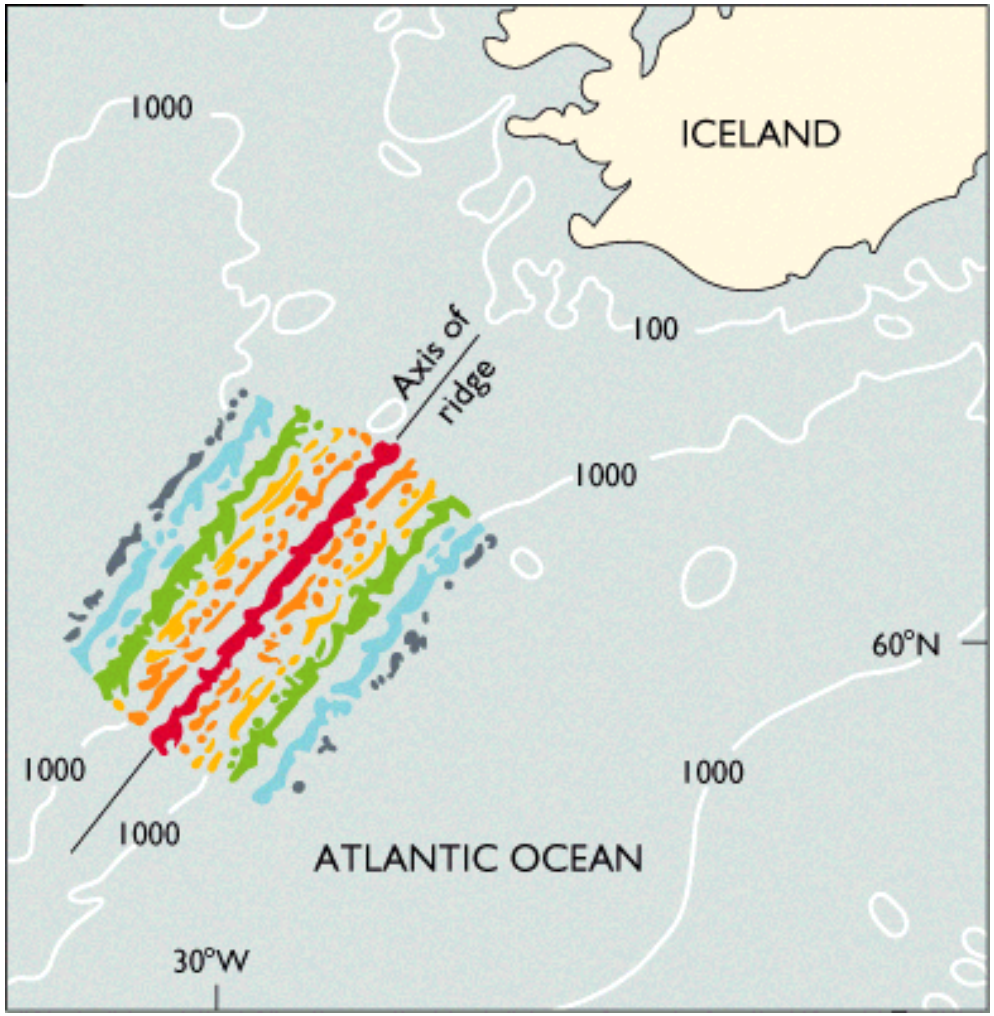
Età della crosta oceanica



Età dei fondi oceanici

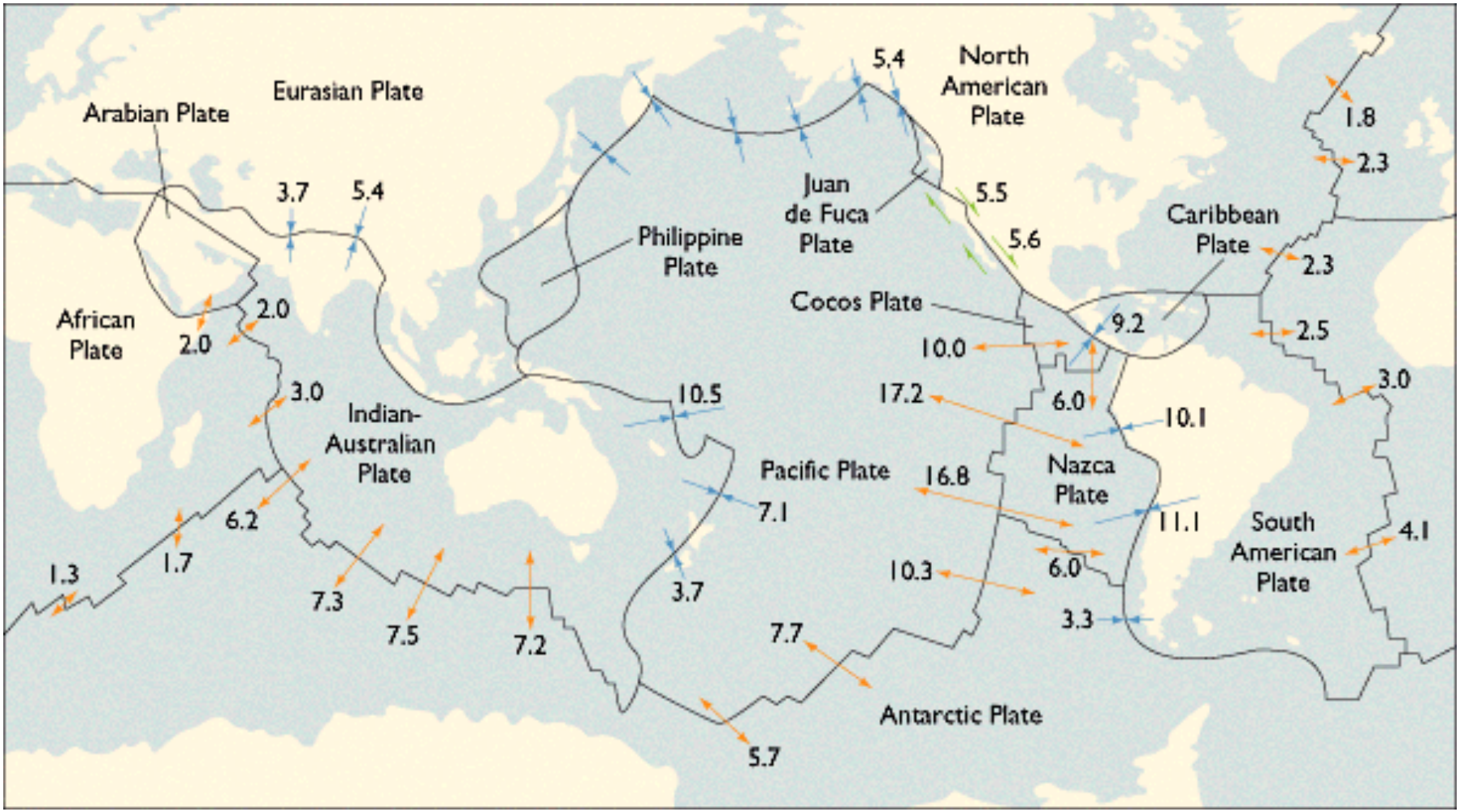


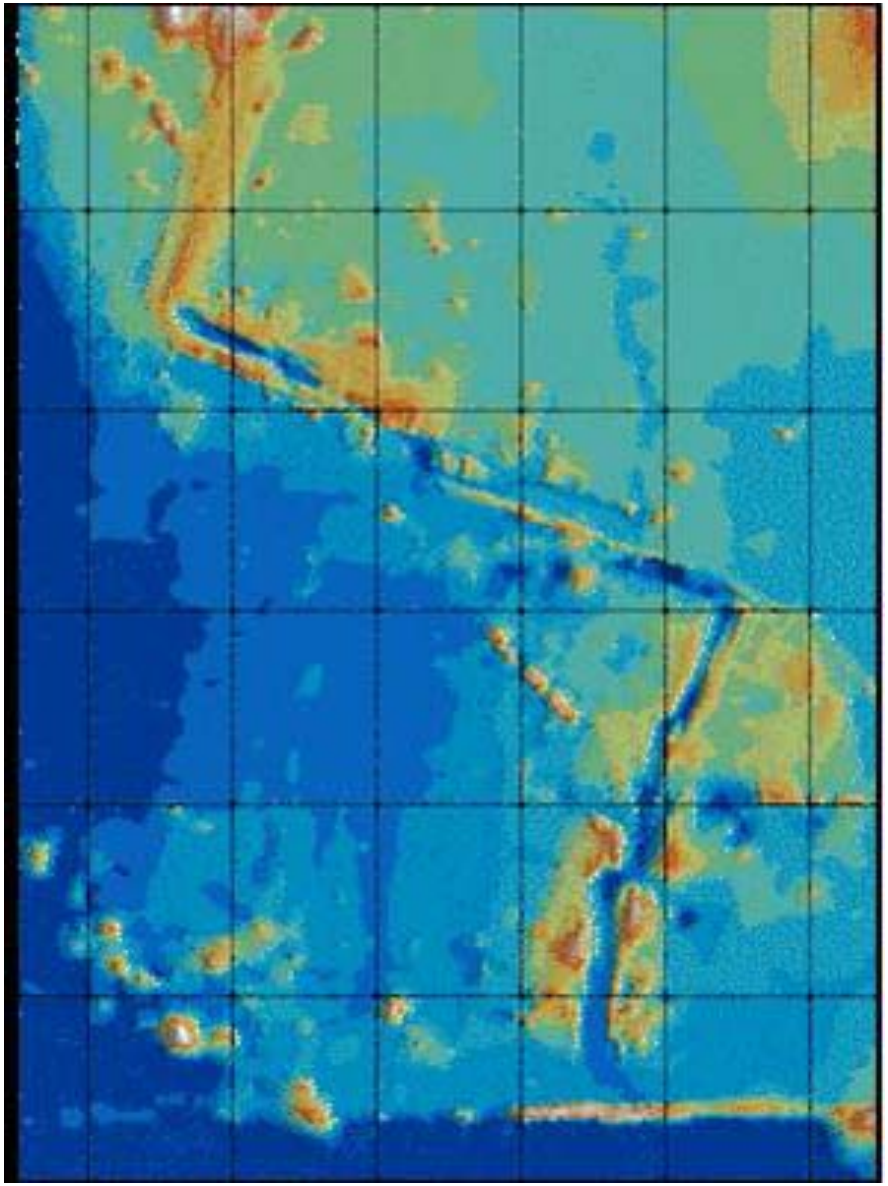
Velocità relativa delle placche



La velocità può essere stimata dalla ***datazione assoluta*** delle inversioni magnetiche e ***l'estensione delle corrispondenti fasce*** basaltiche simmetriche nei fondali oceanici

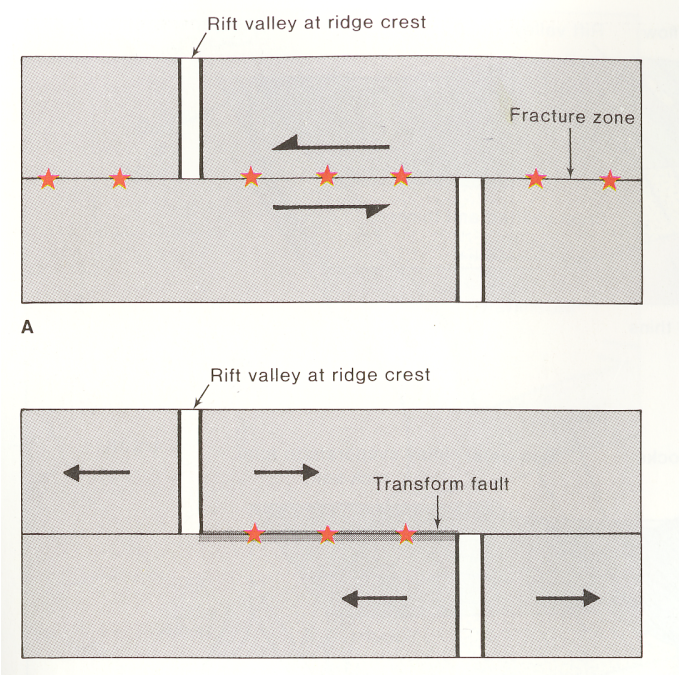
Velocità relative dei movimenti delle placche (centimetri/anno)



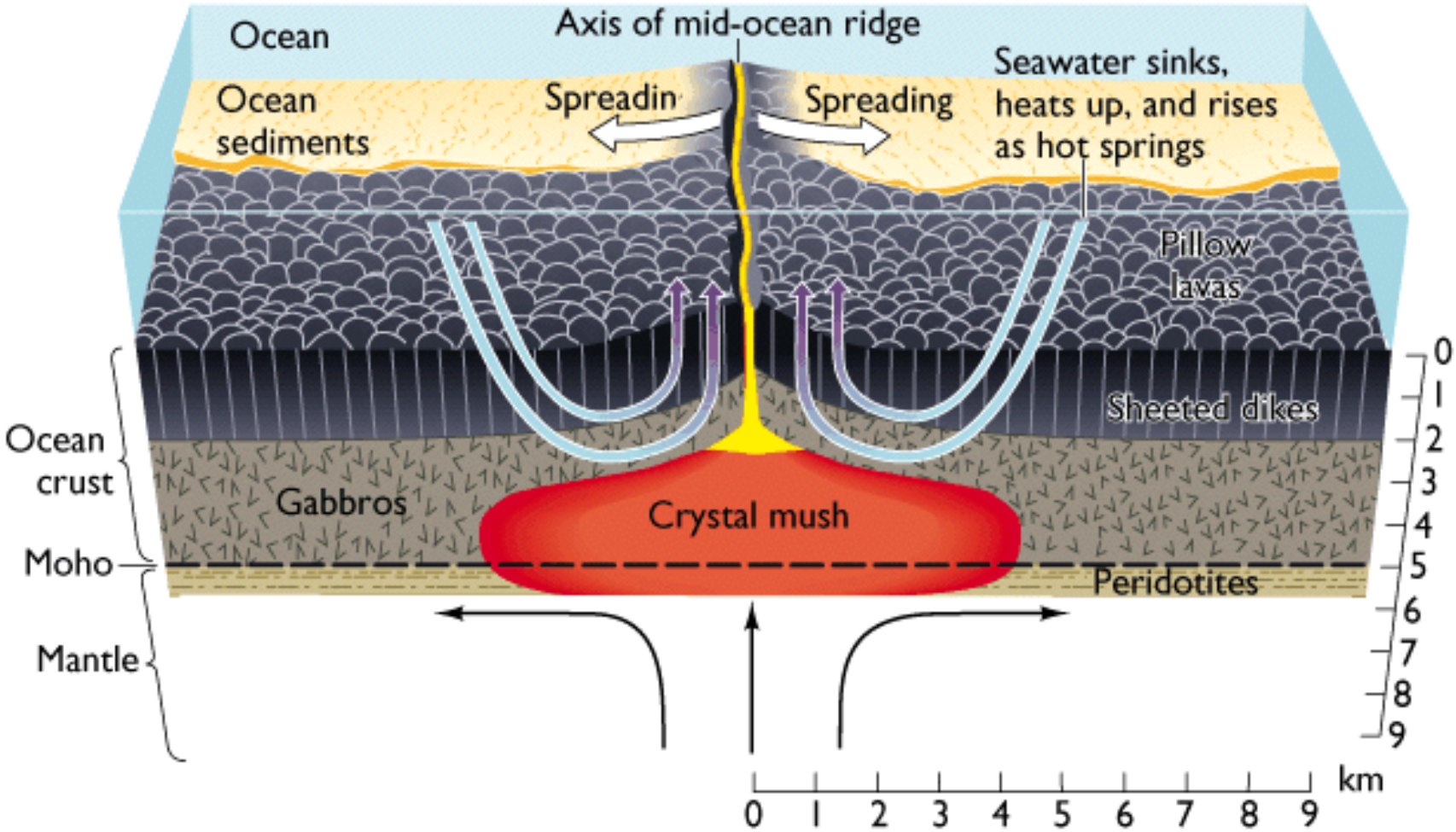


Faglie trasformi

Sono dei margini conservativi che si formano dove due palcche scivolano parallelamente tra loro
Normalemnete sono caratterizzate da scarsa attività sismica e vulcanica

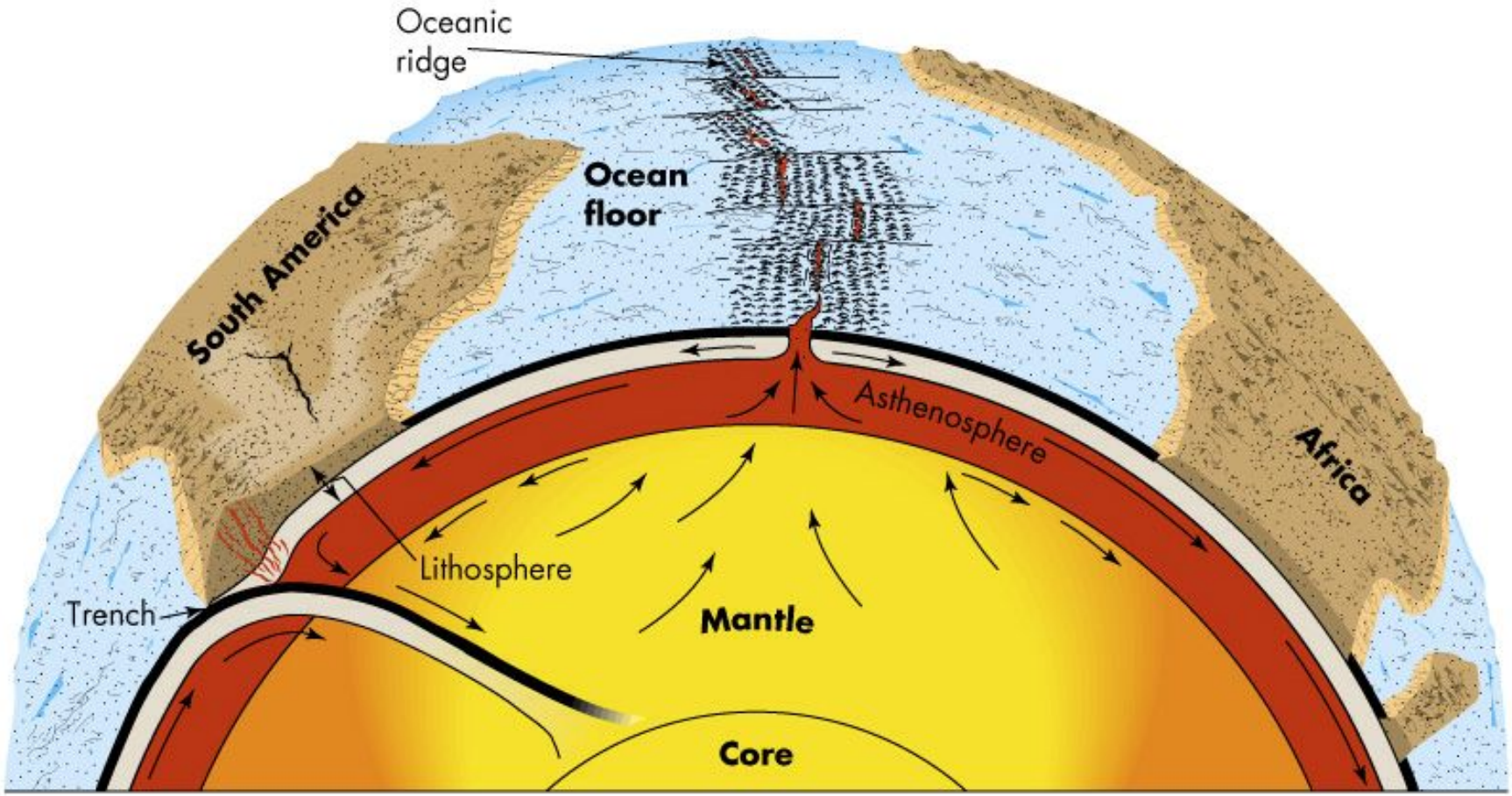


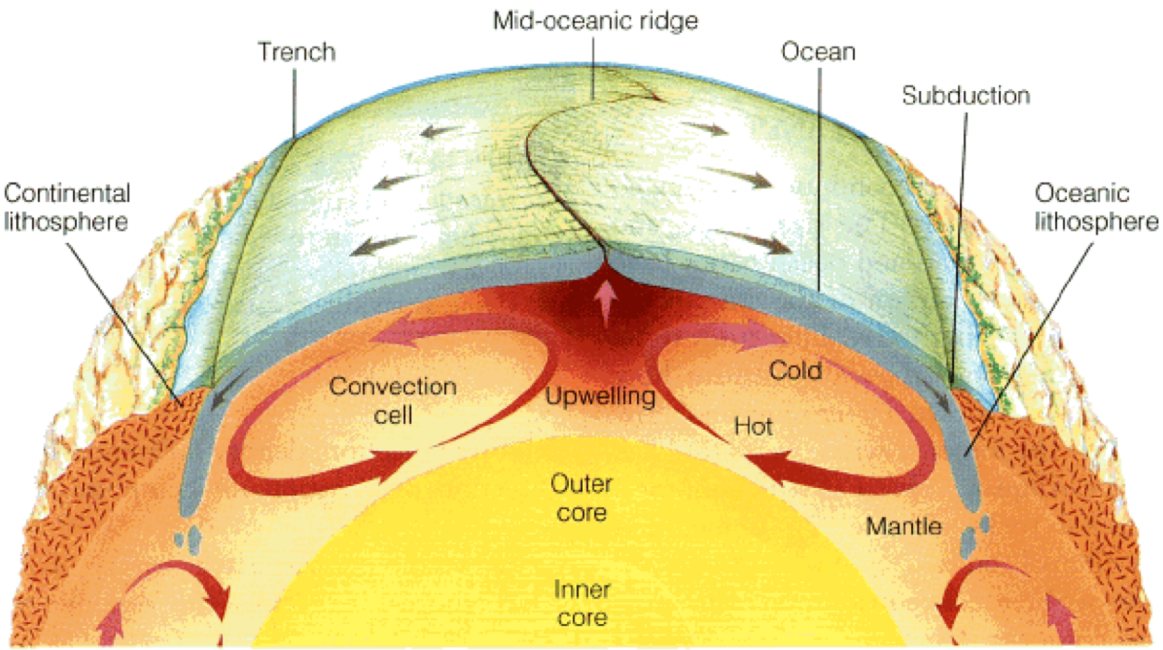
Strutture delle dorsali medio-oceaniche

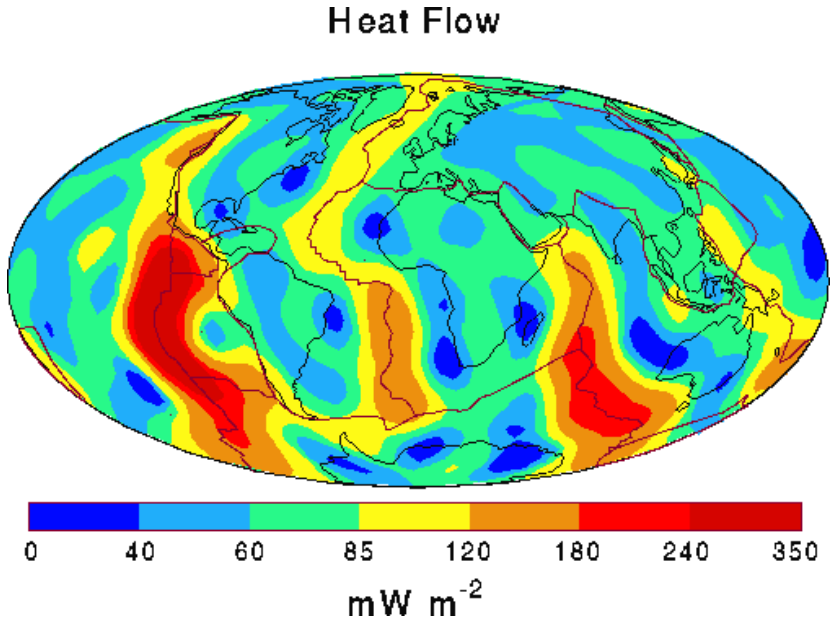


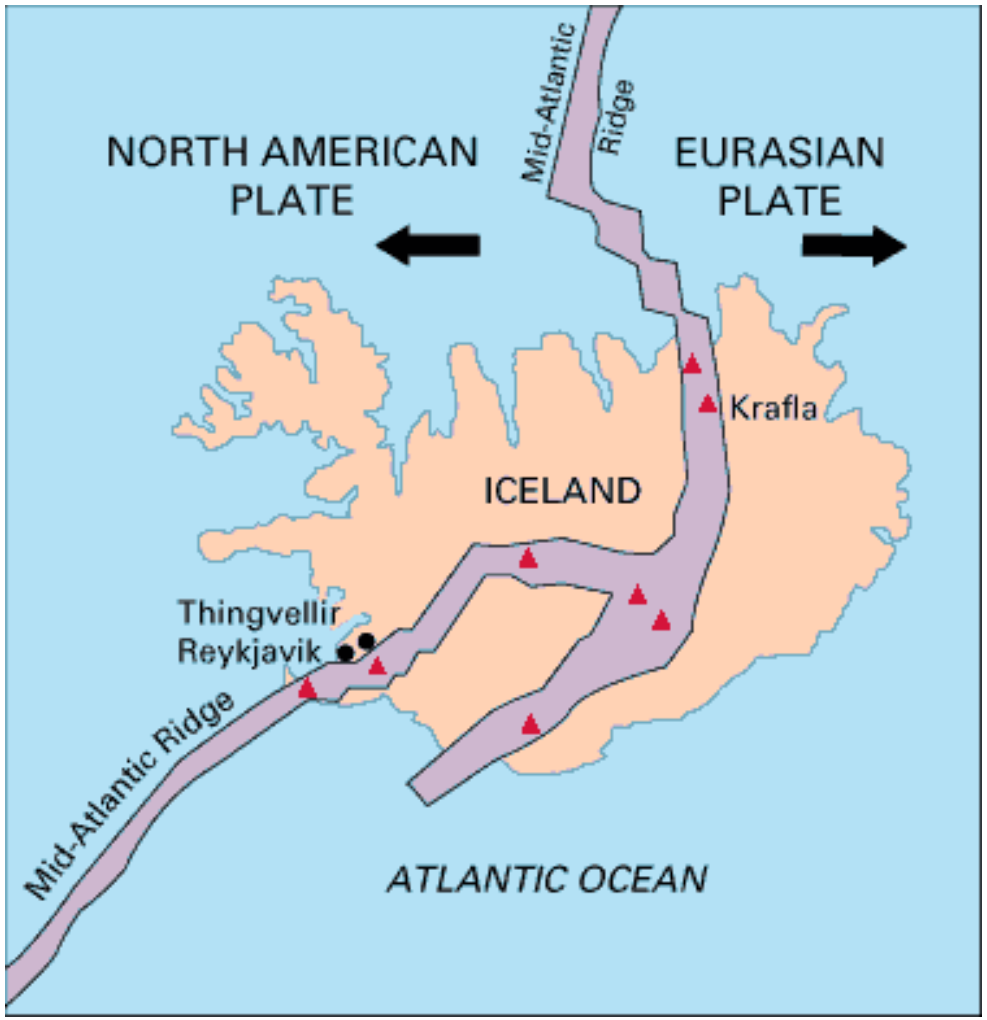
Quale è il motore?

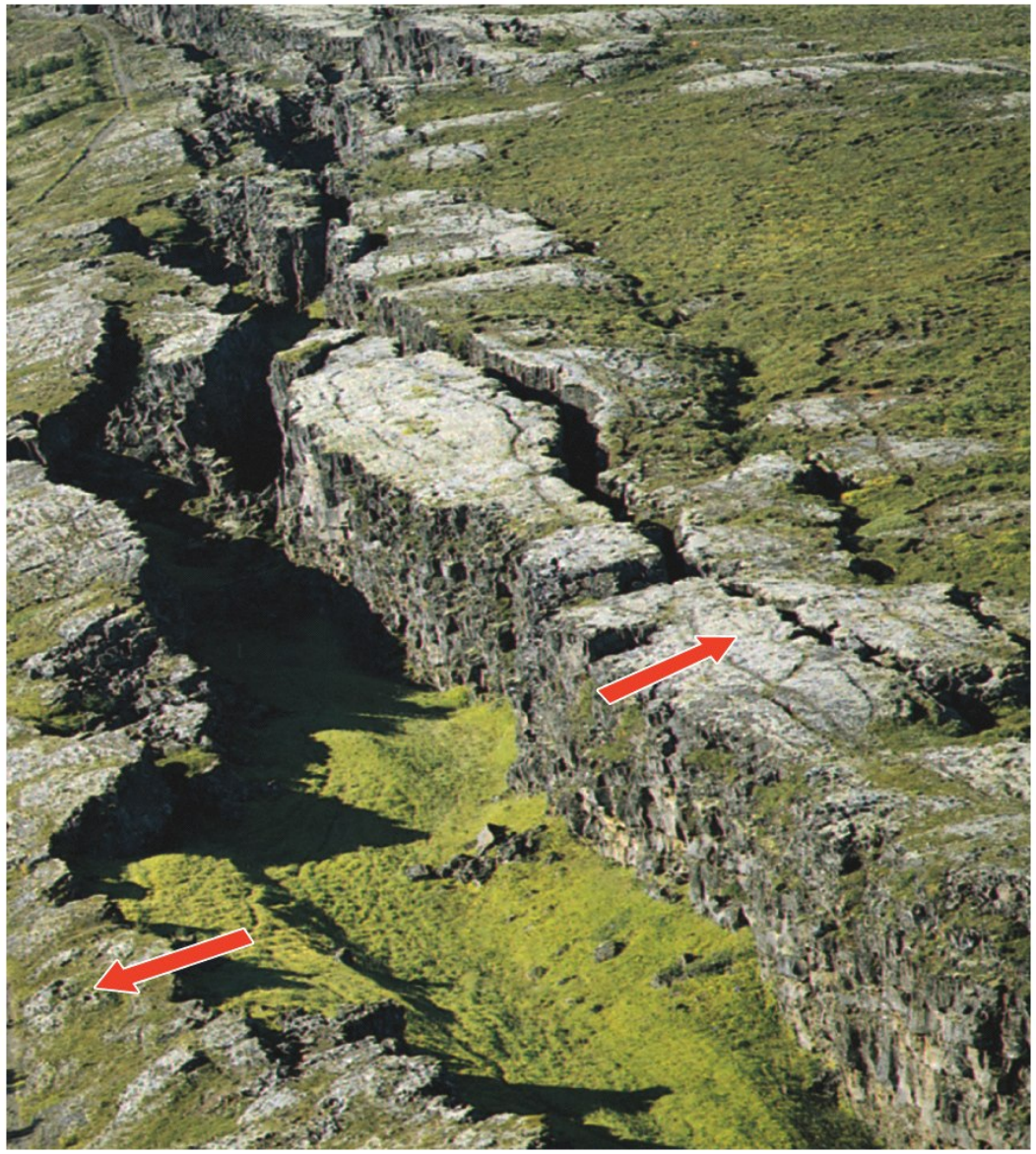
Movimenti convettivi nel mantello superiore

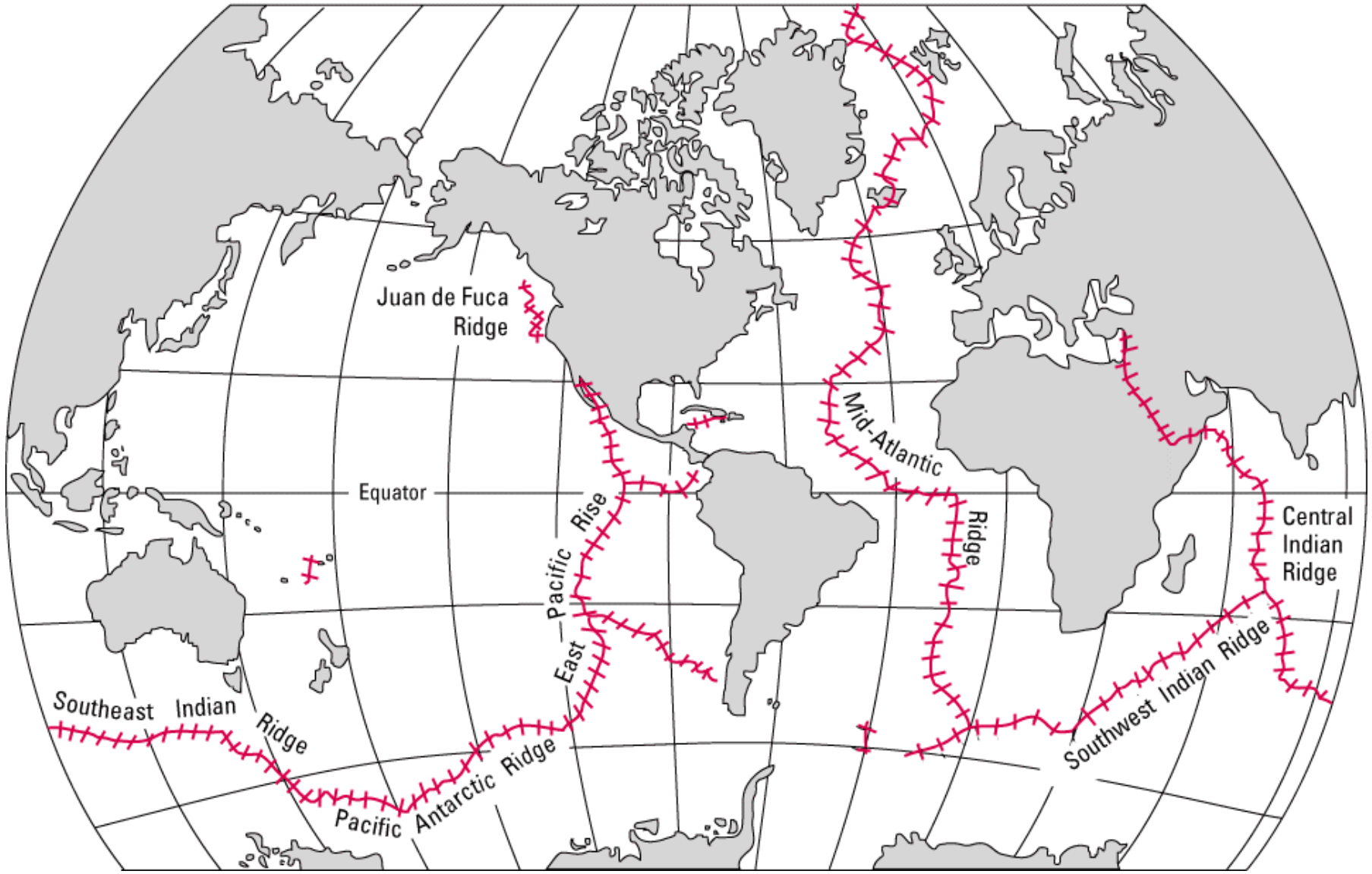



Mid-oceanic ridge
Trench
Ocean
Subduction
Continental lithosphere
Oceanic lithosphere
Convection cell
Upwelling
Cold
Hot
Outer core
Mantle
Inner core


Heat Flow
0
40
60
85
120
180
240
350
mW m-2

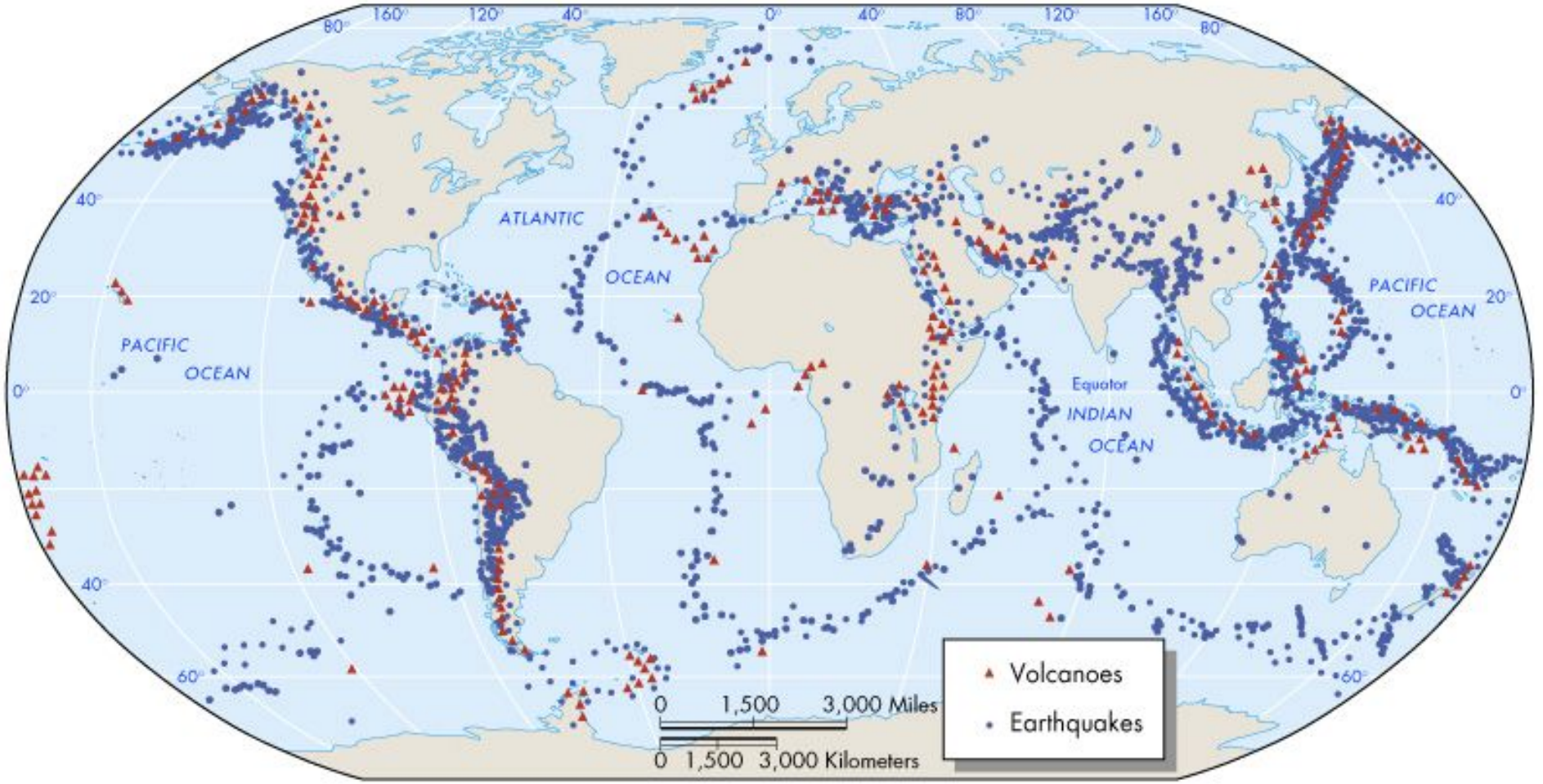

NORTH AMERICAN PLATE
Mid-Atlantic Ridge
EURASIAN PLATE
Krafla
ICELAND
Thingvellir
Reykjavik
Mid-Atlantic Ridge
ATLANTIC OCEAN



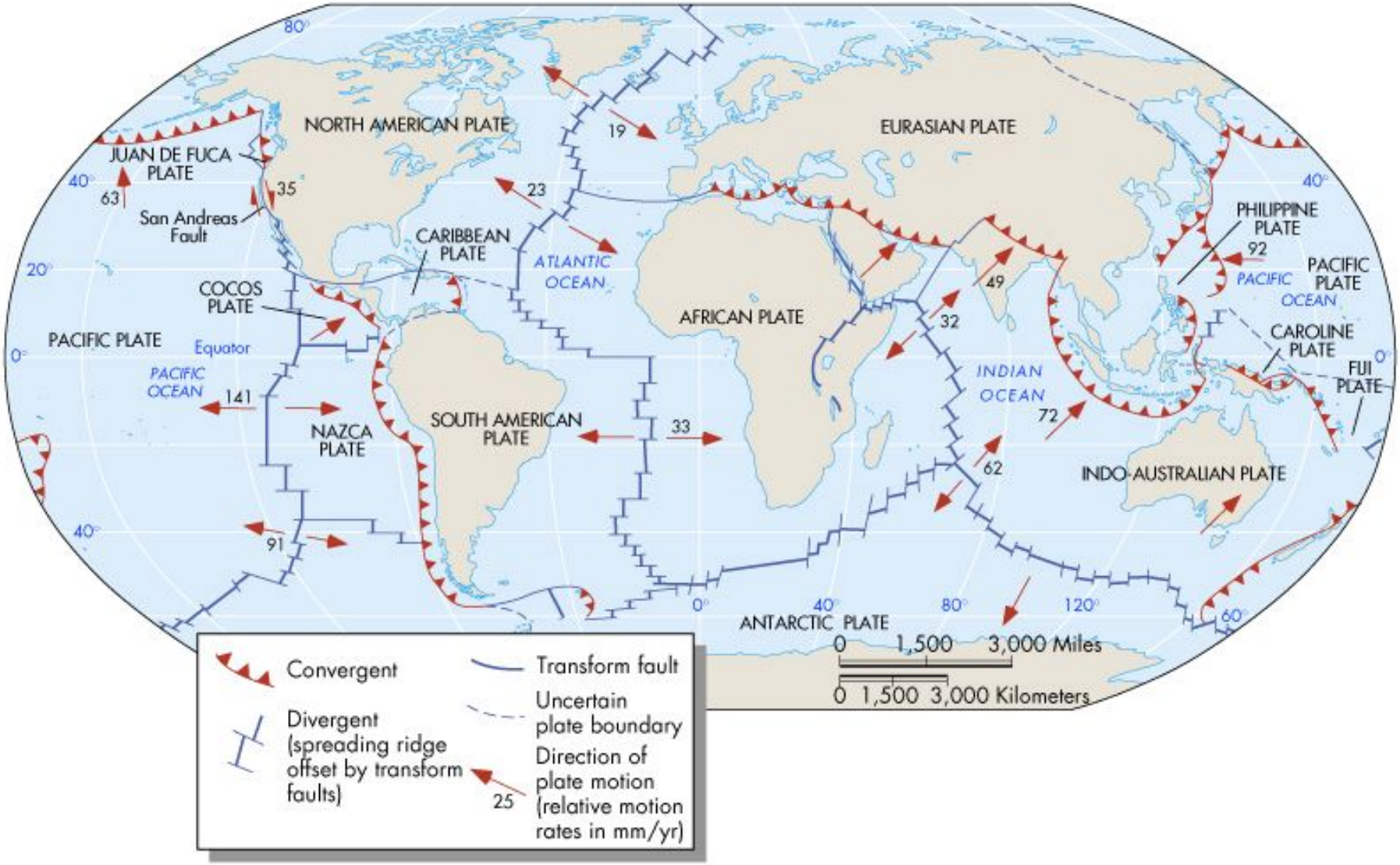

Juan de Fuca Ridge
Equator
East Pacific Rise
Mid-Atlantic Ridge
Central Indian Ridge
Southeast Indian Ridge
Pacific Antarctic Ridge
Southwest Indian Ridge

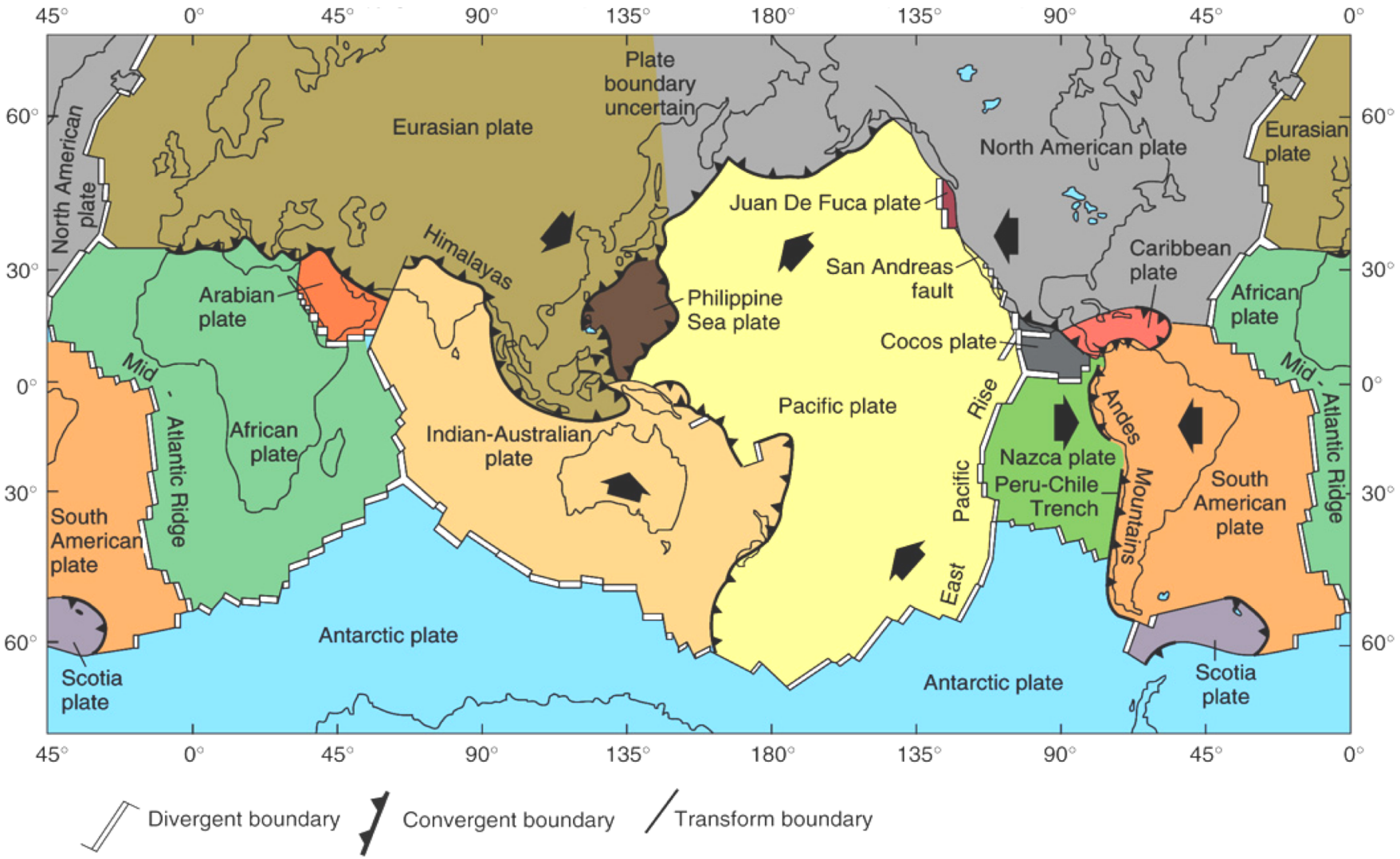
Distribuzione dei vulcani e dei terremoti

Dove le placche si separano o collidono si ha attività sismica e vulcanica

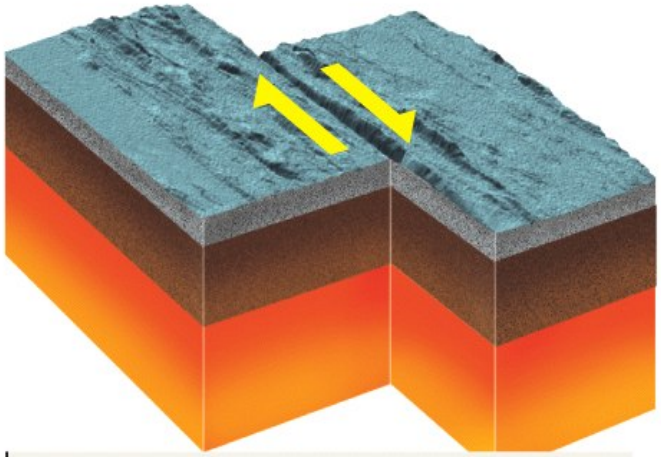


La placche principali



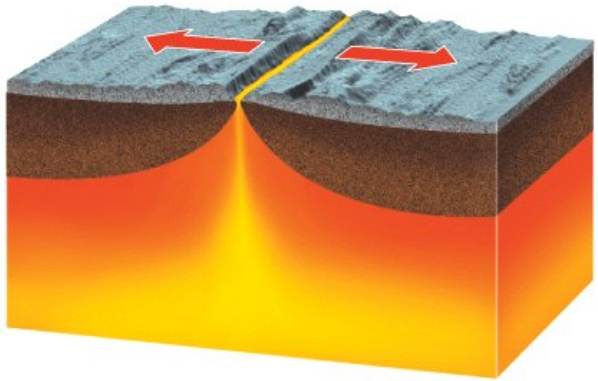

45° 0° 45° 90° 135° 180° 135° 90° 45° 0°
60°
30°
0°
30°
60°
Plate boundary uncertain
Eurasian plate
North American plate
Eurasian plate
North American plate
Juan De Fuca plate
San Andreas fault
Caribbean plate
Himalayas
Philippine Sea plate
Arabian plate
African plate
Cocos plate
Mid - Atlantic Ridge
African plate
Pacific plate
Rise
Andes Mountains
Nazca plate
Peru-Chile Trench
Pacific
East
South American plate
Mid - Atlantic Ridge
Indian-Australian plate
South American plate
Antarctic plate
Antarctic plate
Scotia plate
Scotia plate
Divergent boundary
Convergent boundary
Transform boundary

Margini di placca



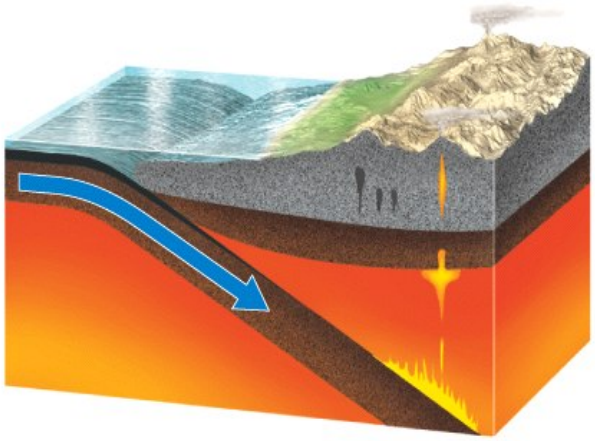
At transform-fault boundaries, plates slide horizontally past each other.

Trascorrenti
o trasformi



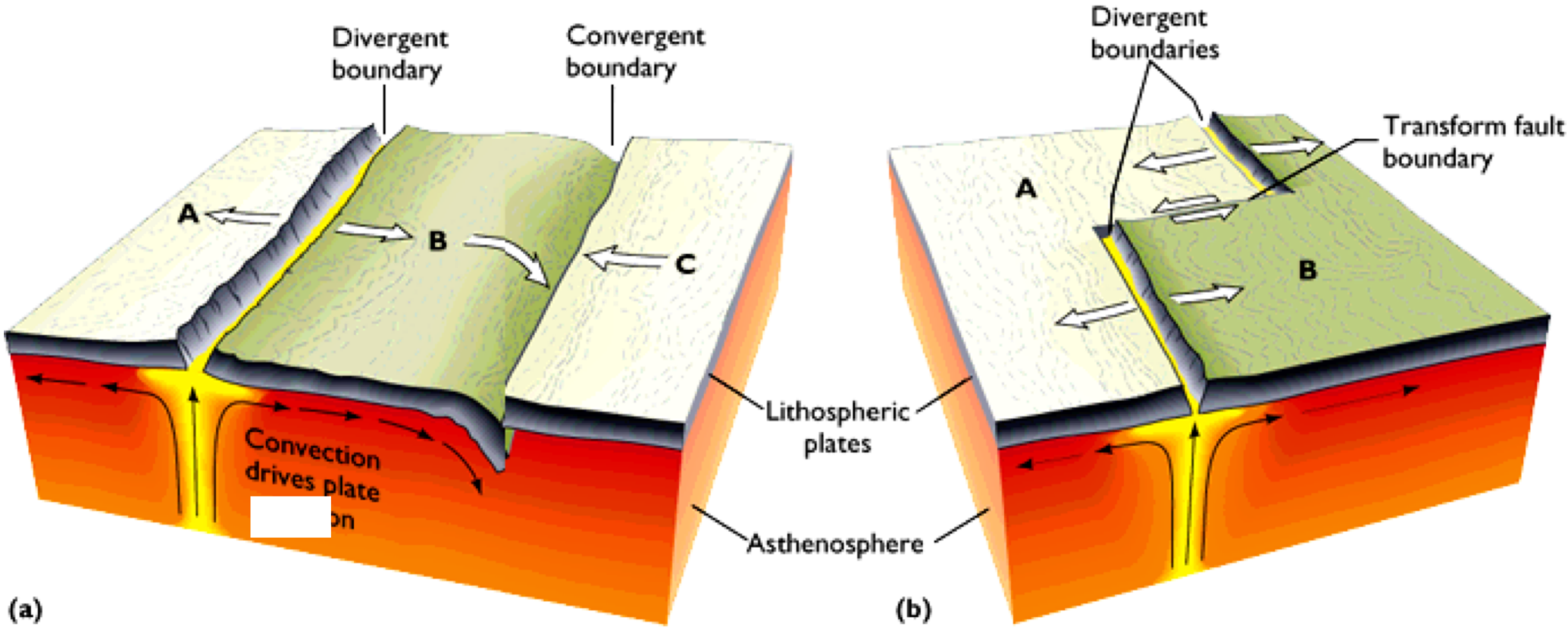
At divergent boundaries, plates move apart and create new lithosphere.

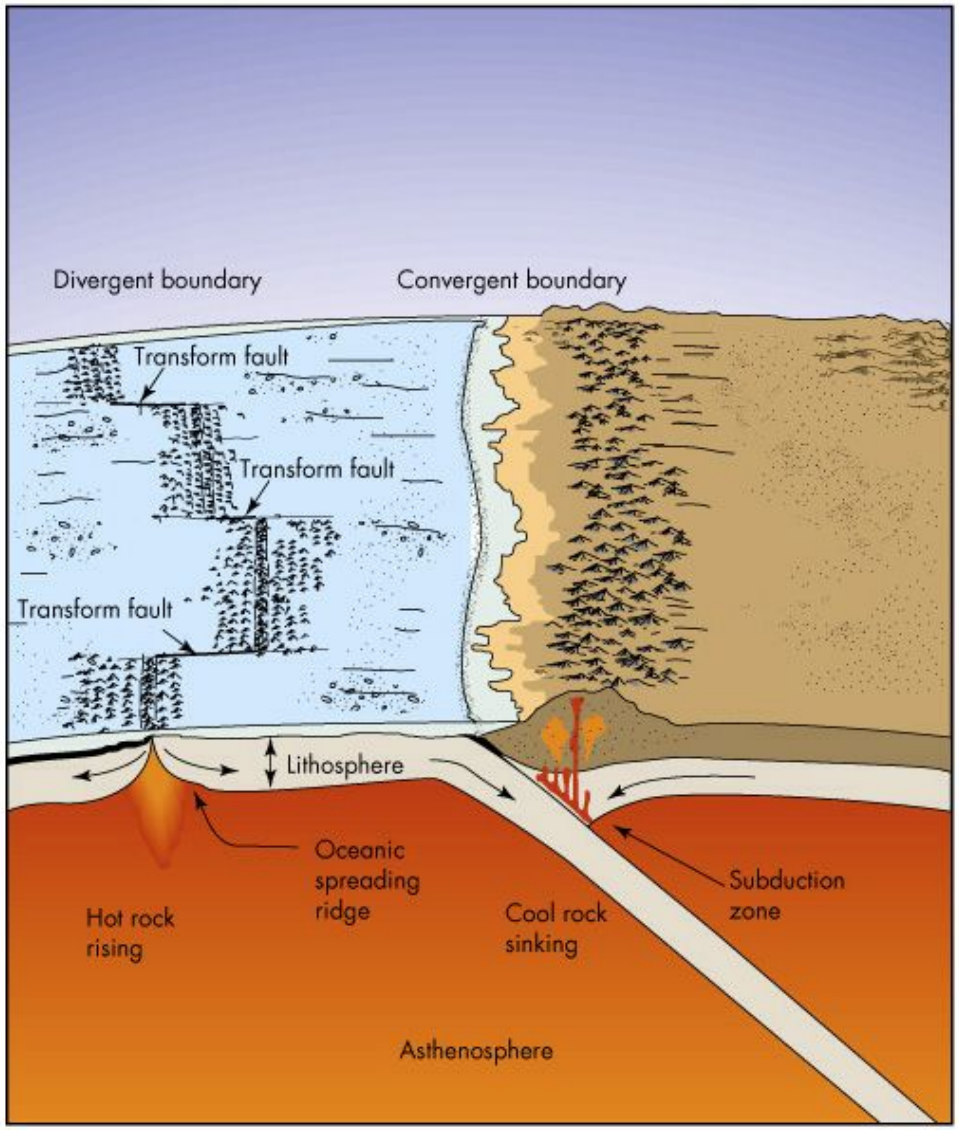
Divergenti



At convergent boundaries, plates collide and one is pulled into the mantle and recycled.

Convergenti


Divergent boundary
Convergent boundary
A
B
C
Convection drives plate
Lithospheric plates
Asthenosphere
(a)
Divergent boundaries
Transform fault boundary
A
B
(b)


Divergent boundary
Convergent boundary
Transform fault
Transform fault
Transform fault
Lithosphere
Oceanic spreading ridge
Hot rock rising
Cool rock sinking
Subduction zone
Asthenosphere

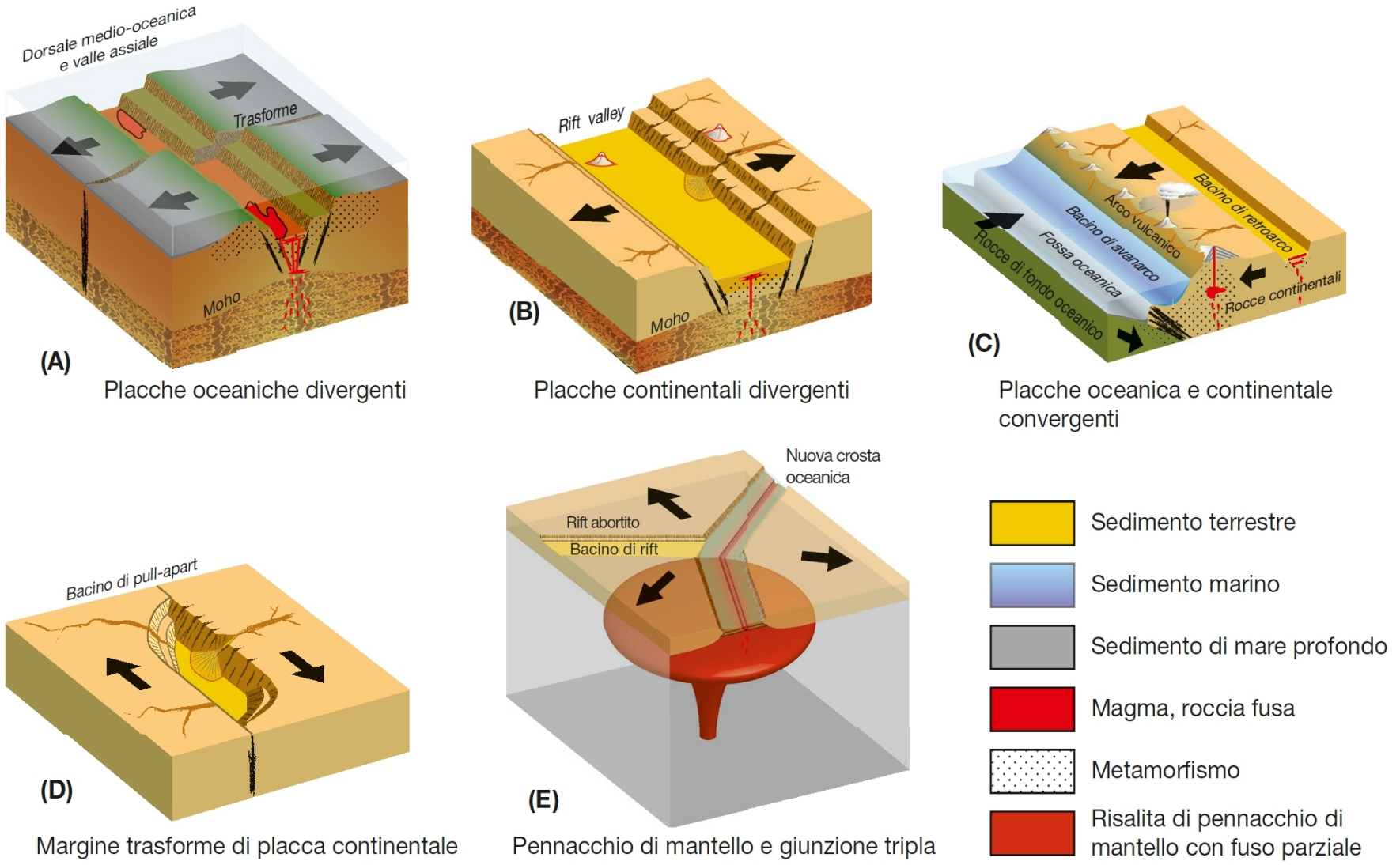
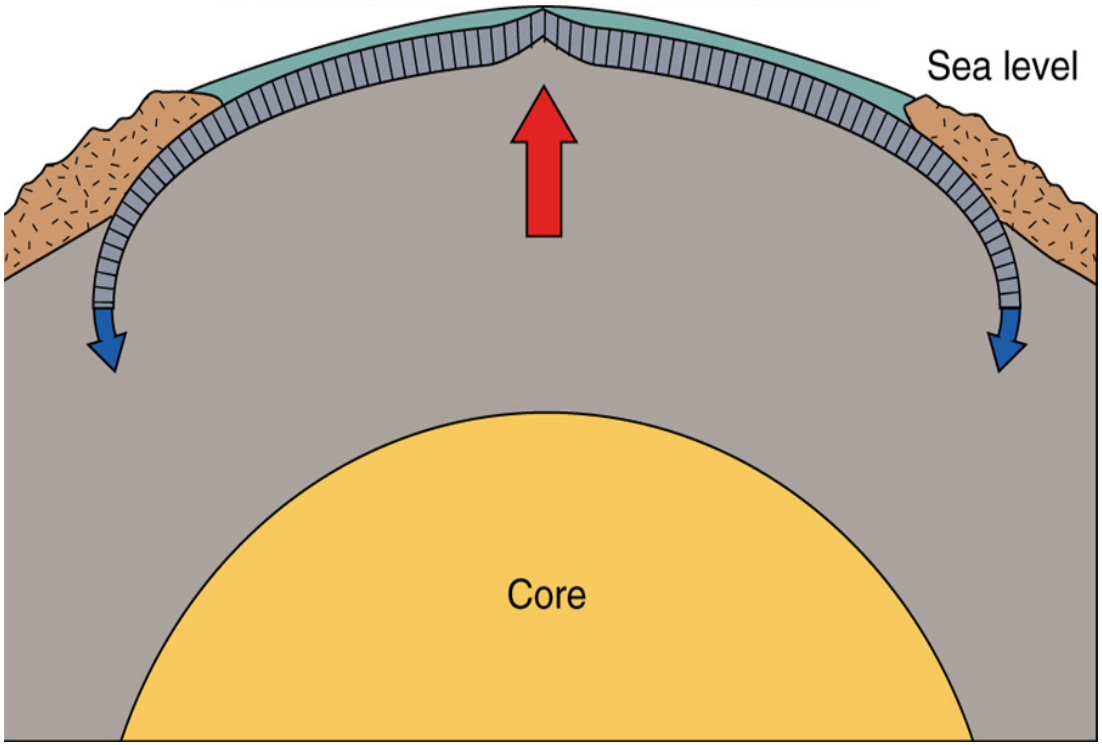
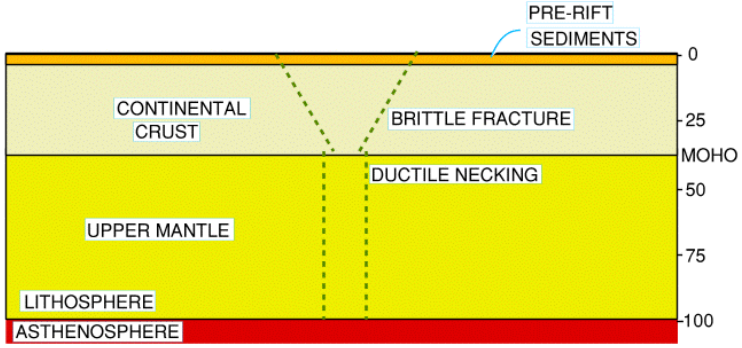


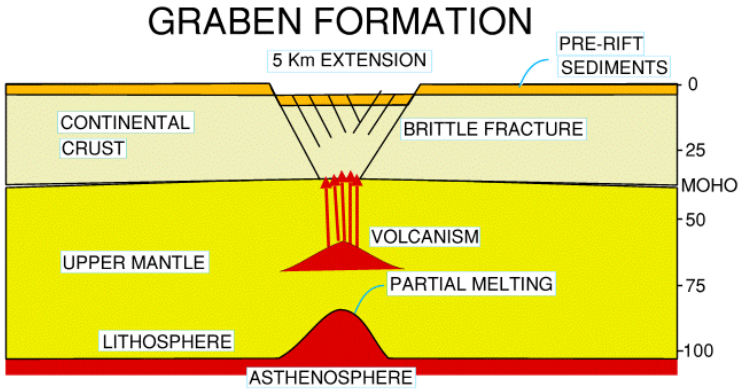
Figura 1.7 Tipi di margini di placca e luoghi di formazione di rocce ignee, sedimentarie e metamorfiche.

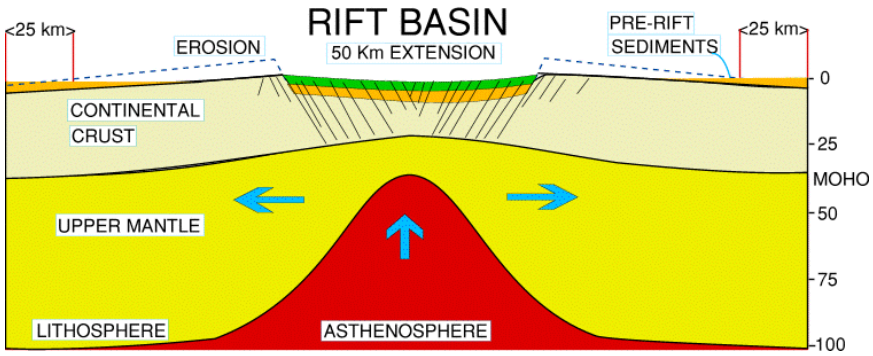
1. Margini divergenti

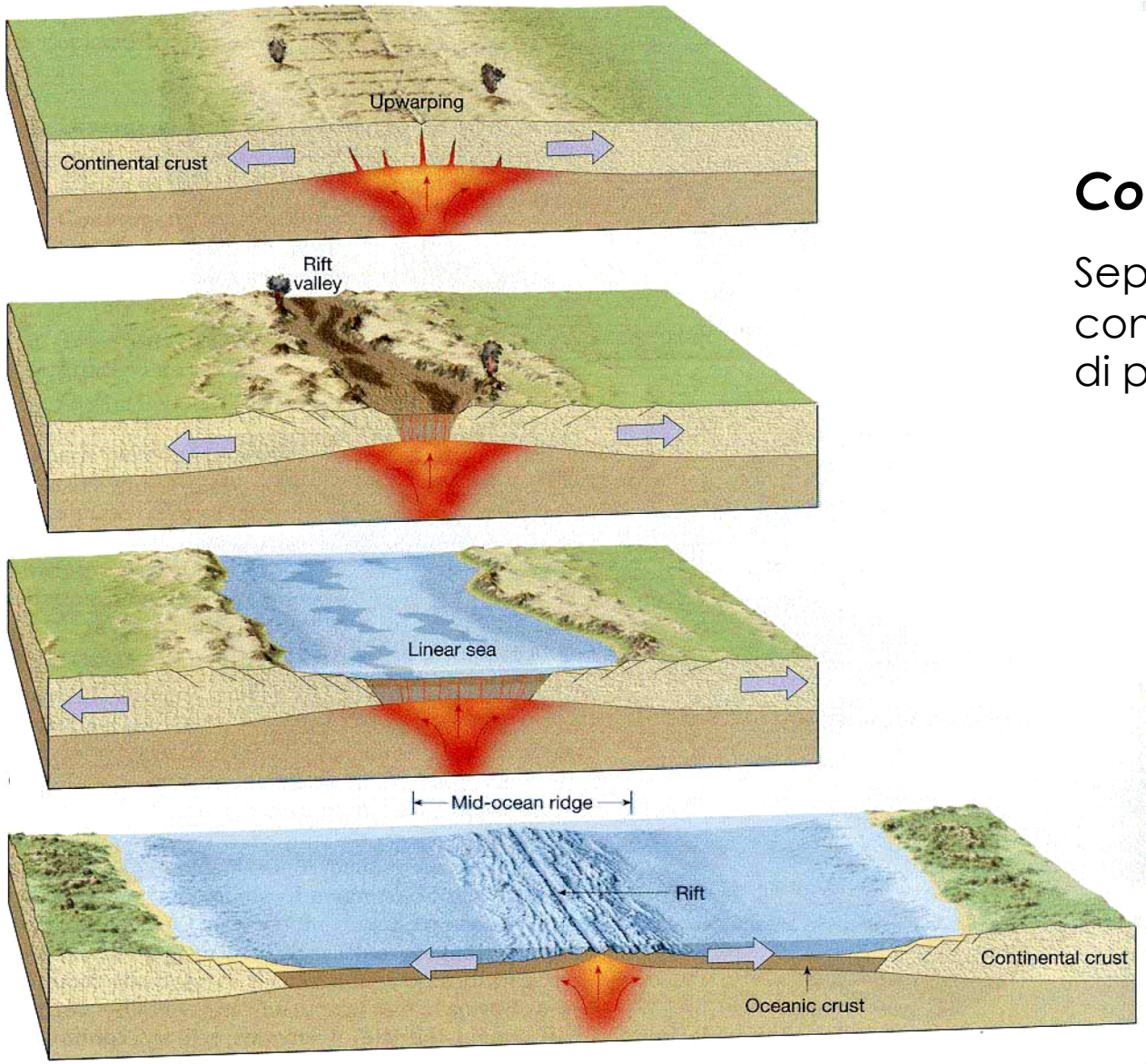
Generazione di nuova crosta





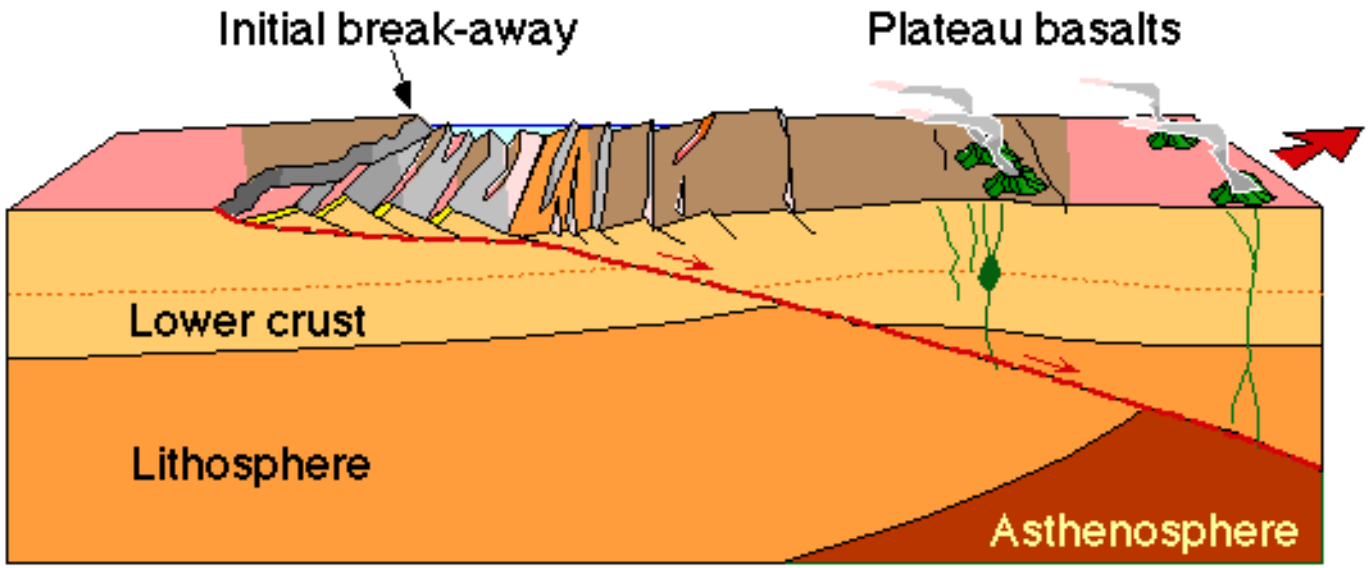


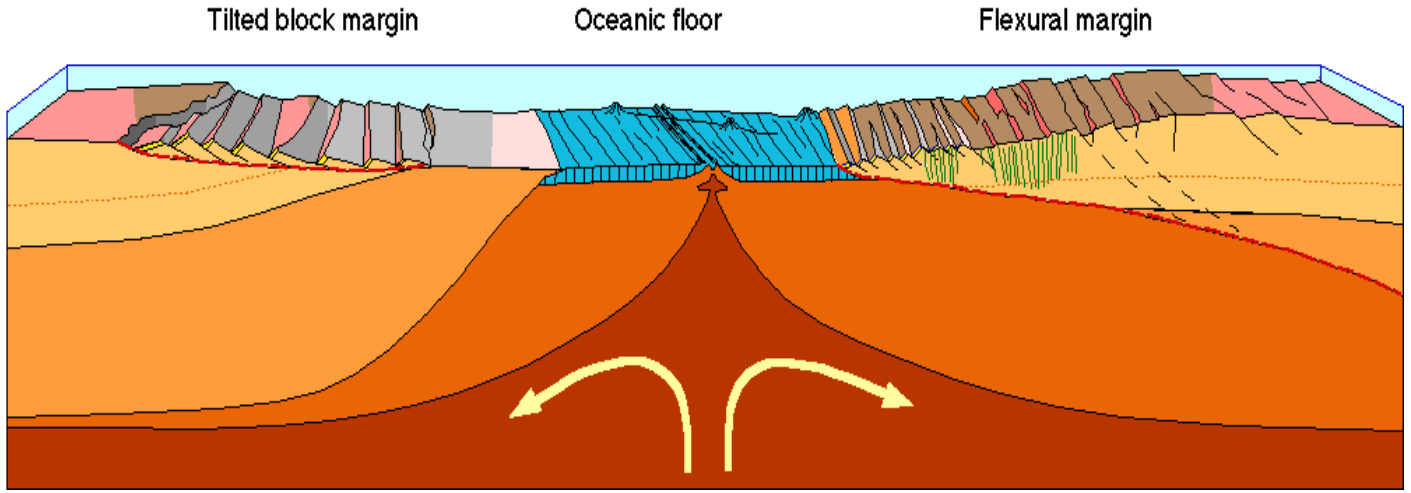


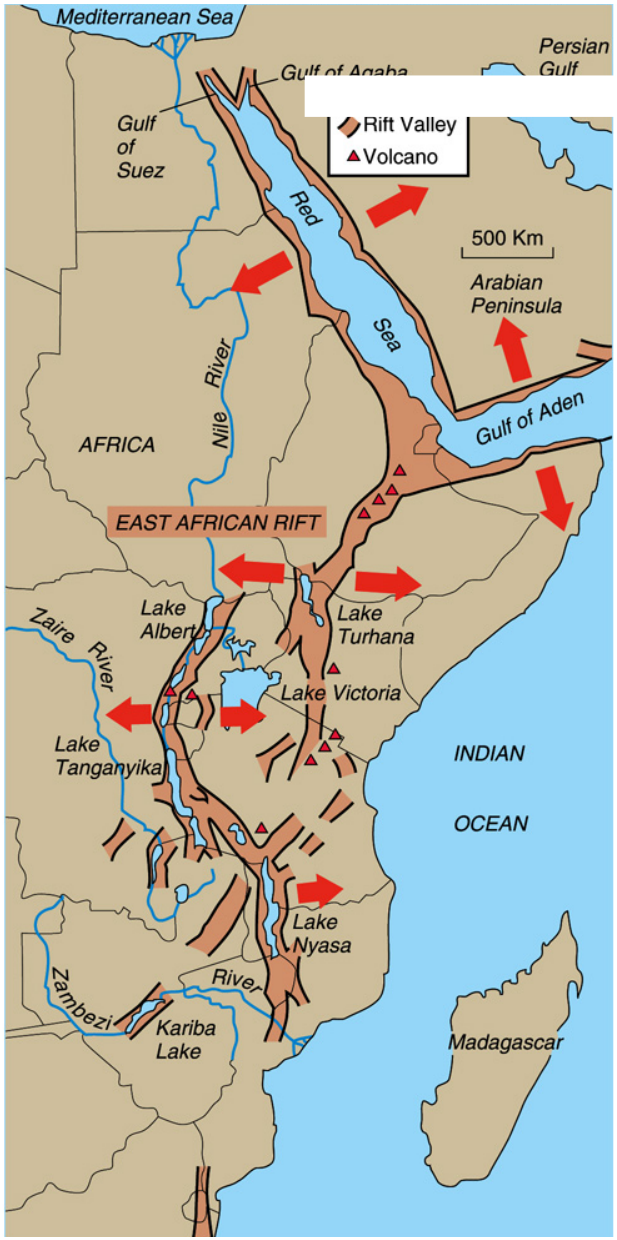


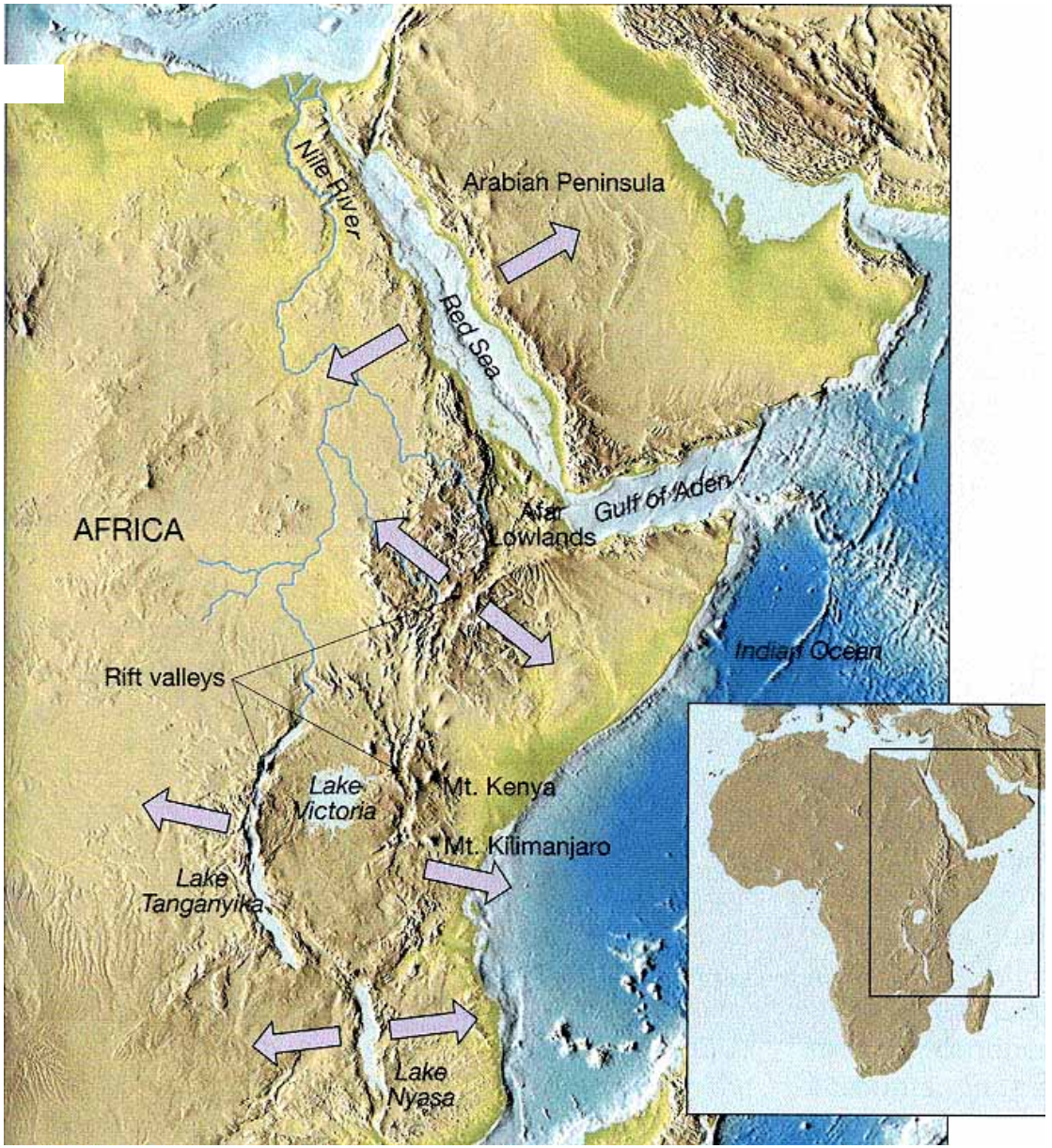
Continental rifting

Separazione di una placca continentale e formazione di placca oceanica

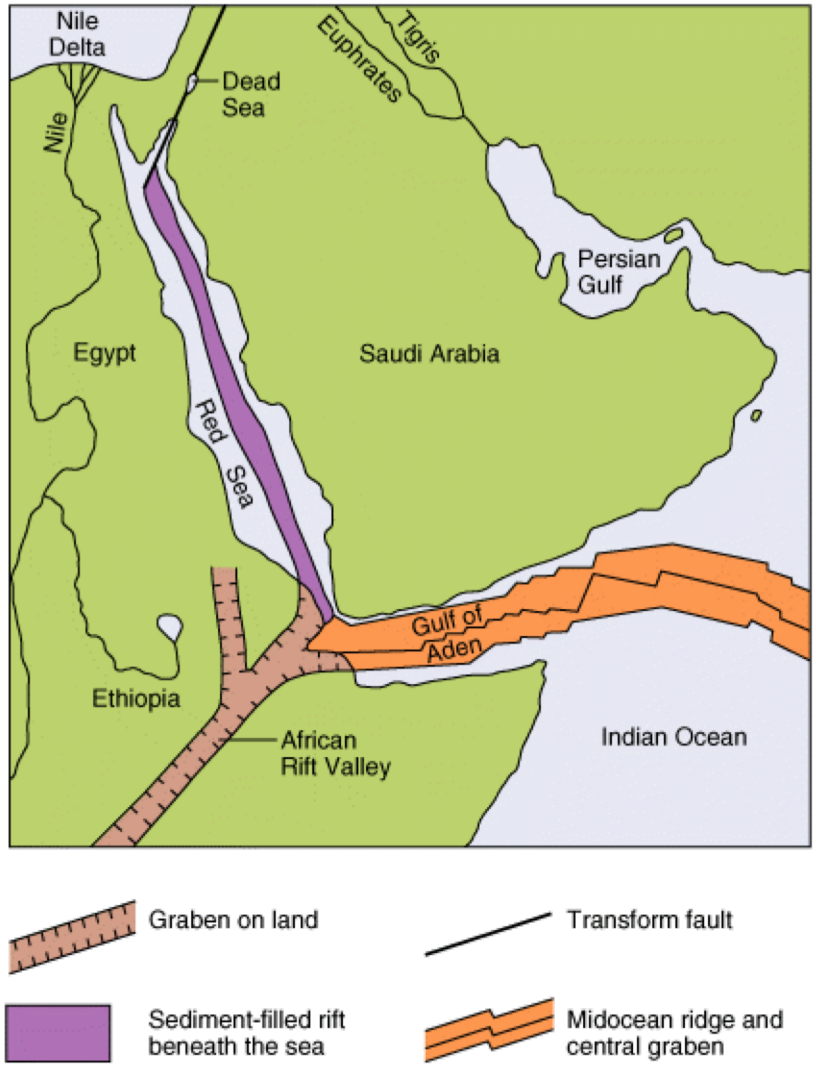

Initial break-away
Plateau basalts
Lower crust
Lithosphere
Asthenosphere

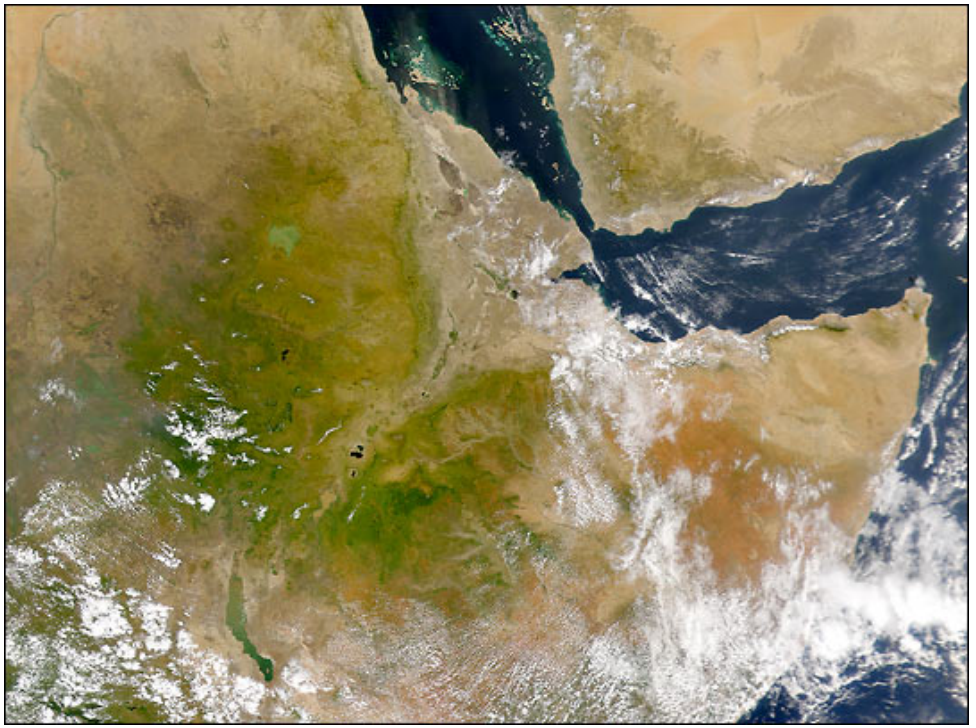

Tilted block margin
Oceanic floor
Flexural margin


Mediterranean Sea
Persian Gulf
Gulf of Suez
Rift Valley
Volcano
500 Km
Red Sea
Arabian Peninsula
Nile River
AFRICA
Gulf of Aden
EAST AFRICAN RIFT
Lake Albert
Lake Turhana
Zaire River
Lake Victoria
Lake Tanganyika
INDIAN OCEAN
Lake Nyasa
Zambezi River
Kariba Lake
Madagascar

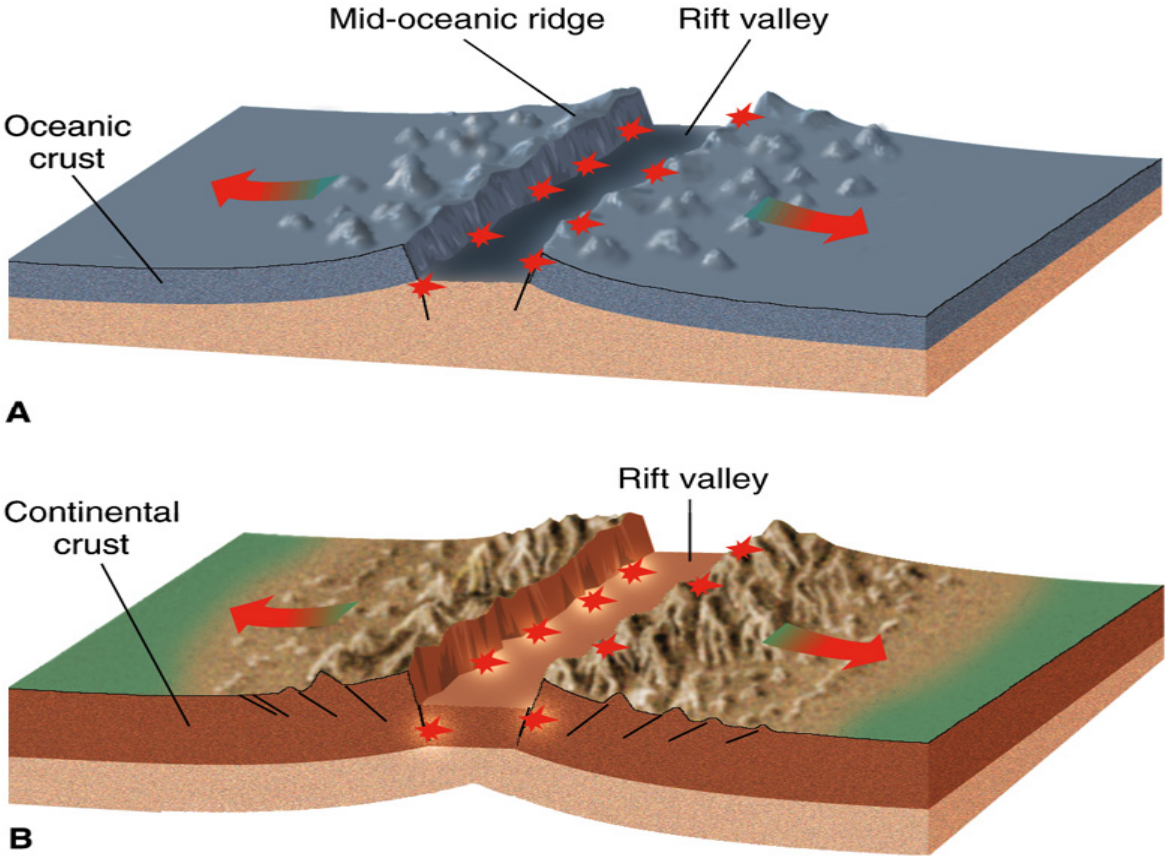

Nile River
Arabian Peninsula
Red Sea
AFRICA
Afar Lowlands
Gulf of Aden
Indian Ocean
Rift valleys
Lake Victoria
Mt. Kenya
Mt. Kilimanjaro
Lake Tanganyika
Lake Nyasa

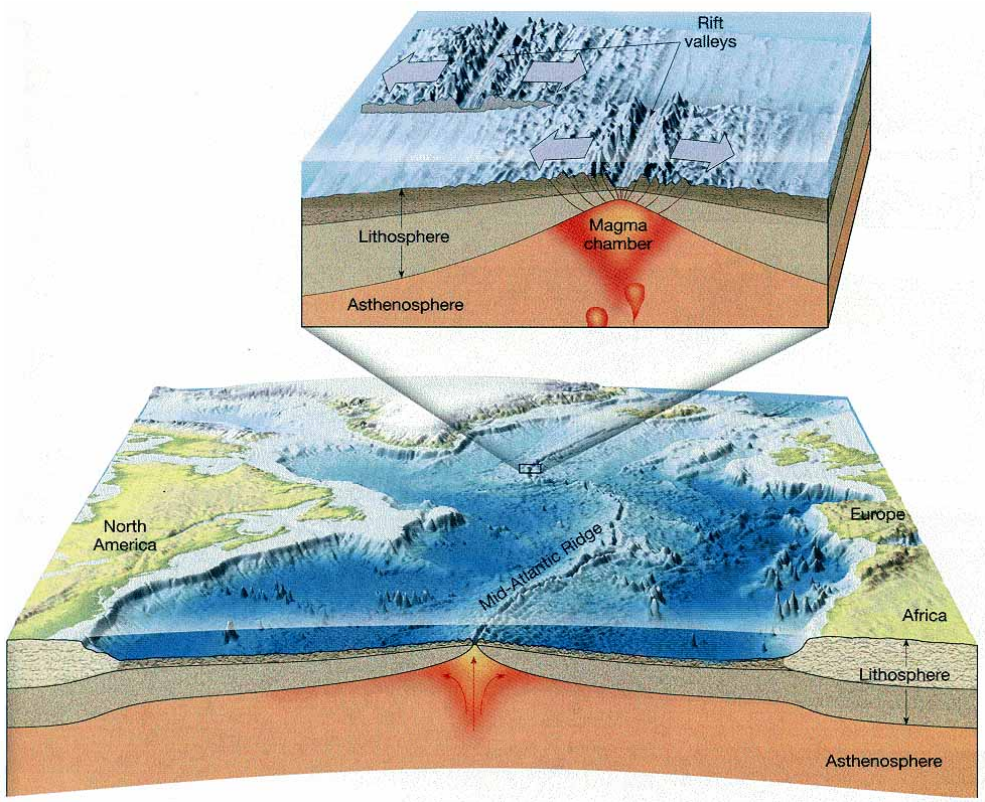
Il continente africano si sta dividendo lungo una frattura della litosfera continentale (East African Rift)



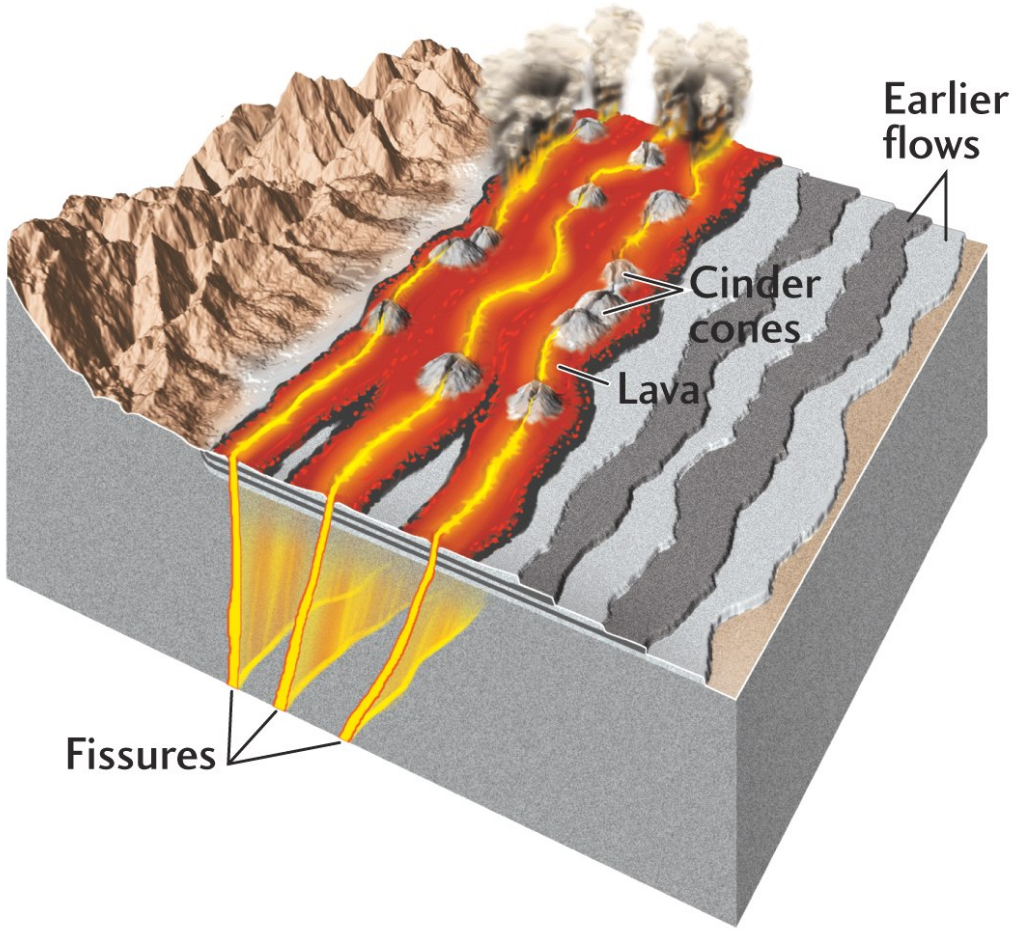


Mid-oceanic ridge – Dorsale medio oceanica



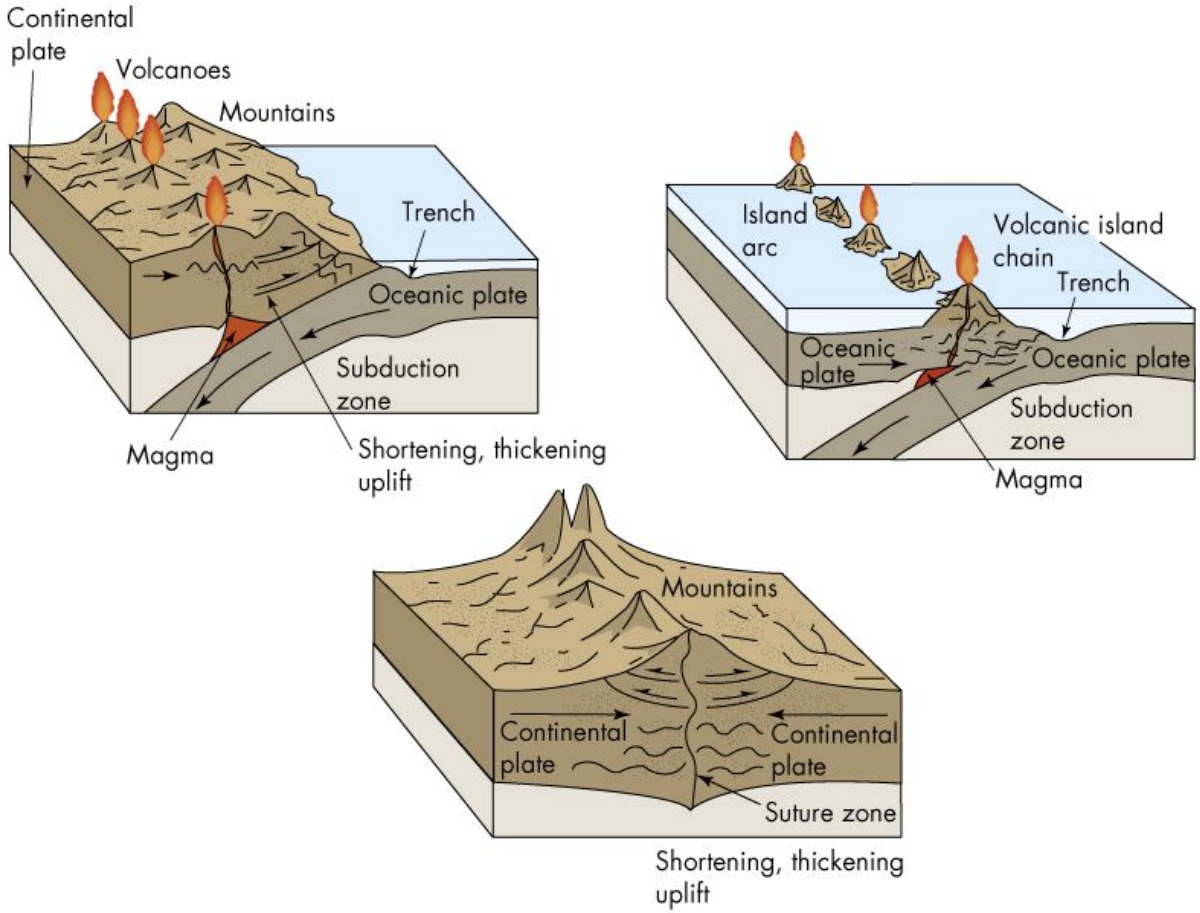


Vulcani fessurali lungo le dorsali medio-oceaniche

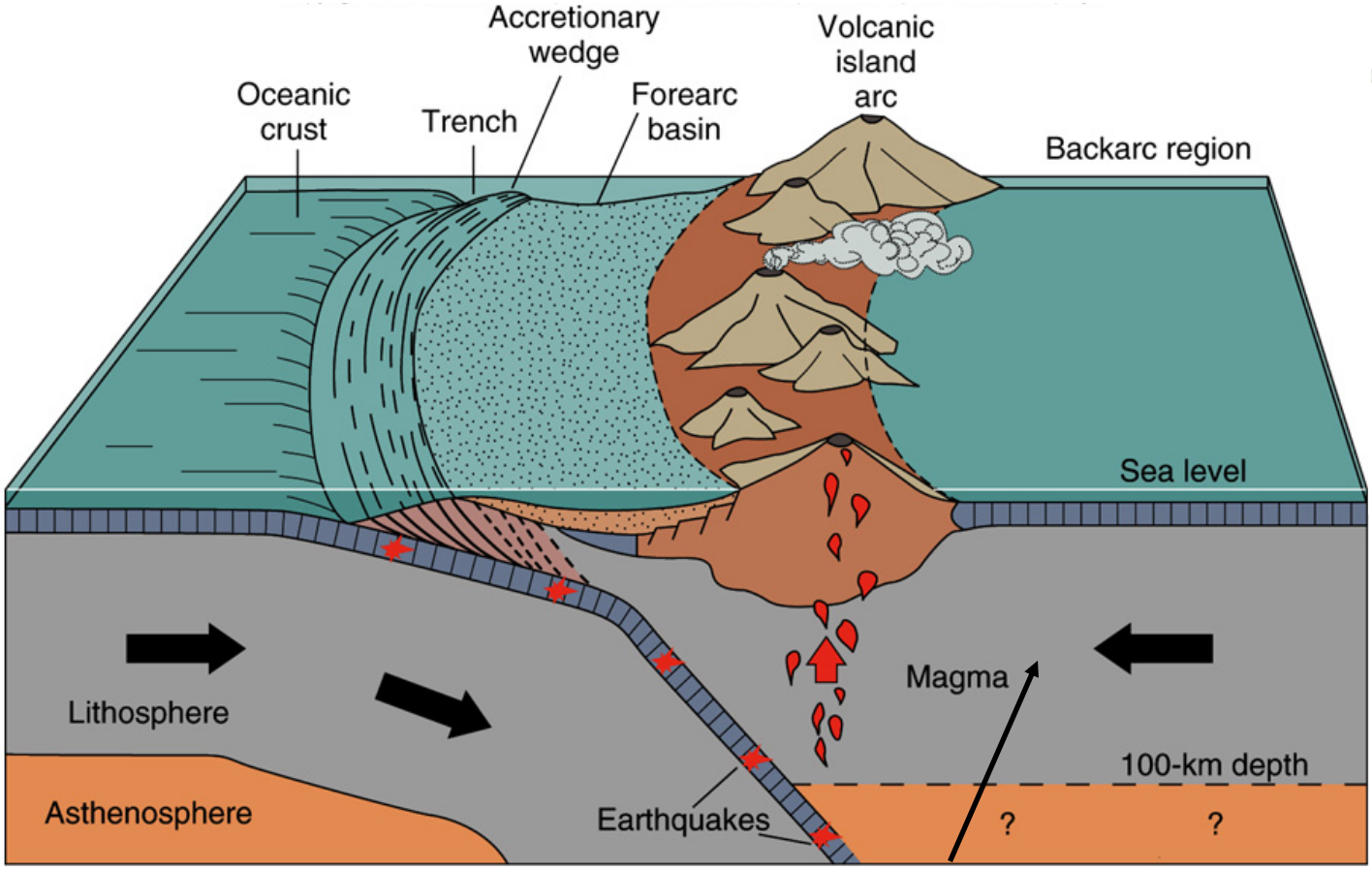


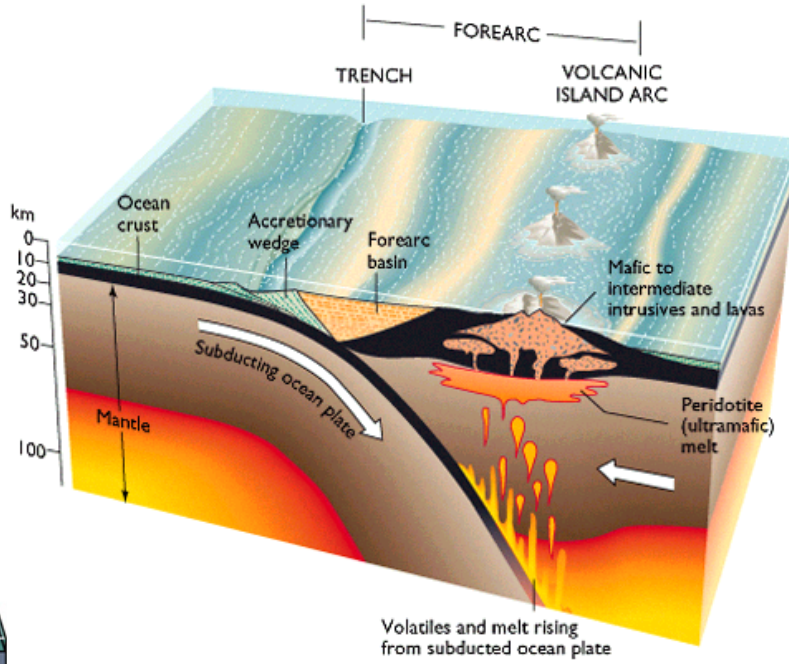
2. Margini convergenti

Variano a seconda del tipo di placche che vengono a convergere



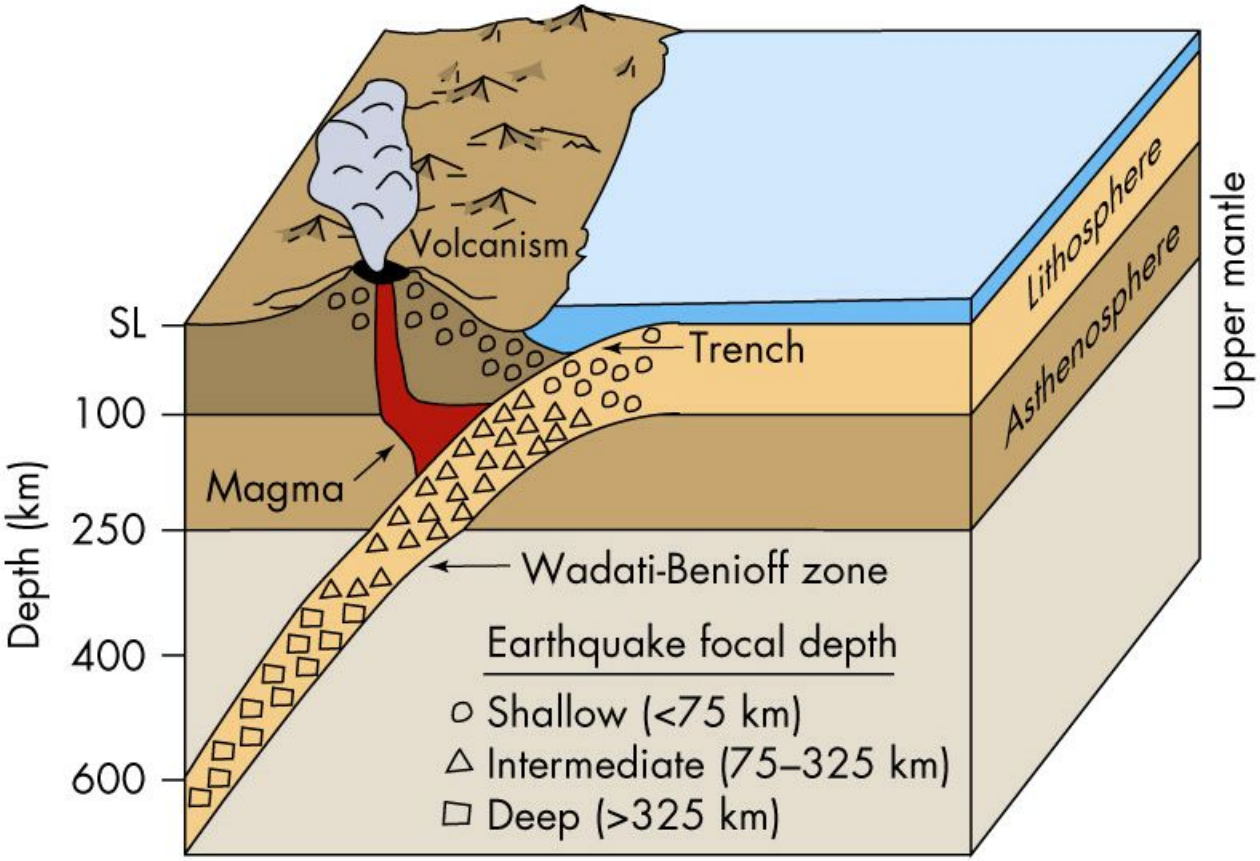
2.1 Collisione oceano-oceano: gli archi insulari

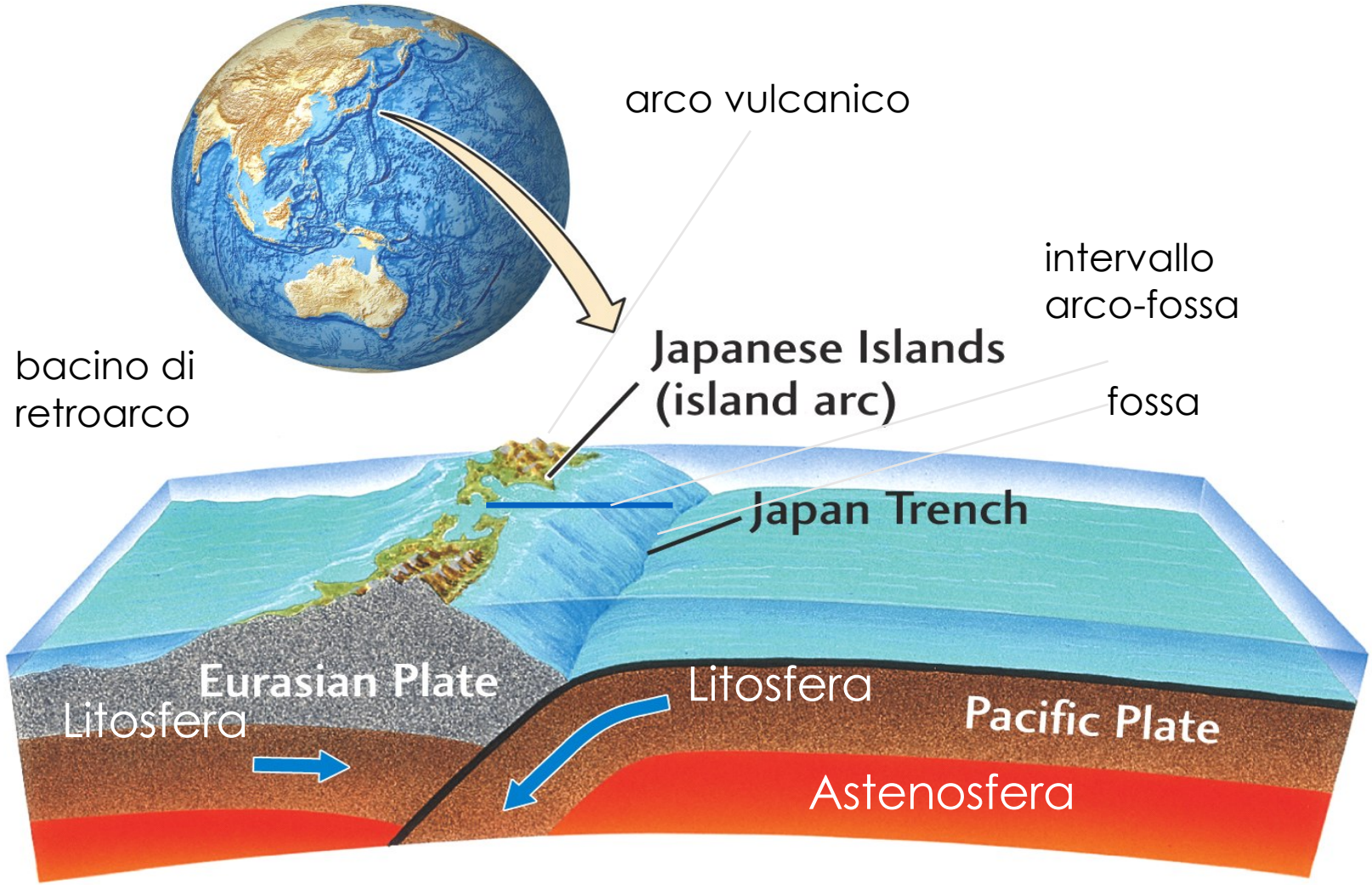




Piano di Benioff

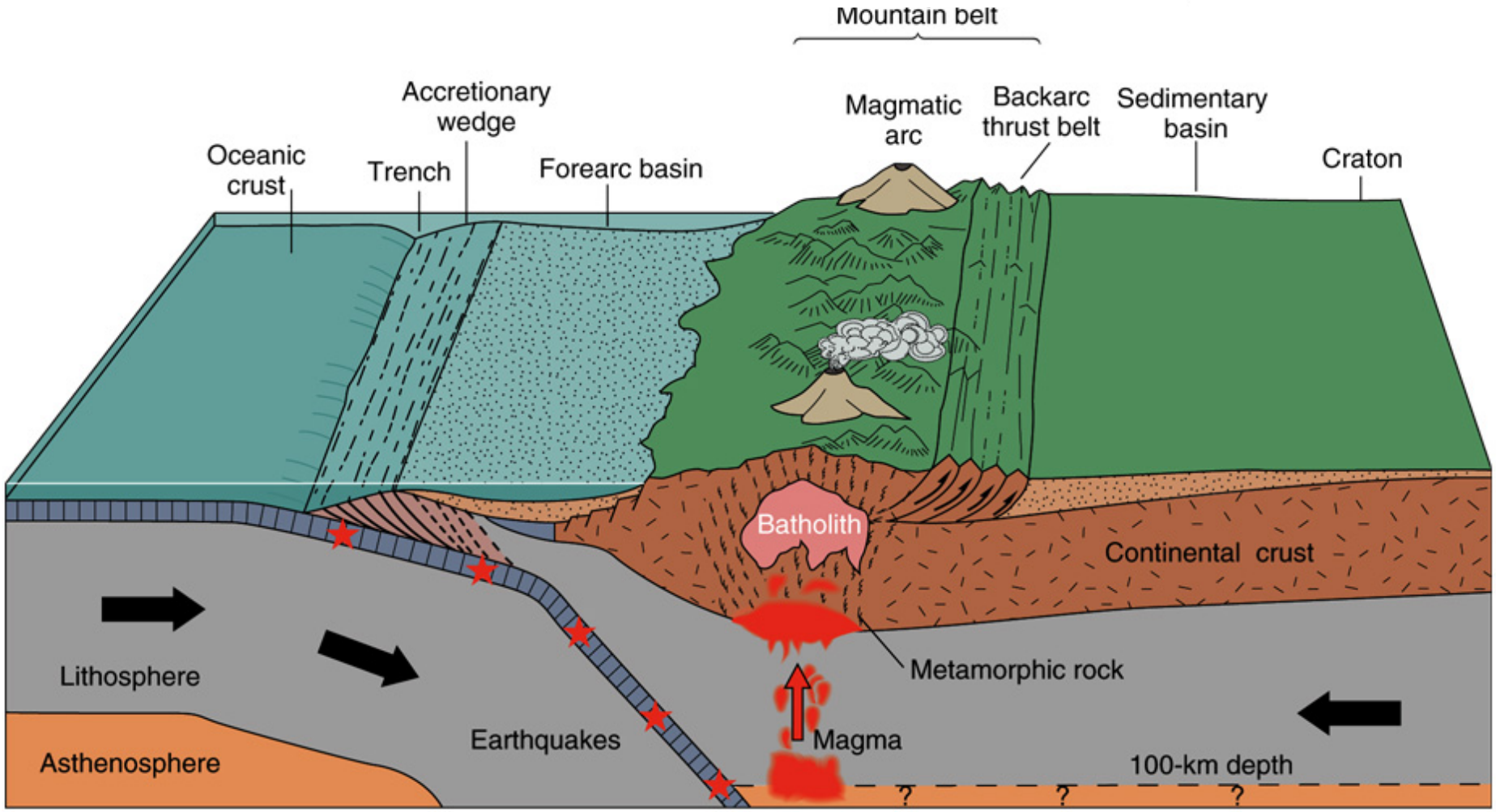
Terremoti profondi lungo i margini convergenti

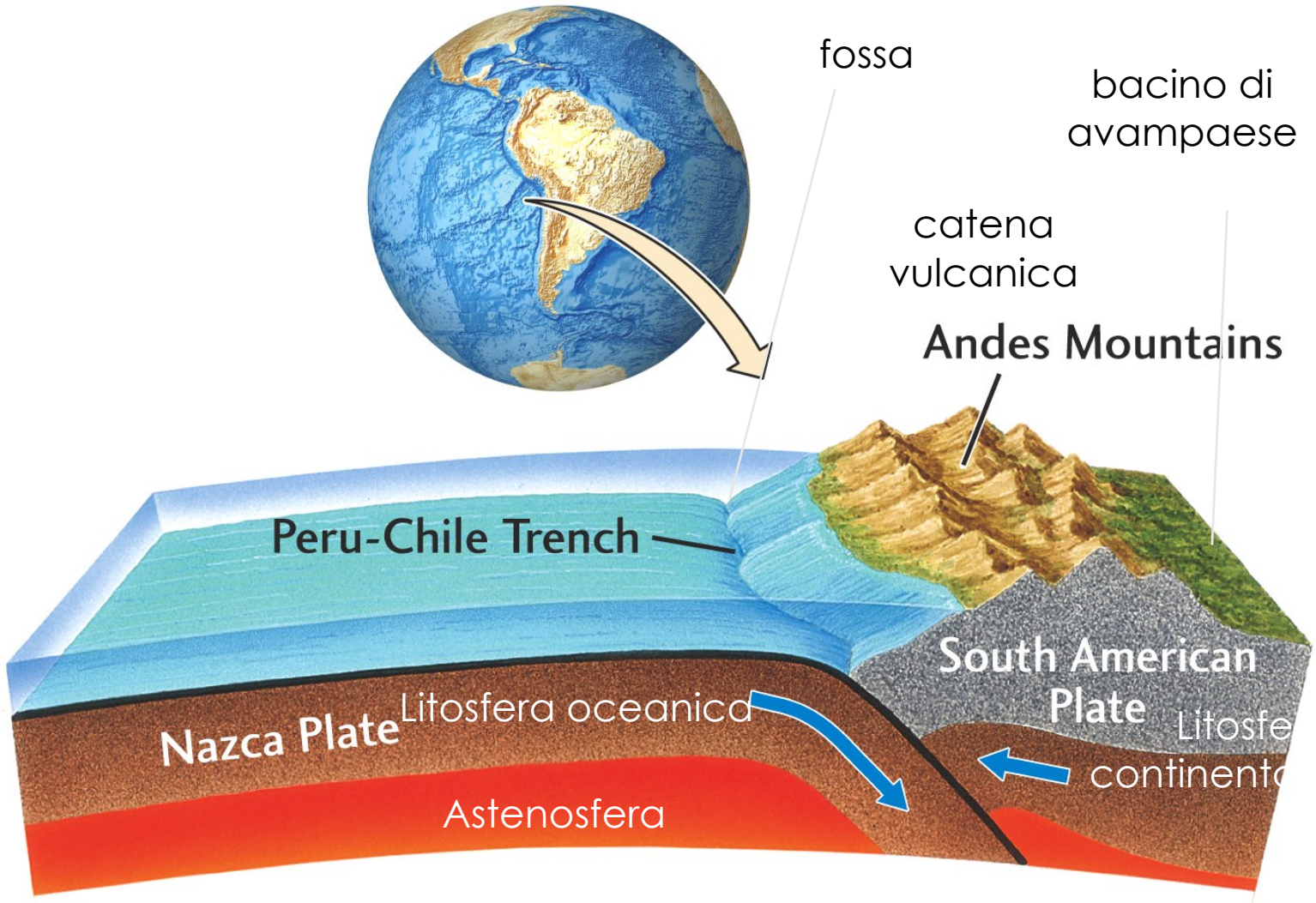


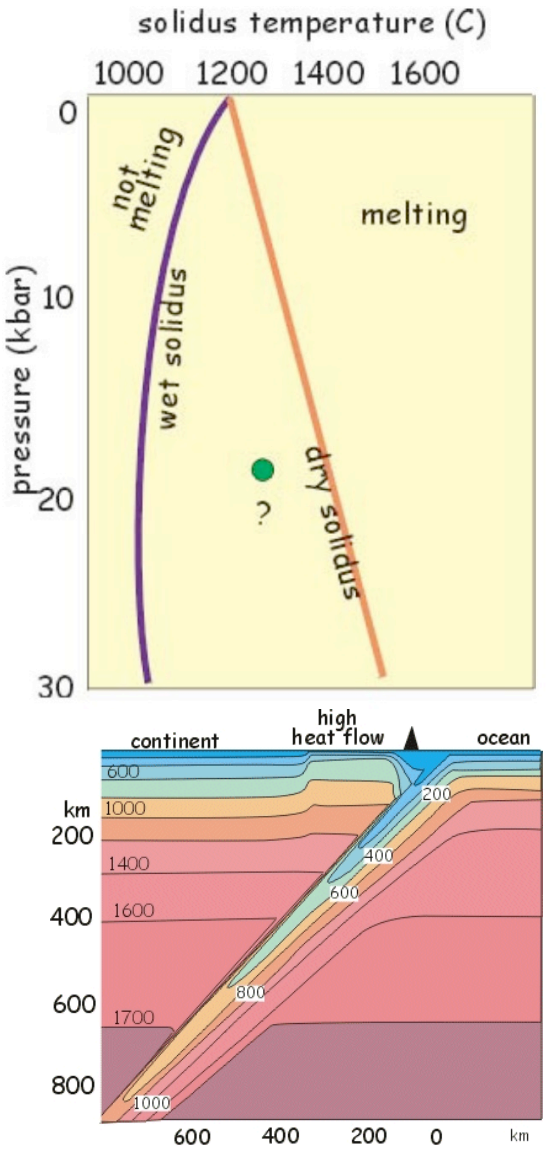


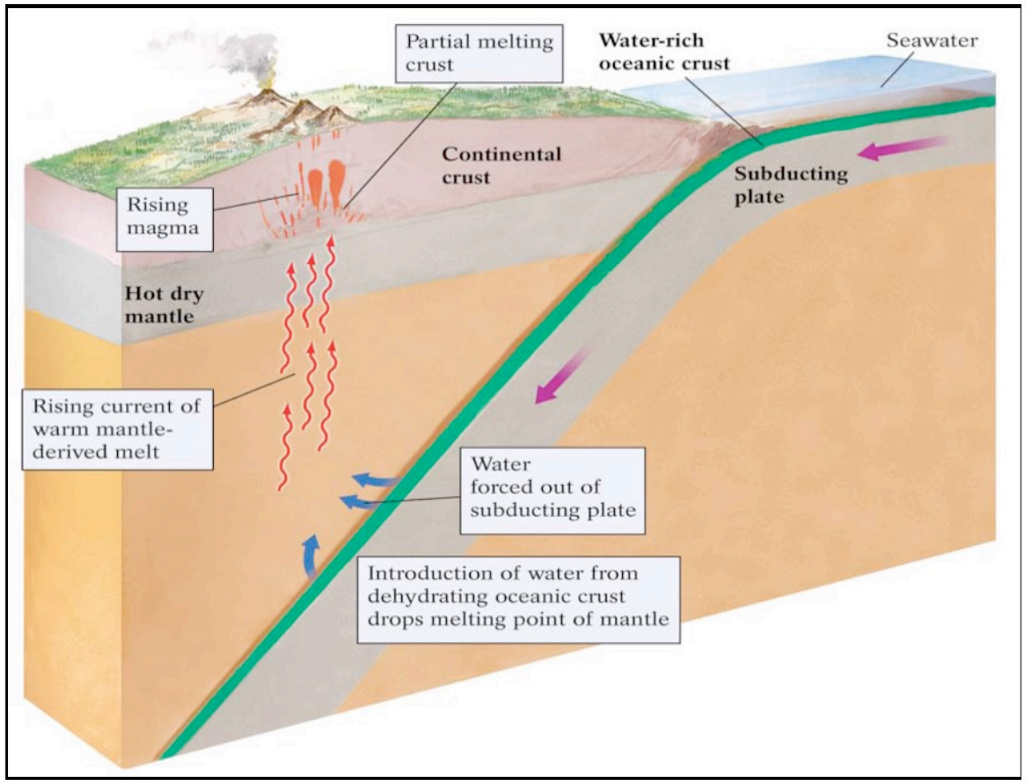
Sistema arco-fossa

2.2 Collisione oceano - continente



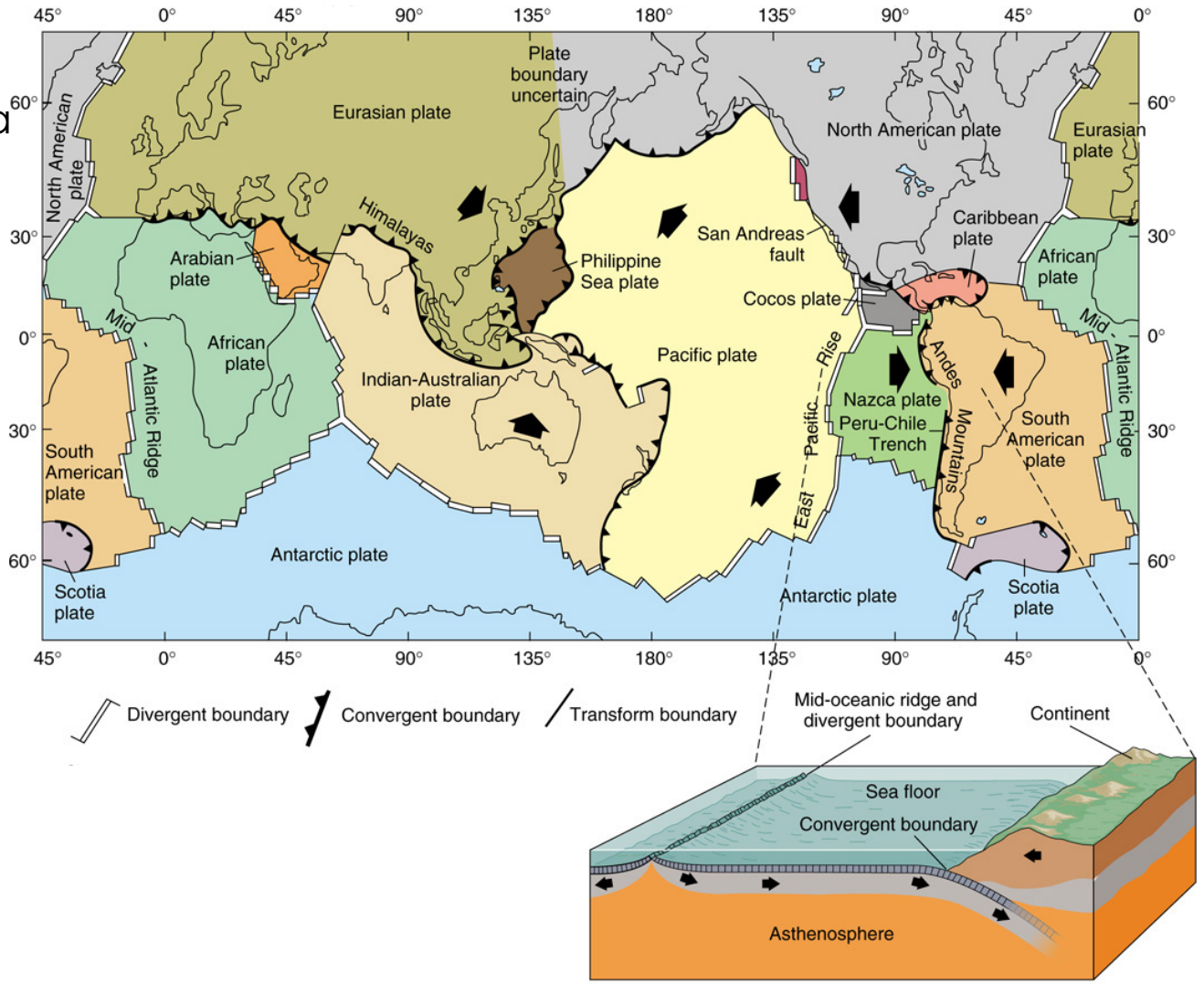

fossa
bacino di avampaese
catena vulcanica
Andes Mountains
Peru-Chile Trench
South American Plate
Litosfe
continento
Nazca Plate
Litosfera oceanica
Astenosfera


solidus temperature (C)
1000 1200 1400 1600
0
10
20
30
pressure (kbar)
not melting
wet solidus
melting
dry solidus
?
continent
high heat flow
ocean
600
1000
1400
1600
1700
200
400
600
800
1000
km
200
400
600
800
600 400 200 0 km


Partial melting crust
Water-rich oceanic crust
Seawater
Continental crust
Subducting plate
Rising magma
Hot dry mantle
Rising current of warm mantle-derived melt
Water forced out of subducting plate
Introduction of water from dehydrating oceanic crust drops melting point of mantle

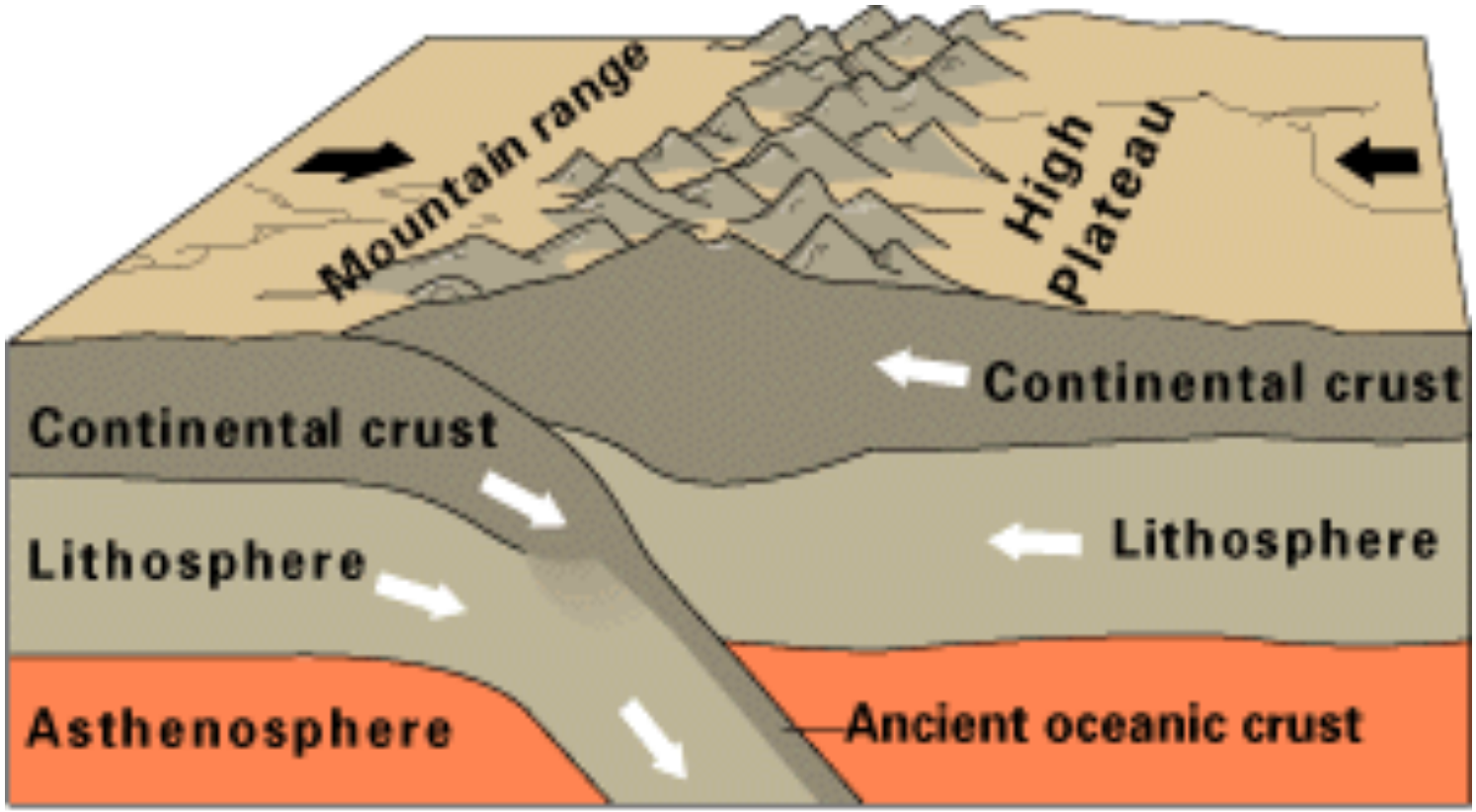
Esempio, le Ande

Subduzione della placca oceanica Nazca sotto il continente sudamerica milioni di anni fa.



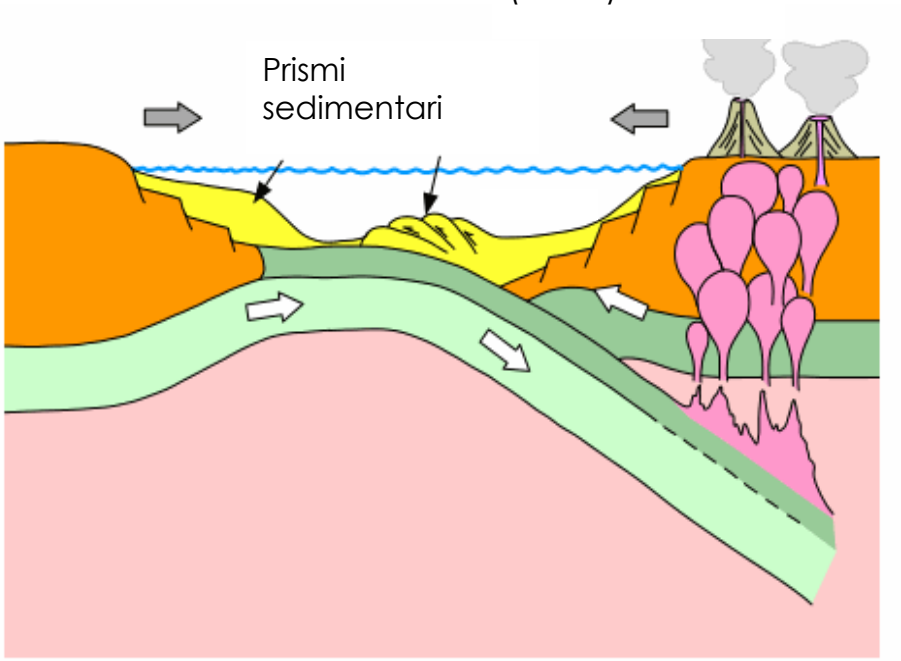
2.3 Collisione continente - continente

Il "peso" delle due placche e' simile, la compressione provoca deformazione e formazione di catene montuose.



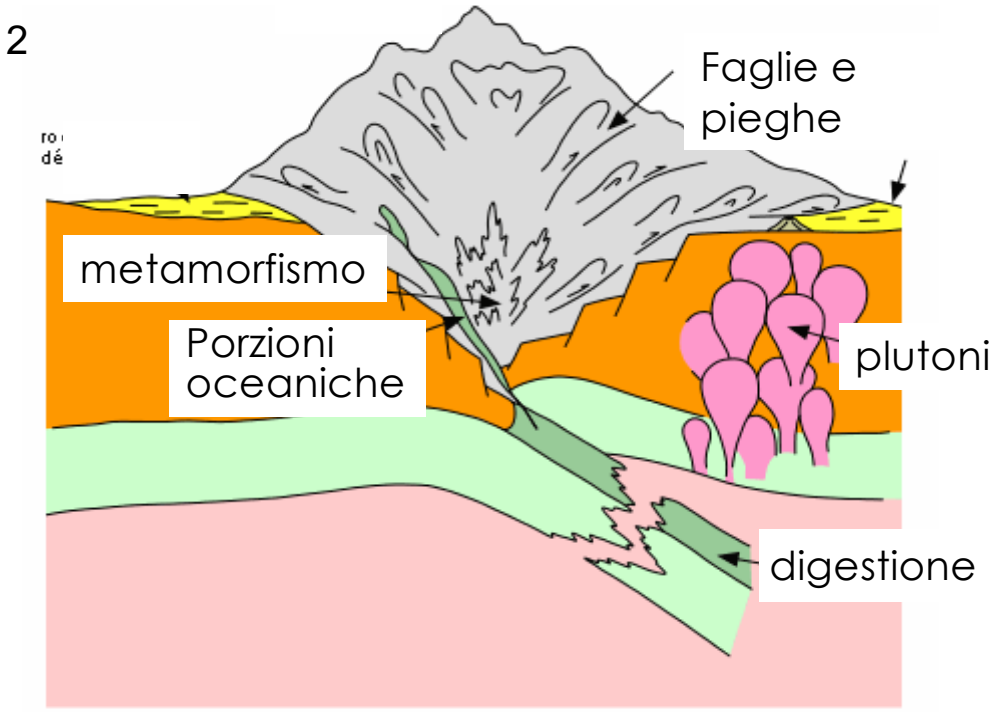
1

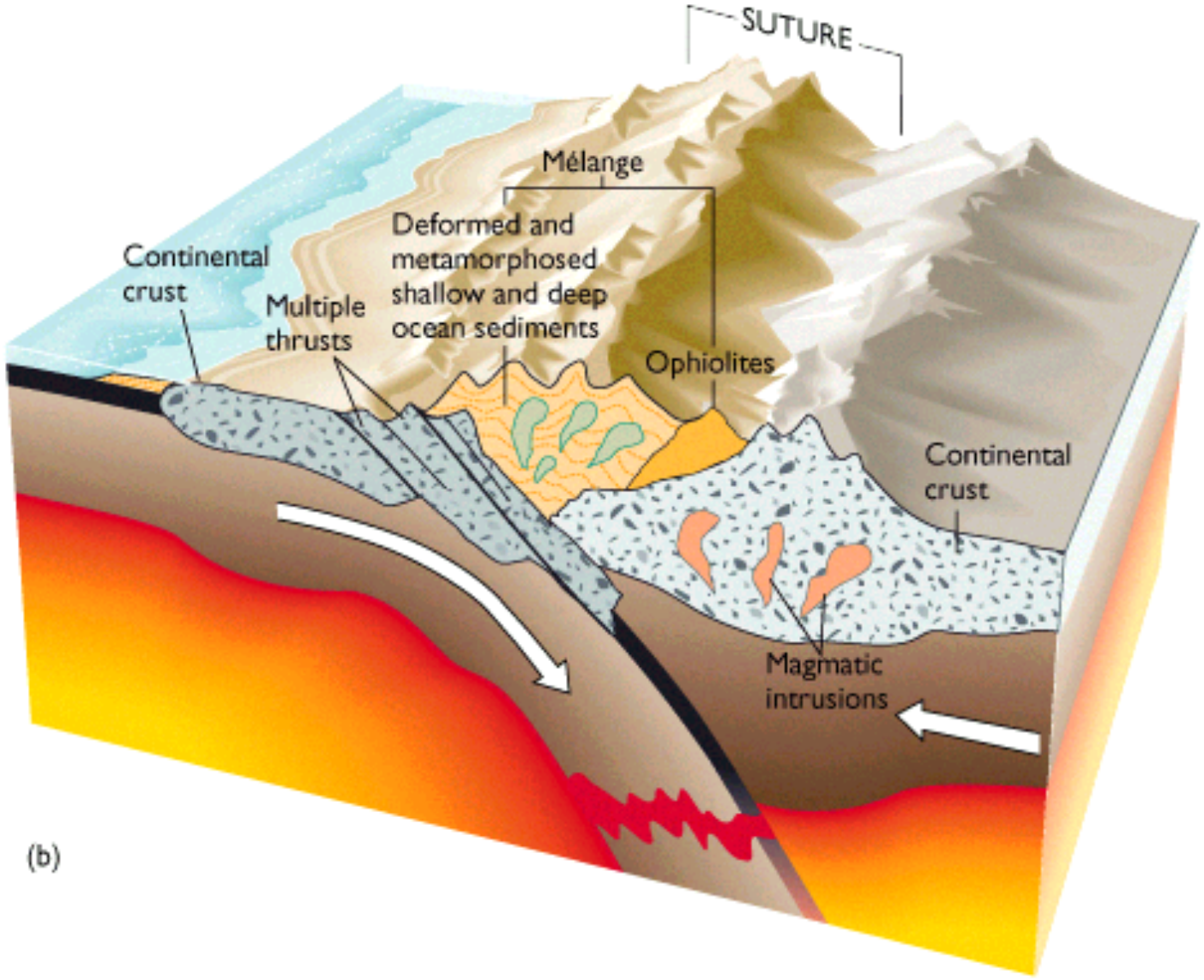
Vulcanismo continentale (Ande)



Catene montuose Alpi

2

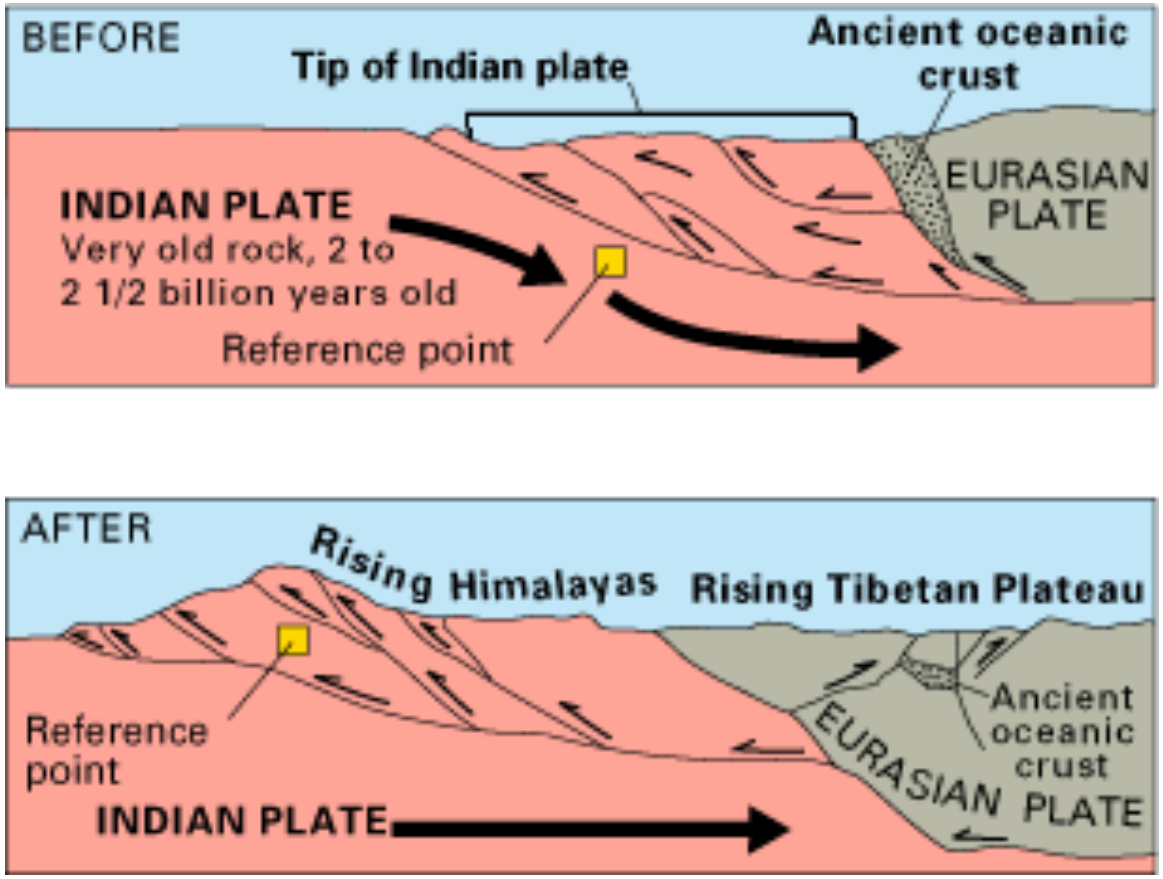


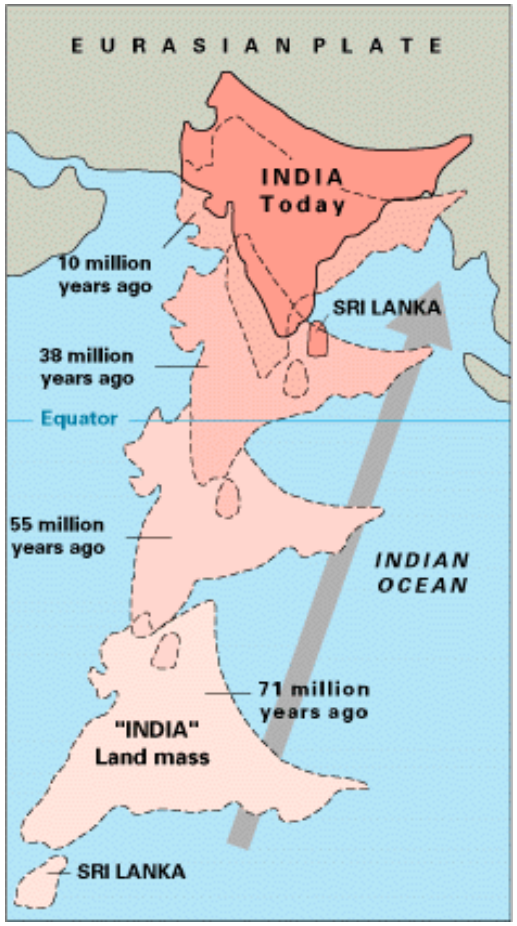

SUTURE
Mélange
Deformed and metamorphosed shallow and deep ocean sediments
Continental crust
Multiple thrusts
Ophiolites
Continental crust
Magmatic intrusions

(b)

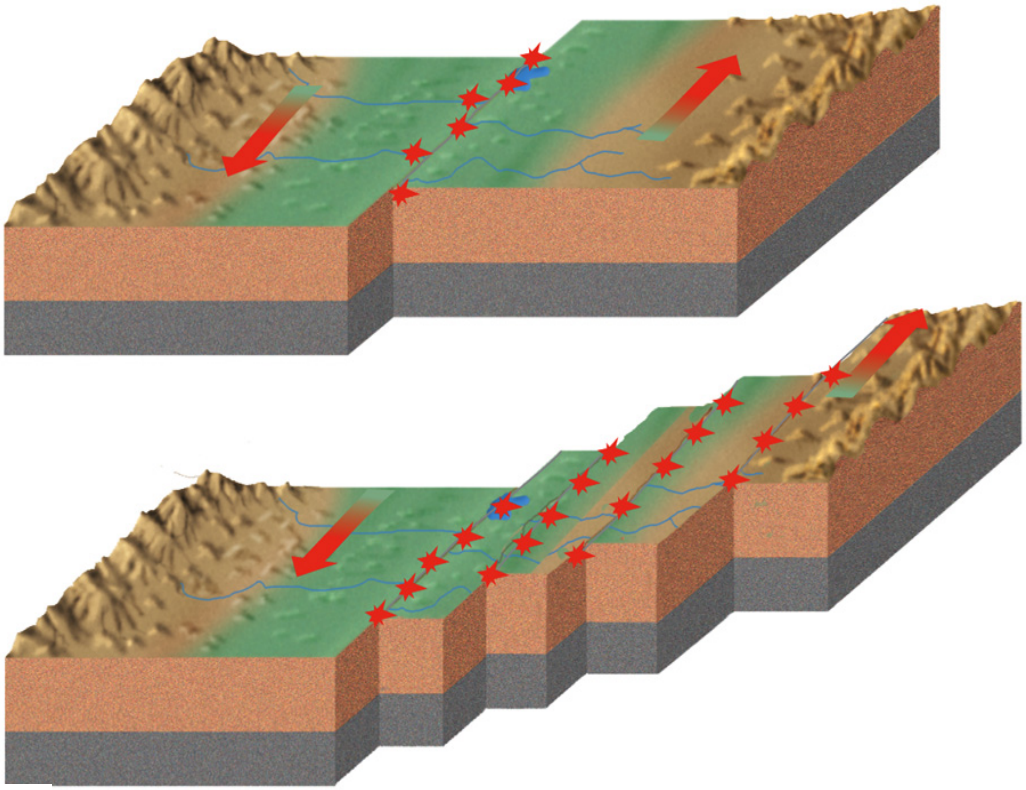
Esempio: l'Hymalaia

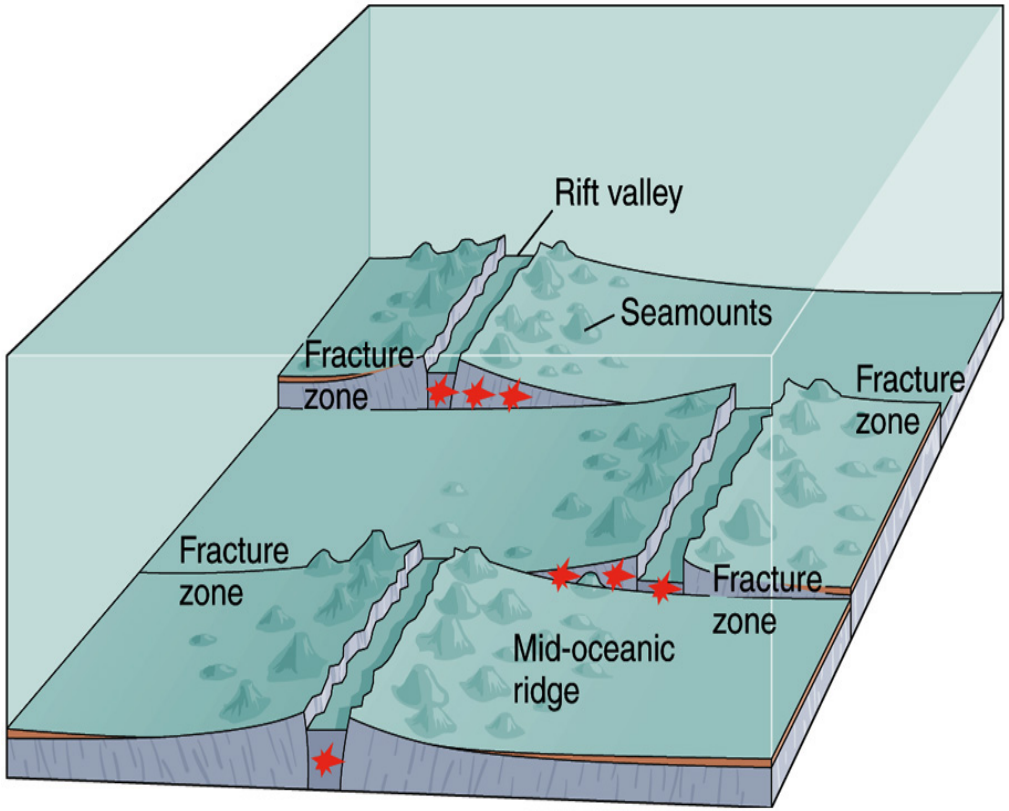
Subduzione della placca continentale dell'India sotto la placca continentale dell'Eurasia.

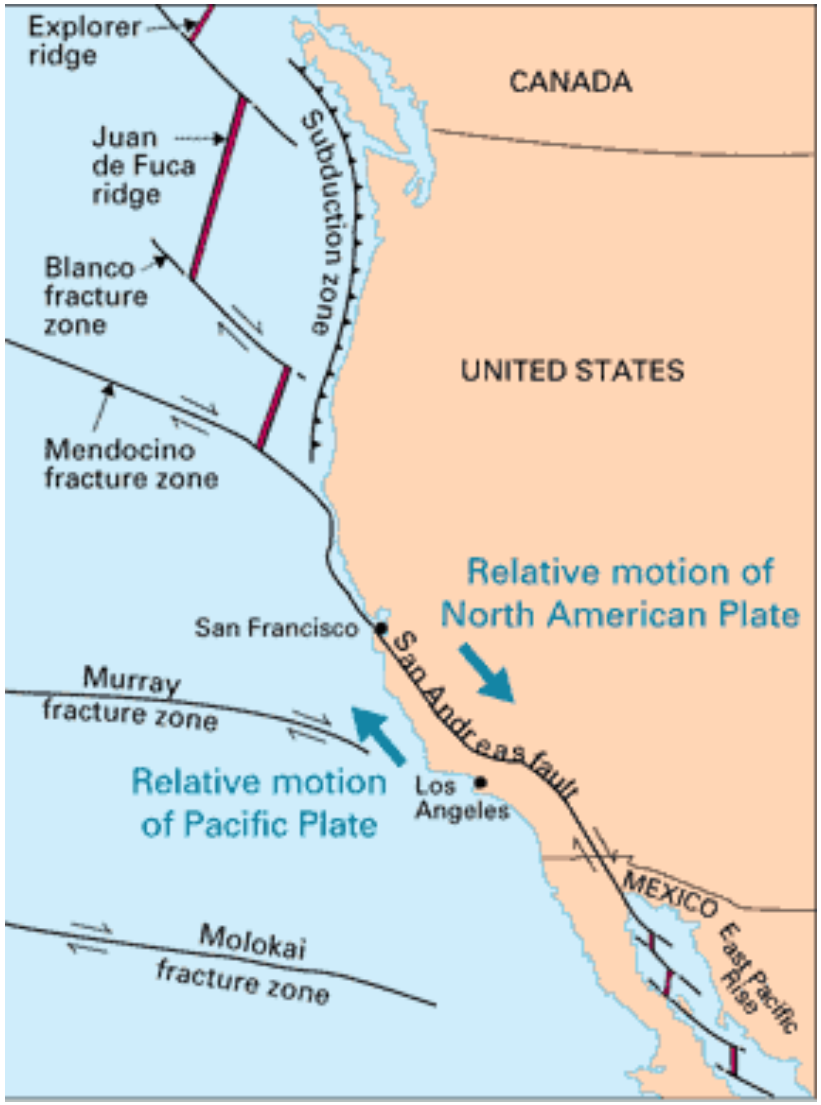




3. Margini trascorrenti

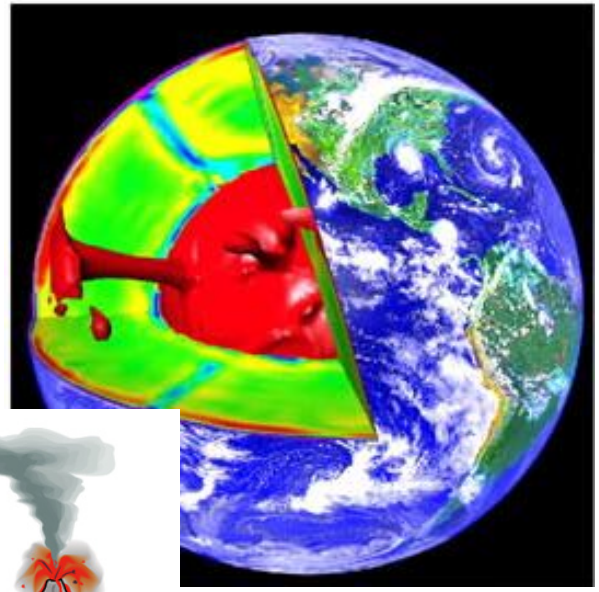


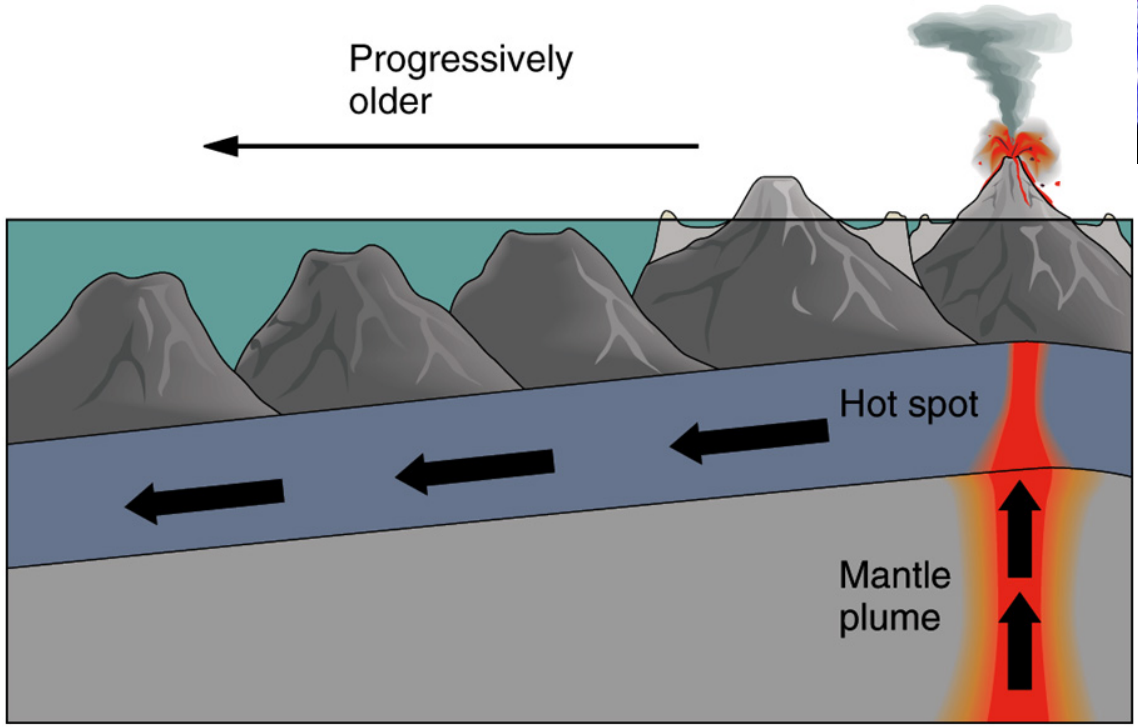


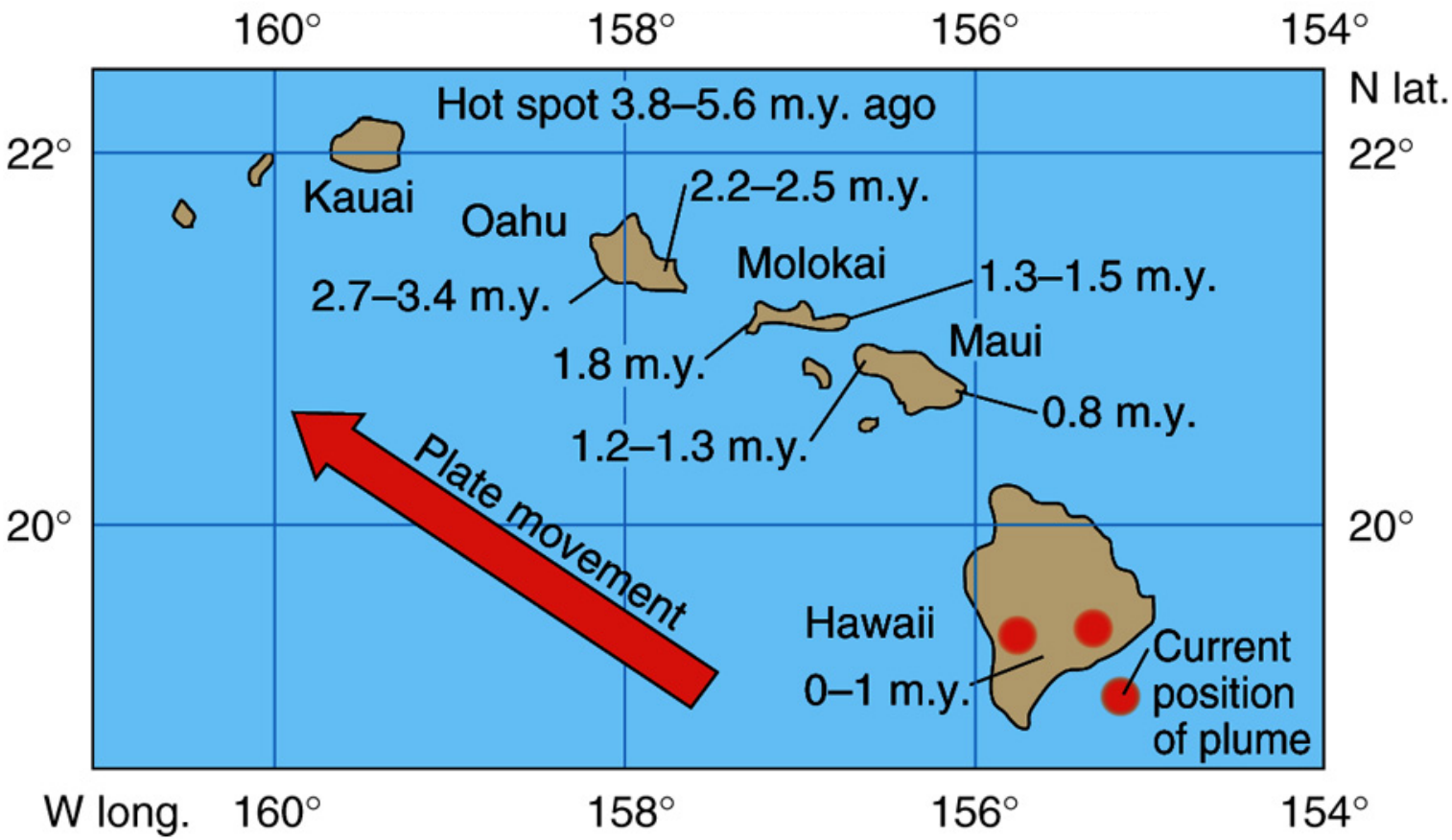

Explorer ridge
Juan de Fuca ridge
Blanco fracture zone
Mendocino fracture zone
Murray fracture zone
Molokai fracture zone
Subduction zone
CANADA
UNITED STATES
MEXICO
San Francisco
Los Angeles
San Andreas fault
East Pacific Rise
Relative motion of North American Plate
Relative motion of Pacific Plate

Hot spots (punti caldi)

I punti caldi sono fissi, ma si muovono le placche






160°
158°
156°
154°
N lat.
22°
Hot spot 3.8–5.6 m.y. ago
Kauai
Oahu
2.2–2.5 m.y.
Molokai
1.3–1.5 m.y.
2.7–3.4 m.y.
1.8 m.y.
Maui
0.8 m.y.
1.2–1.3 m.y.
Plate movement
20°
Hawaii
0–1 m.y.
Current position of plume
W long.

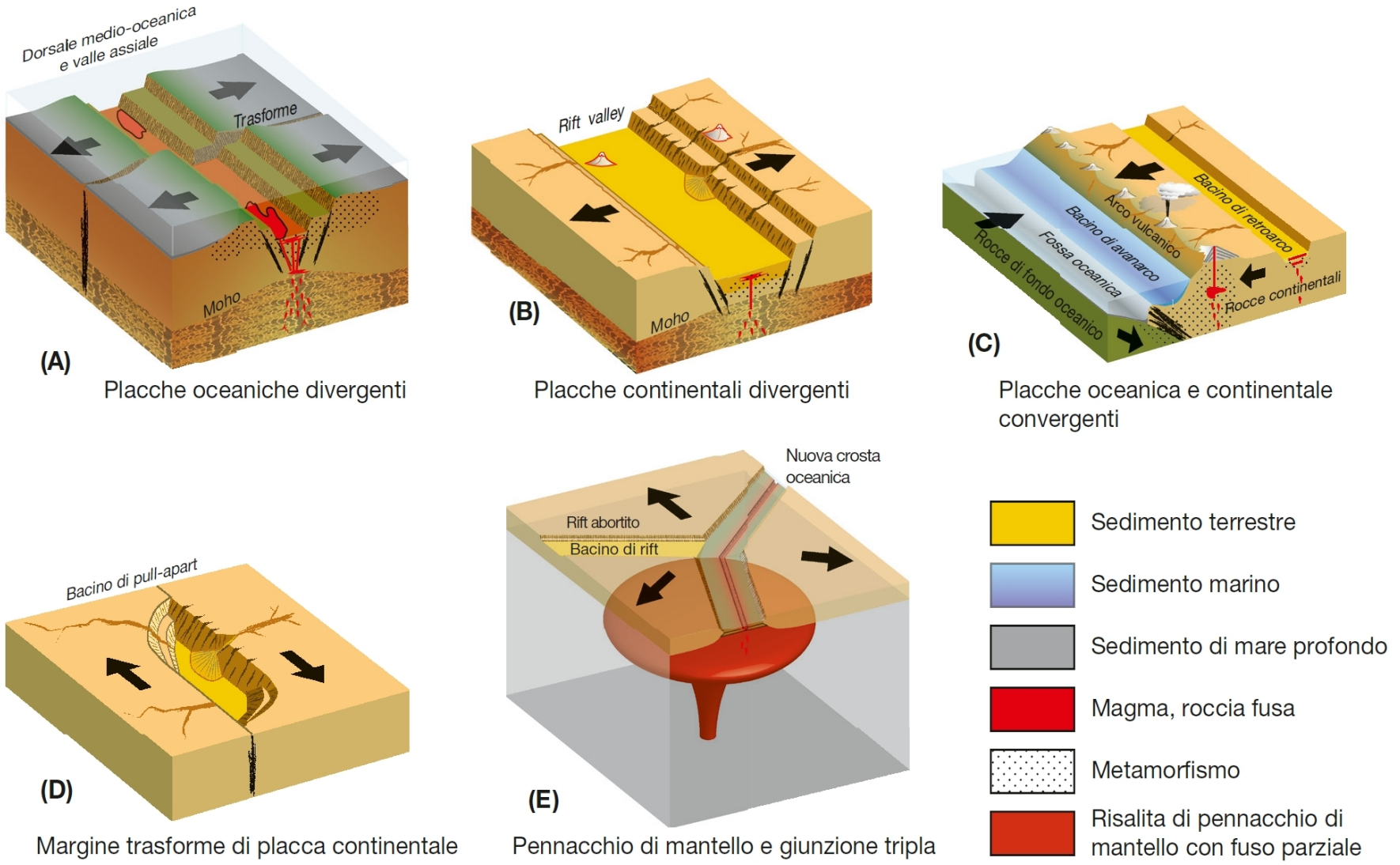


Figura 1.7 Tipi di margini di placca e luoghi di formazione di rocce ignee, sedimentarie e metamorfiche.