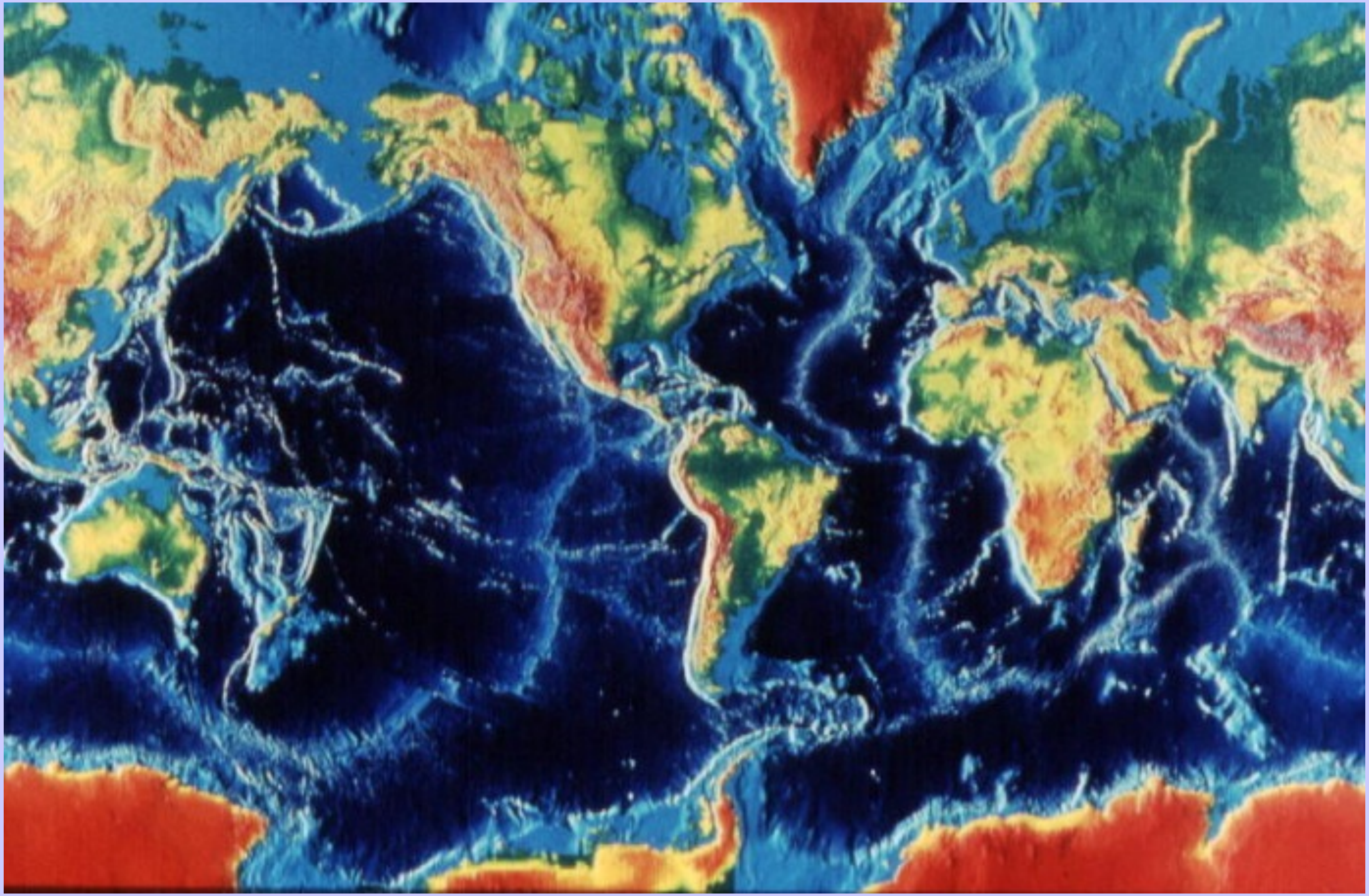
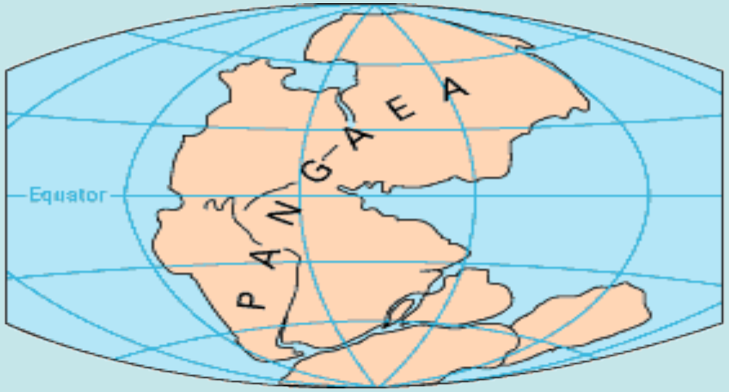
Tectônica de Placas (uma revolução na geociências)

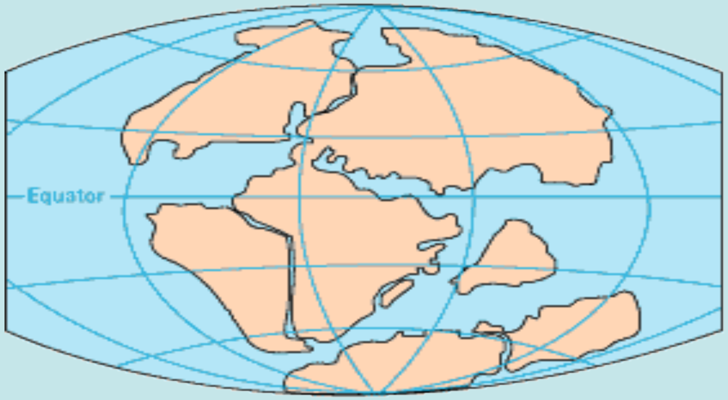
- **-O eixo das cordilheiras meso-oceânicas corresponde a zonas esteitas lineares onde crosta basáltica se forma e se afasta da crista da cordilheira (vários centímetros por ano).**
- **Desde o Jurássico (150 milhões de anos atrás), o oceânico Atlântico tem crescido desde uma bacia estreita até a largura atual. O mesmo é verdadeiro para outras bacias oceânicas.**
- **A presença de faixas de anomalias magnéticas paralela as cristas e aos flancos da cadeia nos oceanos Indico, Artico e Pacífico também indica que o assoalho oceânico está em expansão**
- **Se todos estes oceanos estão em expansão, então o diâmetro da Terra deve estar aumentando proporcionalmente para acomodar toda essa nova área superficial.**
- ***Entretanto, isso é problemático para a Terra uma vez que os geólogos tem determinado que o diâmetro do planeta não mudou apreciávelmente nas ultimas centenas de milhões (até mesmo bilhões de anos).***
- **Como resolver esse dilema ?**



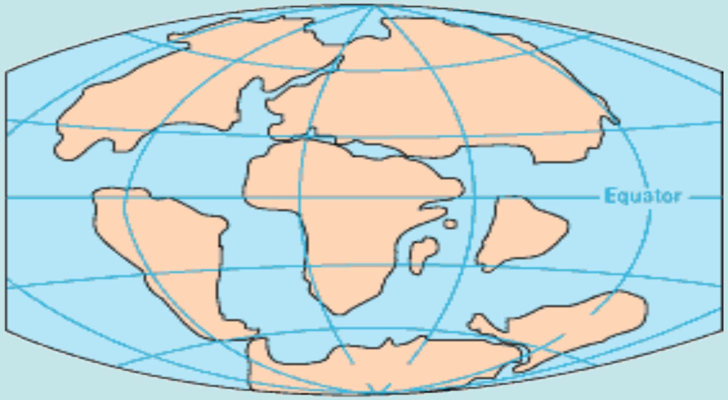


PERMIAN
225 million years ago

TRIASSIC
200 million years ago

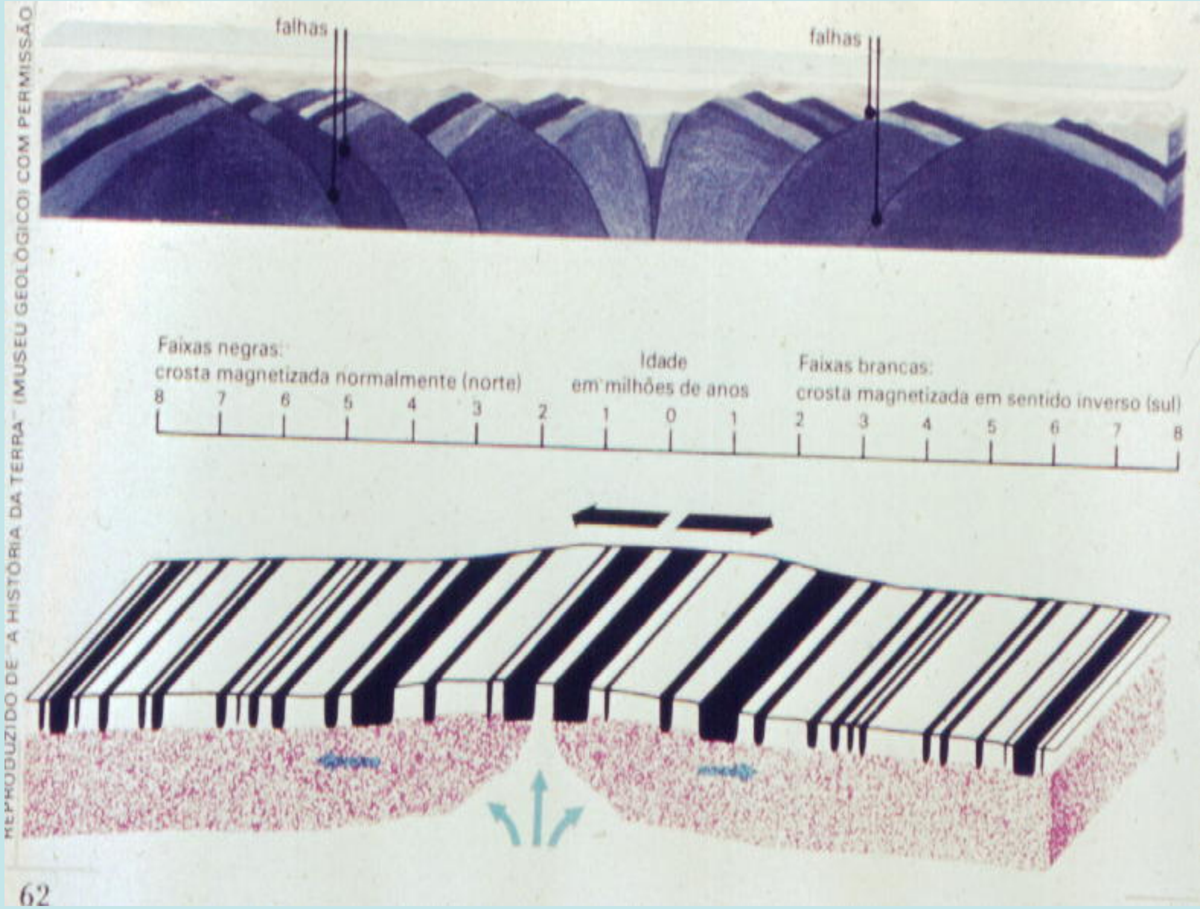


JURASSIC
135 million years ago



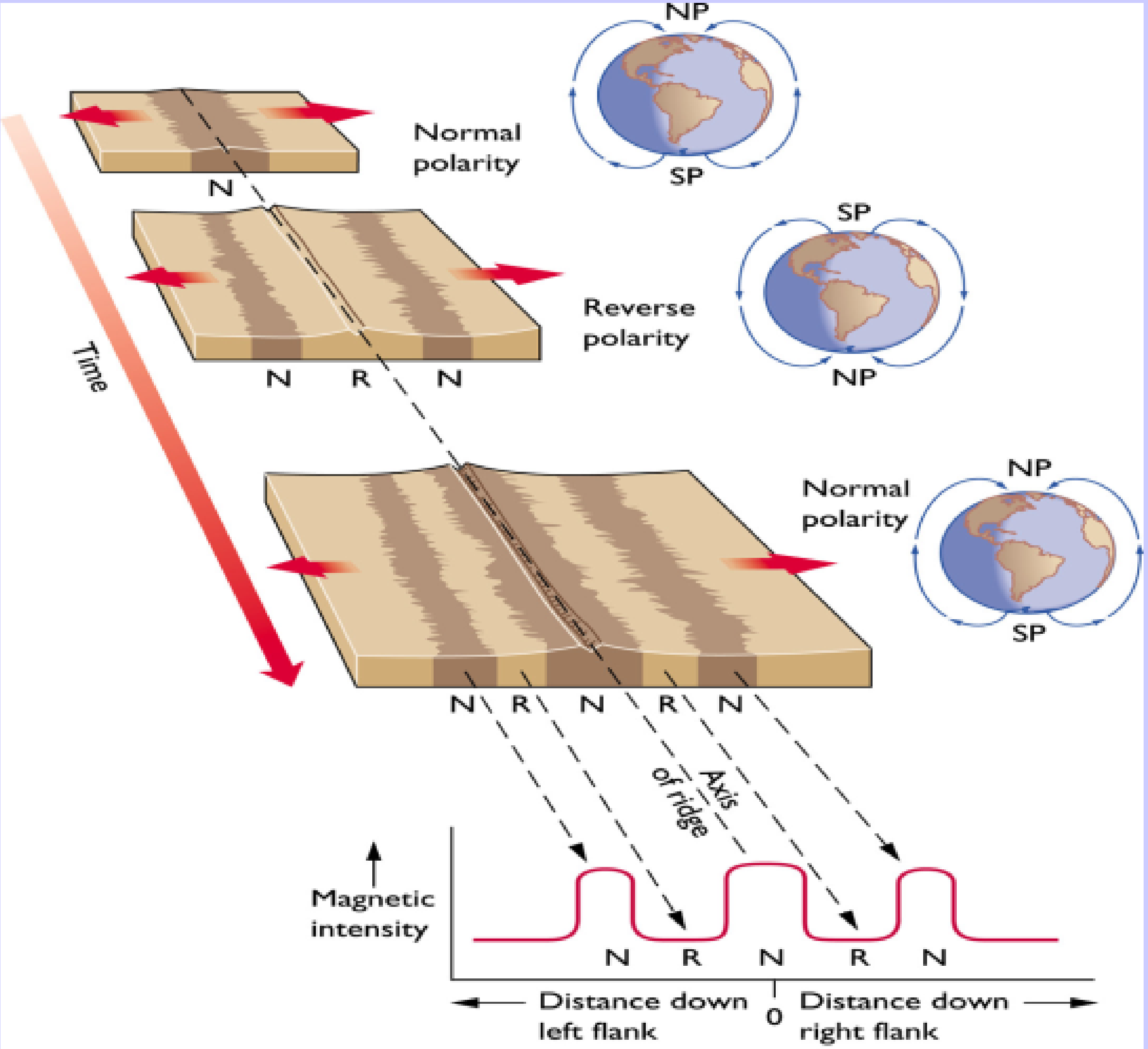
CRETACEOUS
65 million years ago

PRESENT DAY

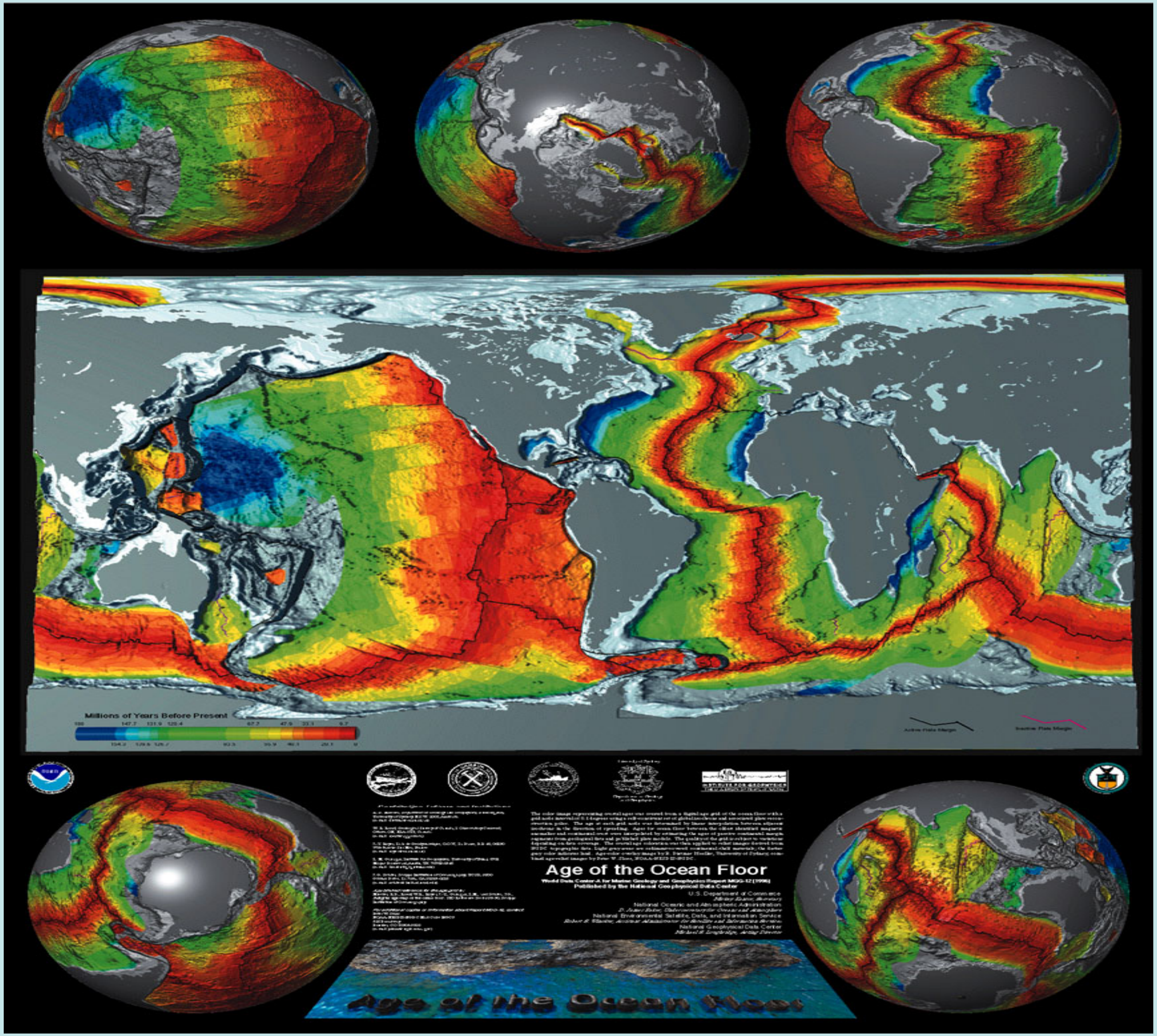


falhas
falhas
Faixas negras:
crosta magnetizada normalmente (norte)
Idade
em milhões de anos
Faixas brancas:
crosta magnetizada em sentido inverso (sul)
8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8
REPRODUZIDO DE "A HISTÓRIA DA TERRA" (MUSEU GEOLÓGICO) COM PERMISSÃO
62

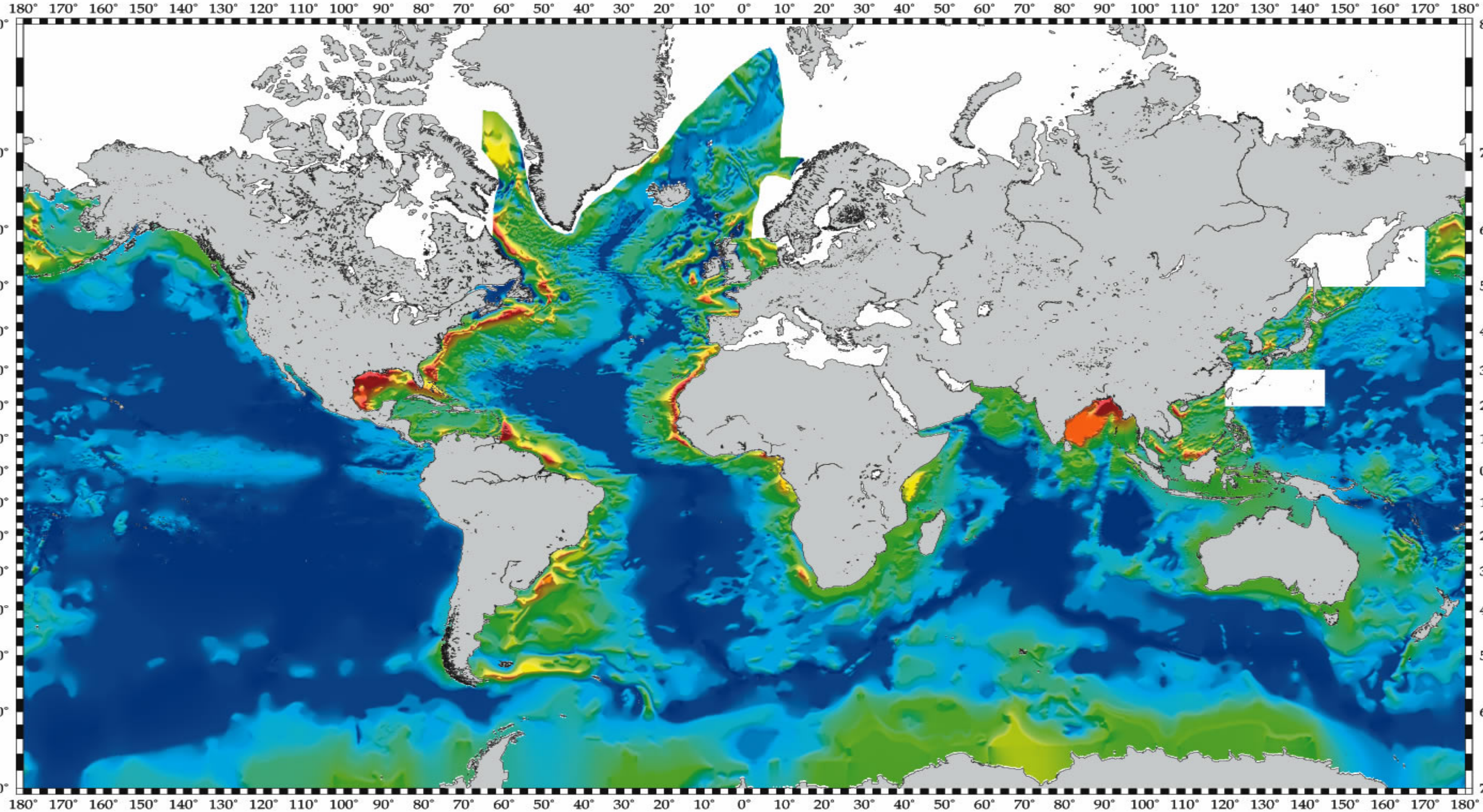
Mid-Atlantic
Ridge



(a) MAGNETIC ANOMALY STRIPES


Millions of Years Before Present
147.7
131.9
120.4
67.7
47.9
23.1
9.7
Age of the Ocean Floor
U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Environmental Satellite, Data, and Information Service
National Geophysical Data Center

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

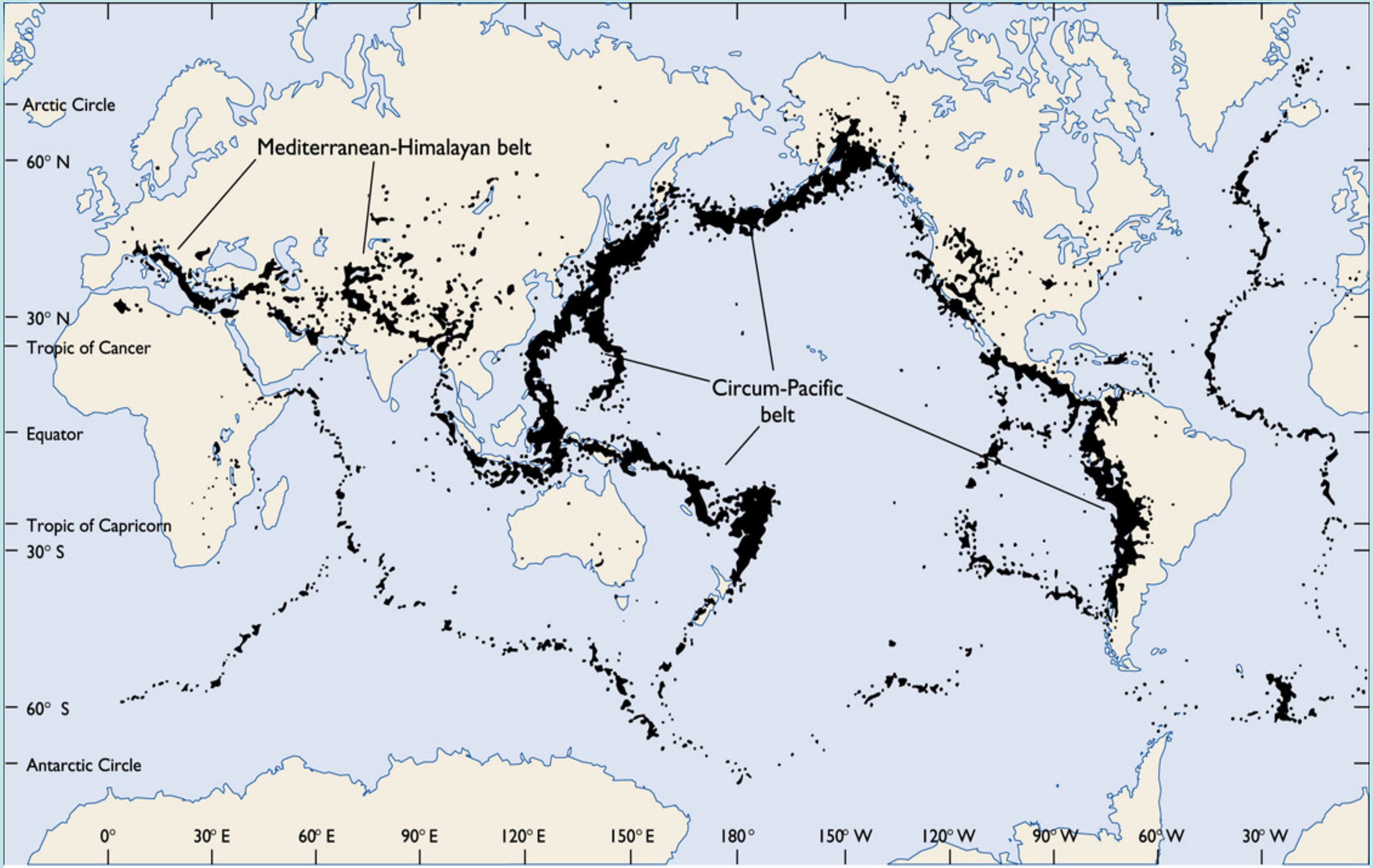
- **Uma maneira : Se o tamanho da Terra é fixo então a adição de novo assoalho oceânico por espalhamento do fundo oceânico deve ser compensado pela destruição de uma área equivalente de assoalho oceânico em algum lugar. Se este for o caso então EFO pode ocorrer numa Terra com diâmetro fixo.**

ZONAS DE SUBDUCÇÃO

- **Se rochas crustais estão sendo amassadas e destruídas a uma taxa equivalente a sua criação nas CMO, esta atividade deve gerar terremotos.**
- **Uma análise da sismicidade mundial (frequência e magnitude/ força) revela dois grupos diferentes**

1) Faixa estreita: Fracos, foco raso, próximos da crista da CMO e das falhas de transformação—associados a falhamentos normais e a falhas de transformação.

2) Faixa larga : Fortes, rasos a profundos contornando as bordas oeste da AN e AS, os arcos ao redor do oeste e Noroeste do Pacífico estendendo-se desde o sul da Ásia até a parte terrestre dos Himalaias e através dos Alpes Europeus.



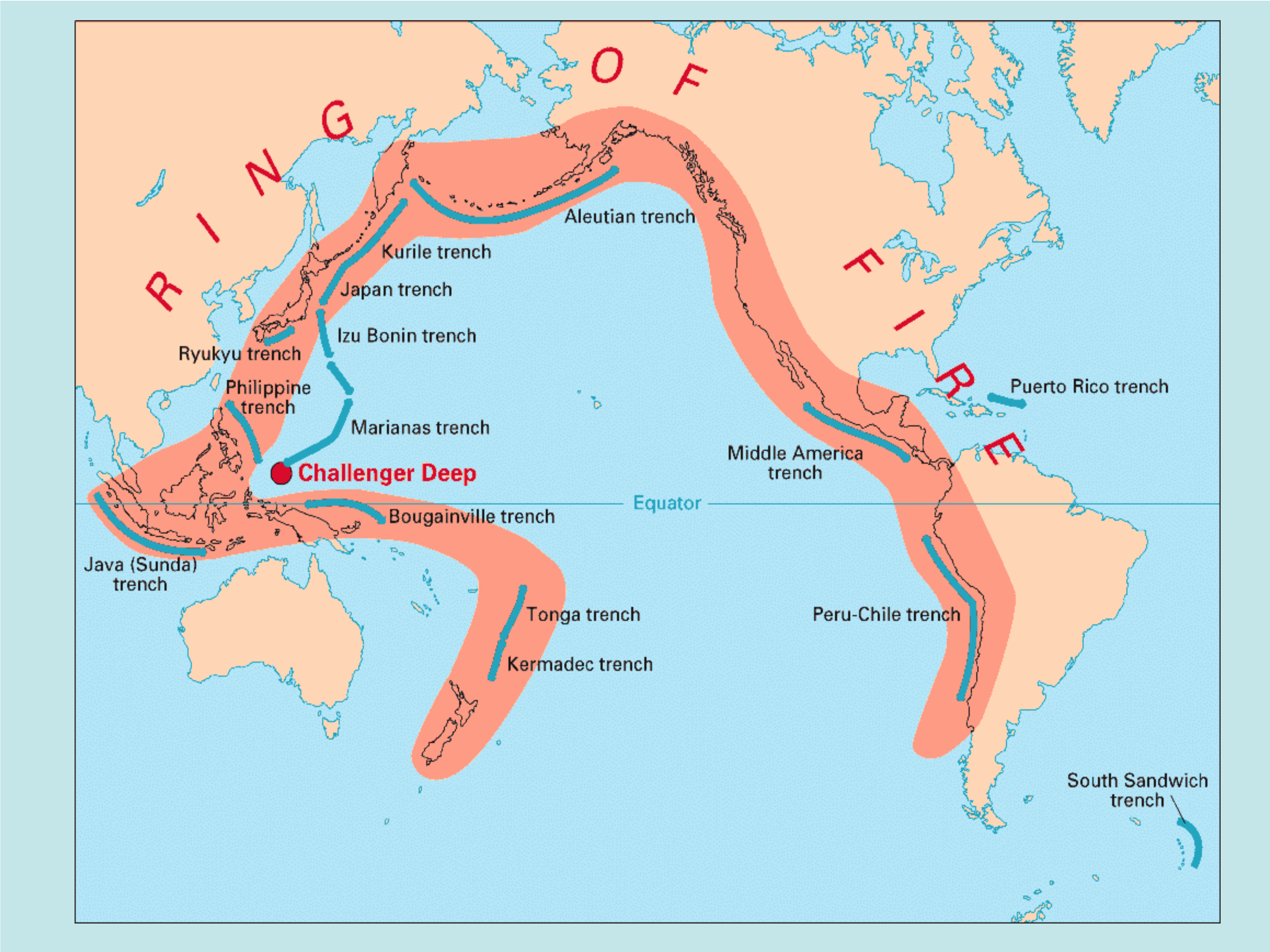
(a) GLOBAL DISTRIBUTION OF EARTHQUAKES

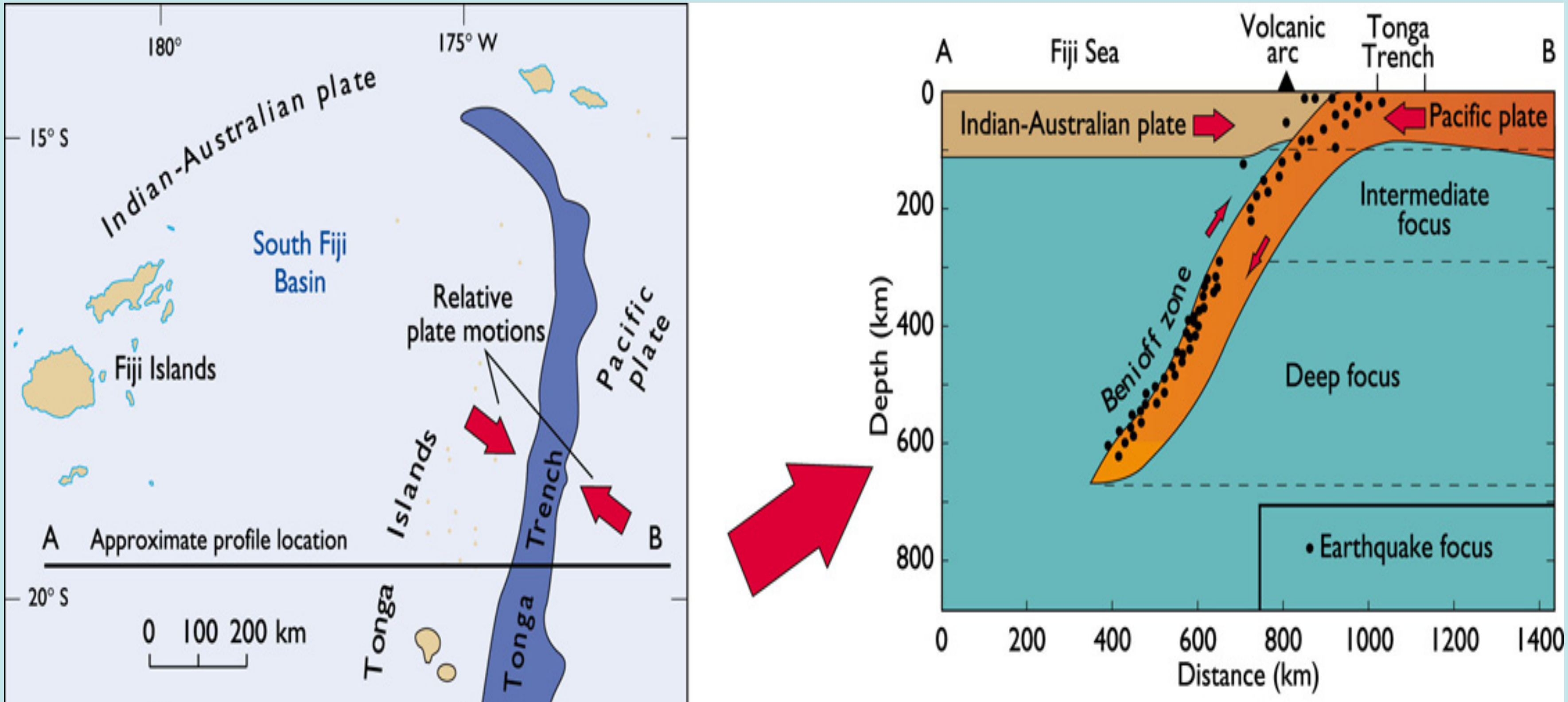
- **A frequência e magnitude dos terremotos denota intenso TECTONISMO (dobramento, curvamento, falhamento, compressão da crosta).**

- **Circundando o Pacífico, terremotos são associados com fossas oceânicas profundas e arcos vulcânicos. Essas massas vulcânicas foram construídas por abundante extrusão de ANDESITOS, uma lava com composição intermediária entre o Granito e o Basalto .**

- **Depósitos sedimentares e vulcânicos entre os vulcões ativos e as fossas estão altamente deformados, dobrados e fraturados implicando que a crosta oceânica está sofrendo redução por forças compressionais poderosas.**

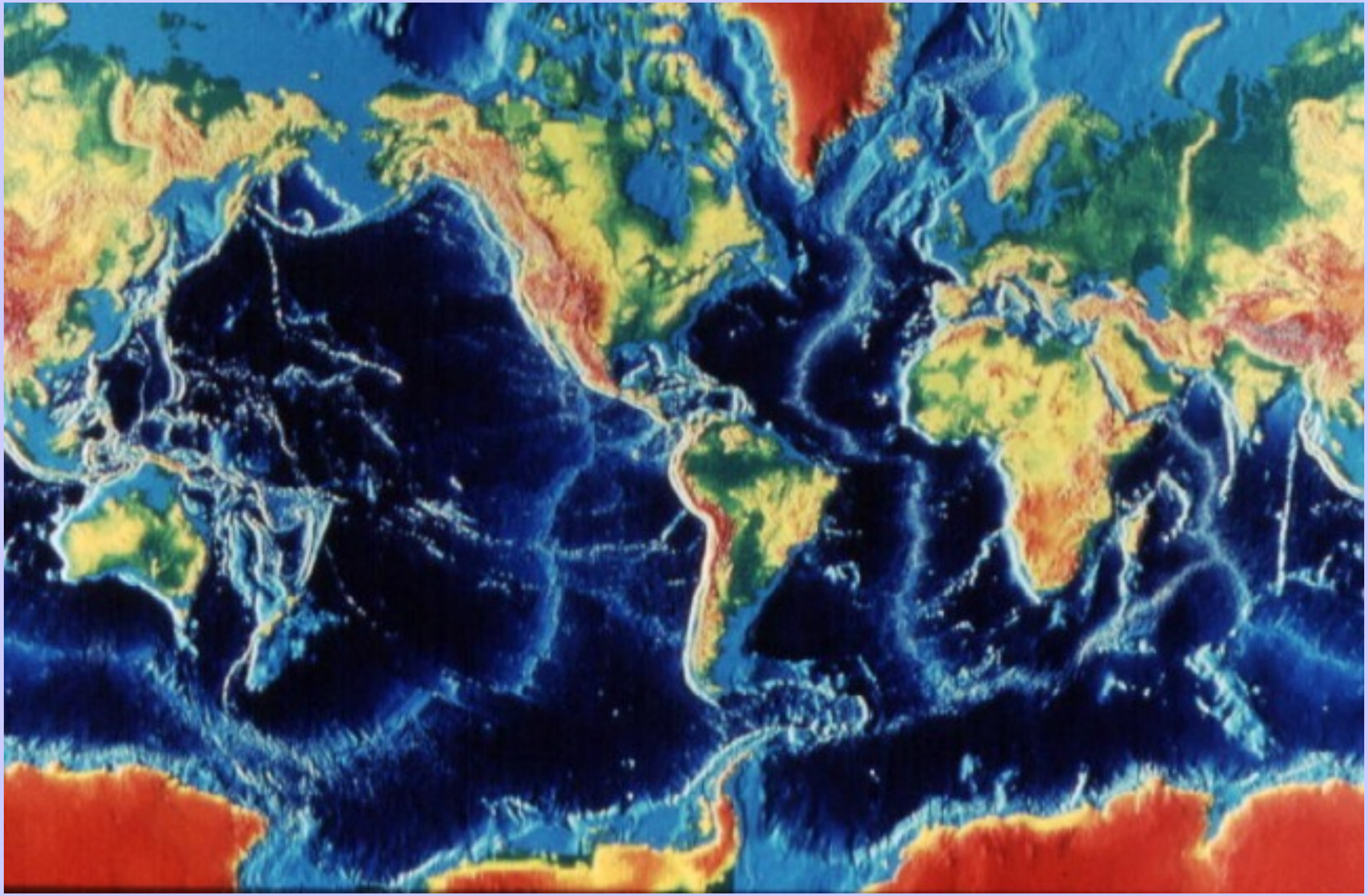
- **Distribuição precisa de terremotos nos sistemas arco-fossa mostra que não é aleatória, mas sim apresenta um padrão ordenado sendo que os de foco profundos e intermediários se distânciam da fossa e mergulham com inclinação abaixo do arco de ilhas (700 Km)---ZONA de BENIOFF(placas rochosas que mergulham no interior do manto superior—sofrem fusão parcial a profundidades de 100 a 200 Km). O material quente, menos denso sobe então sai dos vulcões como lava andesítica .**


RING OF FIRE
Aleutian trench
Kurile trench
Japan trench
Izu Bonin trench
Ryukyu trench
Philippine trench
Marianas trench
Challenger Deep
Equator
Bougainville trench
Java (Sunda) trench
Tonga trench
Kermadec trench
Middle America trench
Puerto Rico trench
Peru-Chile trench
South Sandwich trench



(b) SOUTH FIJI BASIN AND CROSS SECTION SHOWING BENIOFF ZONE

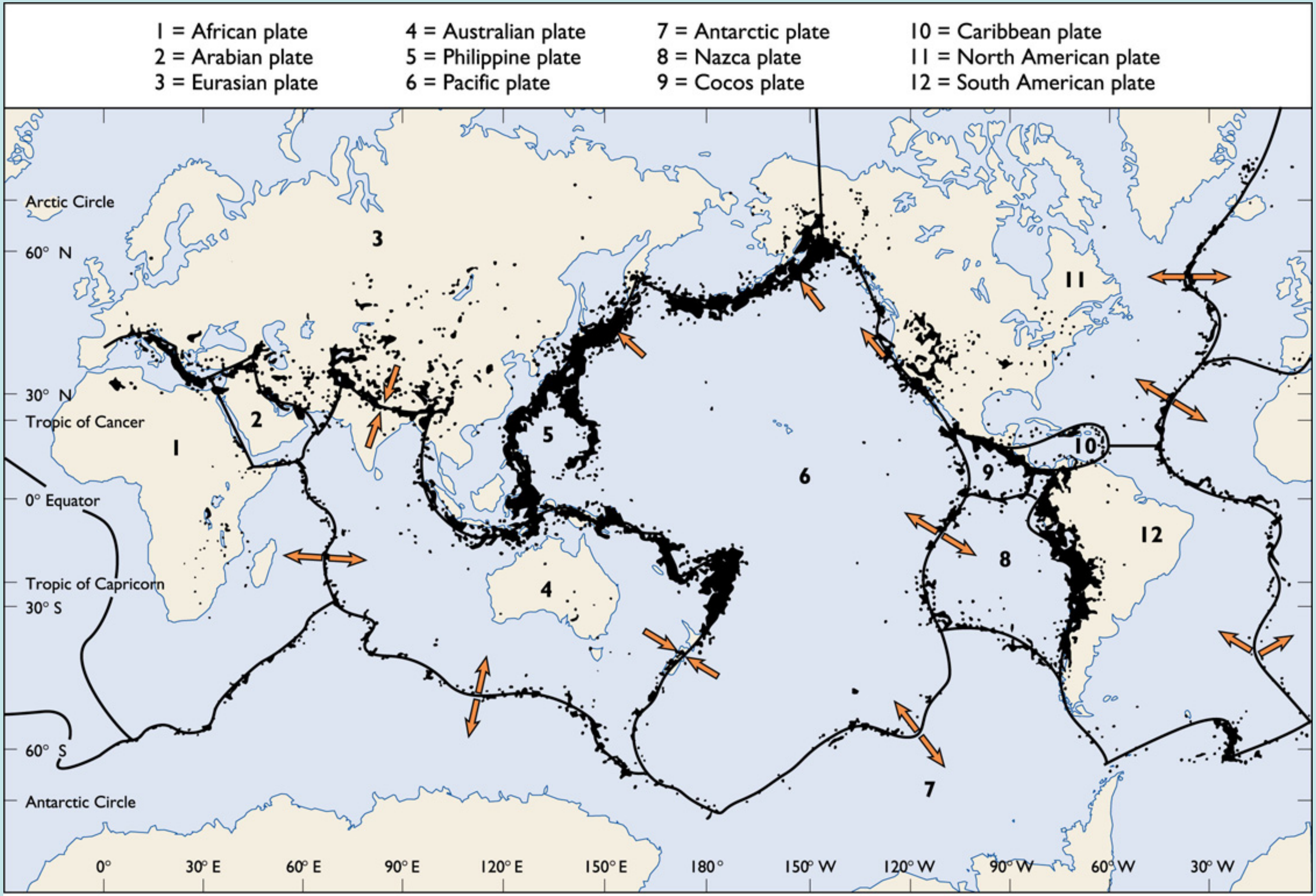
- **Poucas zonas de subducção são evidentes nos oceanos Atlântico, Indico e Ártico—CMO são as principais feições tectônicas**
- **Sómente nas bordas do Pacífico achamos ZS quase contínuas onde as taxas de consumo chegam a atingir entre 15 e 45 cm/ano. *Essas taxas são mais rápidas do que as de EFO porque existem mais EFO do que ZS*.**
- **Por outro lado a falta de ZS no Atlântico, Indico e Artico indicam que estes oceanos estão em expansão – e o Pacífico está encolhendo rápidamente em termos geológicos embora também crosta oceânica esteja se formando ao longo de sua Cordilheira meso oceânica na EAST PACIFIC RISE (cordilheira leste do Pacífico) como mostram todas as evidências para outras áreas (anomalias magnéticas, crosta nova, vulcanismo submarino etc....).**



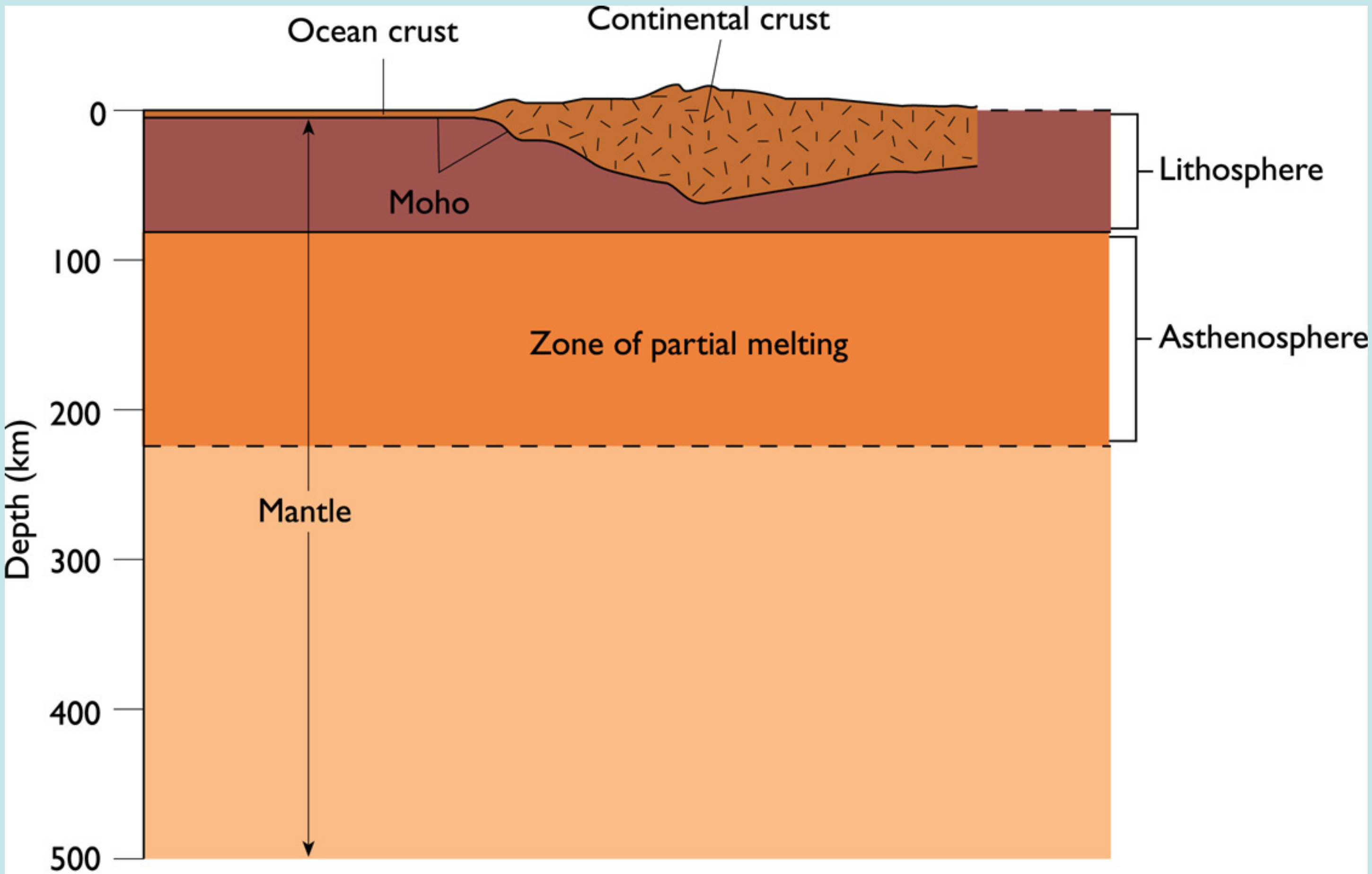

Koyukuk terrane
ALASKA
Aleutian Trench
Wrangellia terrane
PACIFIC PLATE
CANADA
Alexander terrane
JUAN DE FUCA PLATE
Cascadia Trench
NORTH AMERICAN PLATE
Sonoma terrane
SAN ANDREAS FAULT
UNITED STATES
Salton Trough
Guerrero terrane
MEXICO
East Pacific Rise
EXPLANATION
Island arc
Submarine deposits
Ancient ocean floor
Attached fragments
Ancient continental interior (craton)
Divergent boundary
Convergent boundary
Transform boundary

O modelo da Tectônica de Placas ou Tectônica Global

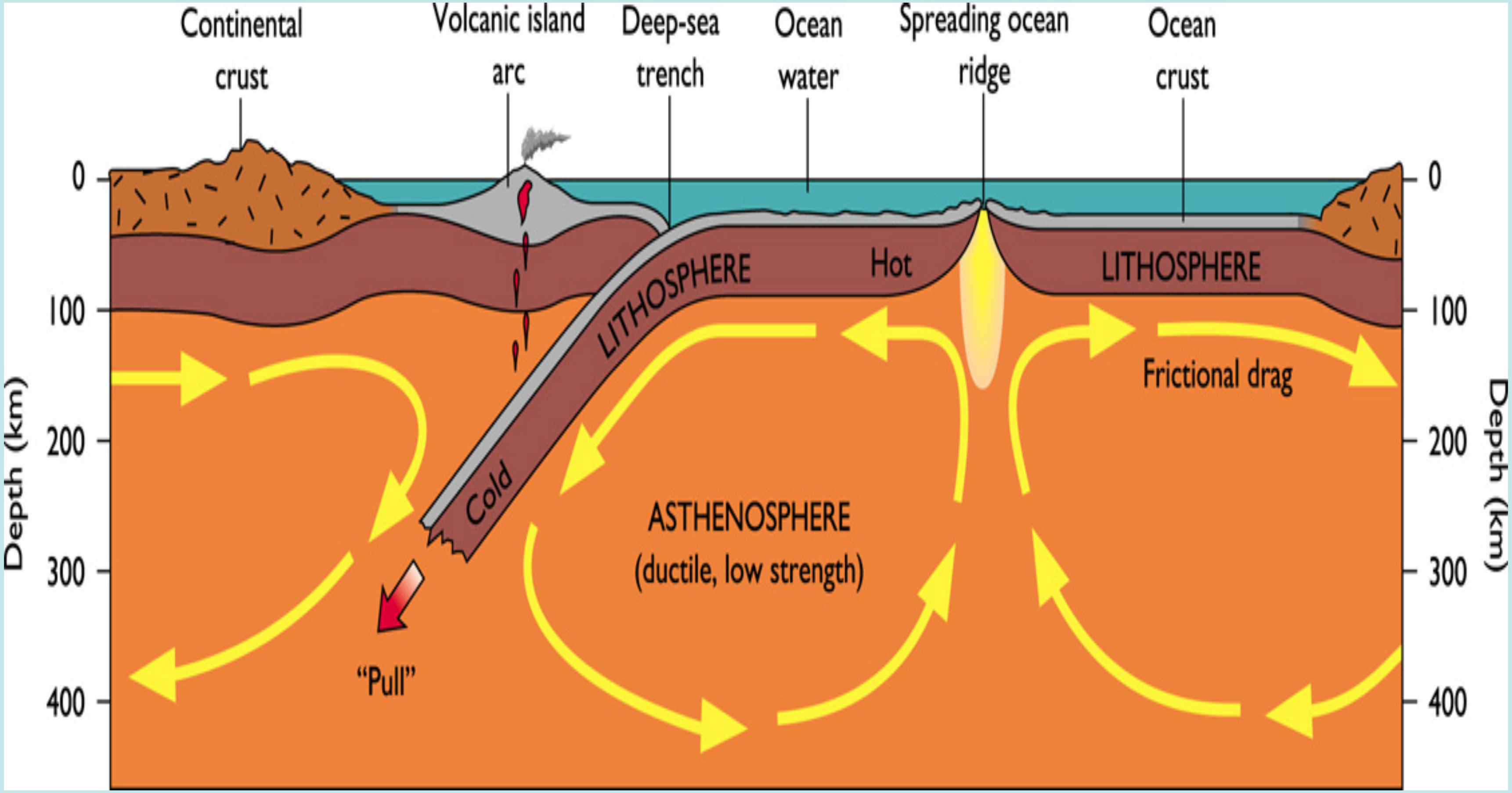
- **Podemos combinar tudo que vimos sobre EFO num conceito unificado chamado de Tectônica Global das Placas, conceito formulado na década de 60 o qual revolucionou a história geológica da Terra. J.Tuzo Wilson (1965) e W.J. Morgan (1968)**
- **A idéia básica da teoria é que a Superficie da Terra é dividida em uma série de Placas com margens que são definidas pela SISMICIDADE.**
- **As placas podem constituir-se principalmente de assoalho oceânico, ou mais comumente de alguma combinação entre assoalho oceânico (crosta oceânica) e uma massa continental (crosta continental).**
- **O limite estende-se para baixo através de toda a litosfera, a qual é a camada externa quebradiça que inclui a crosta e o manto superior—PLACAS LITOSFÉRICAS.**
- **Sismicidade e vulcanismo não estão distribuídos aleatóriamente sobre a superfície da Tera, ao contrario são confinados as bordas das placas.**

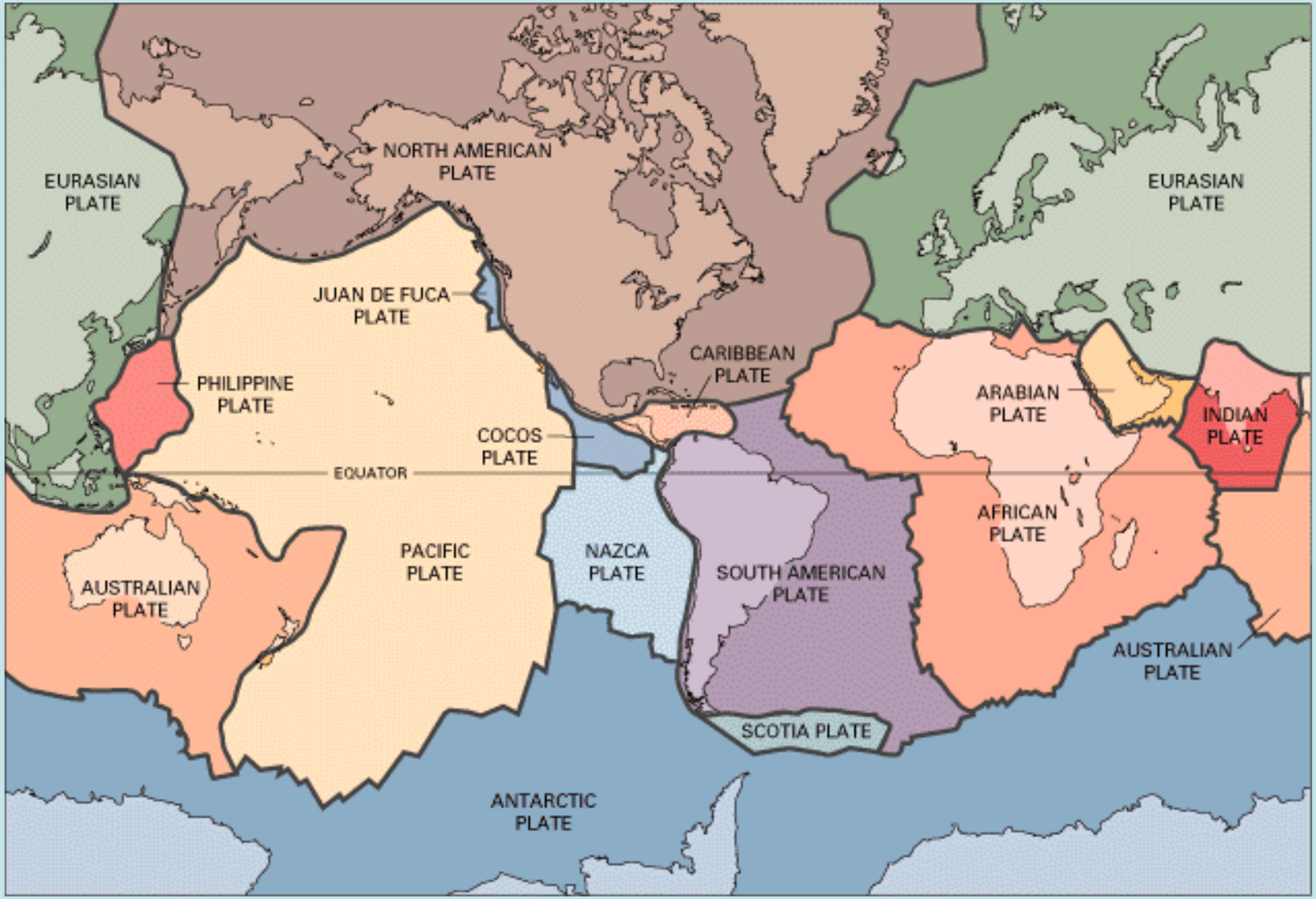


(a) LITHOSPHERIC PLATES



(b) THE LITHOSPHERE AND THE ATHENOSPHERE


Continental crust
Volcanic island arc
Deep-sea trench
Ocean water
Spreading ocean ridge
Ocean crust
0
100
200
300
400
Depth (km)
LITHOSPHERE
Hot
LITHOSPHERE
Frictional drag
Cold
ASTHENOSPHERE
(ductile, low strength)
"Pull"
0
100
200
300
400
Depth (km)


NORTH AMERICAN PLATE
EURASIAN PLATE
EURASIAN PLATE
JUAN DE FUCA PLATE
CARIBBEAN PLATE
PHILIPPINE PLATE
ARABIAN PLATE
INDIAN PLATE
COCOS PLATE
EQUATOR
AFRICAN PLATE
PACIFIC PLATE
NAZCA PLATE
SOUTH AMERICAN PLATE
AUSTRALIAN PLATE
AUSTRALIAN PLATE
SCOTIA PLATE
ANTARCTIC PLATE

Existem tres tipos fundamentais de limites de placas.

- **Limites divergentes** (distensão)—CMO—geração
- **Limites convergentes** (compressão—ZS) consumo-uma cavalga a outra que é consumida—andesito aparece em picos vulcânicos nos altos Andes. Subducção também aparece onde duas massas continentais colidem como nos Himalaias
- **Falhas de Transformação** –limites de placas onde fundo oceânico não é criado nem destruído. A placas resvalam lateralmente. ***Embora haja uma variedade de limites transformantes, os mais comuns são os que conectam dois segmentos das cadeias meso-oceânicas como se estivessem deslocados um do outro***.

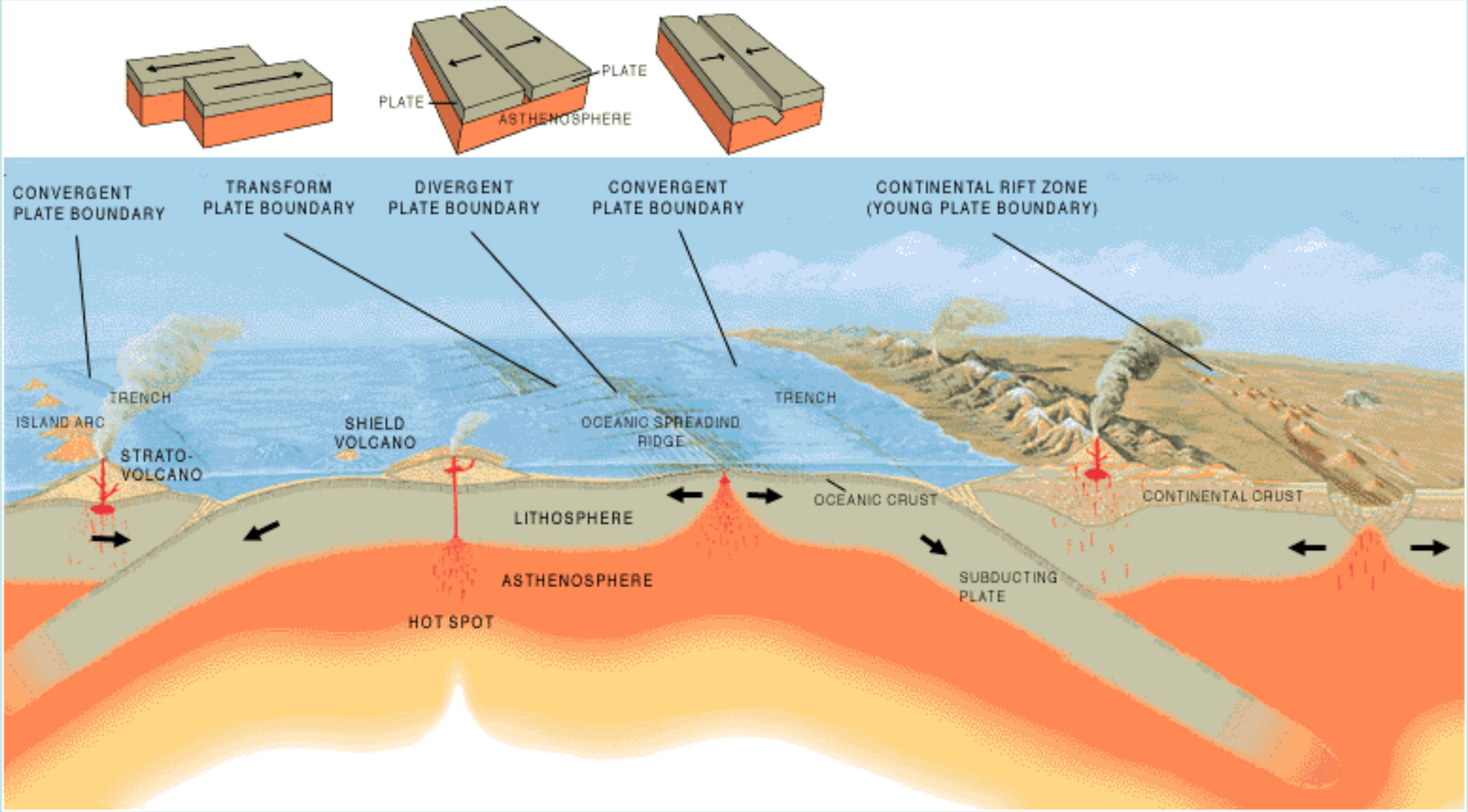


PLATE
PLATE
ASTHENOSPHERE
CONVERGENT
PLATE BOUNDARY
TRANSFORM
PLATE BOUNDARY
DIVERGENT
PLATE BOUNDARY
CONVERGENT
PLATE BOUNDARY
CONTINENTAL RIFT ZONE
(YOUNG PLATE BOUNDARY)
TRENCH
ISLAND ARC
STRATO-
VOLCANO
SHIELD
VOLCANO
OCEANIC SPREADIND
RIDGE
TRENCH
OCEANIC CRUST
CONTINENTAL CRUST
LITHOSPHERE
ASTHENOSPHERE
HOT SPOT
SUBDUCTING
PLATE

EXPLANATION

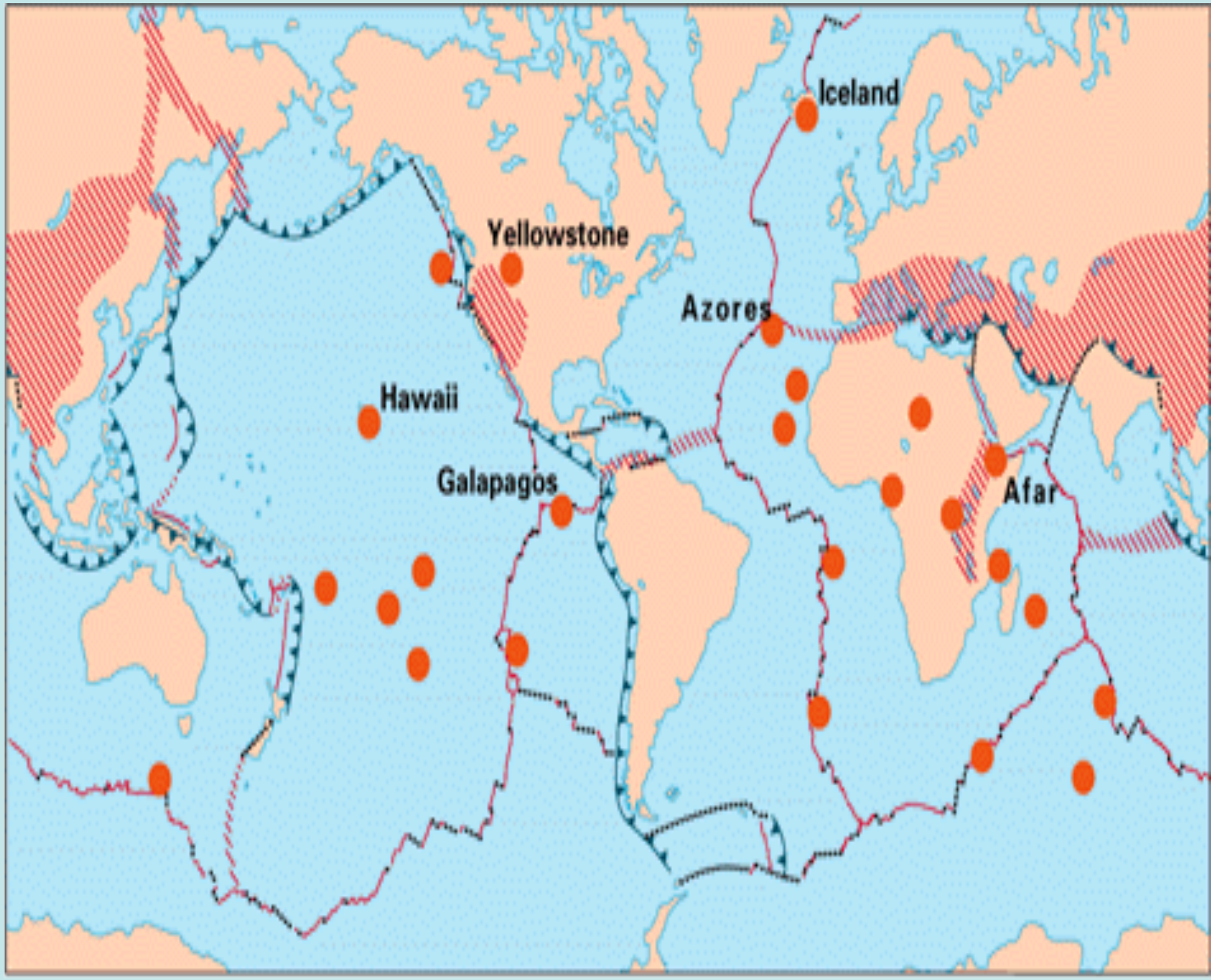
Divergent plate boundaries—
Where new crust is generated as the plates pull away from each other.

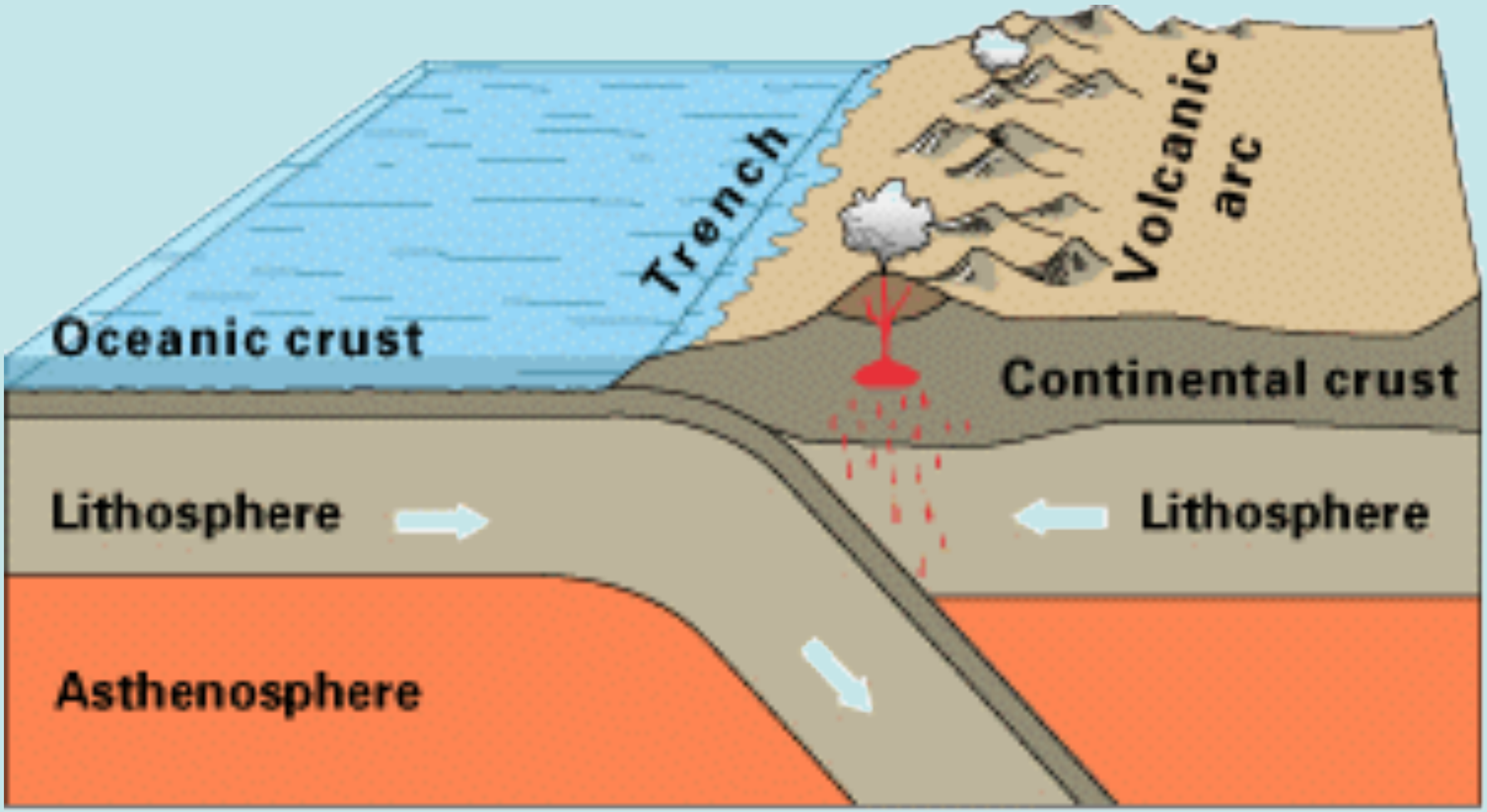
Convergent plate boundaries—
Where crust is consumed in the Earth's interior as one plate dives under another.

Transform plate boundaries—
Where crust is neither produced nor destroyed as plates slide horizontally past each other.

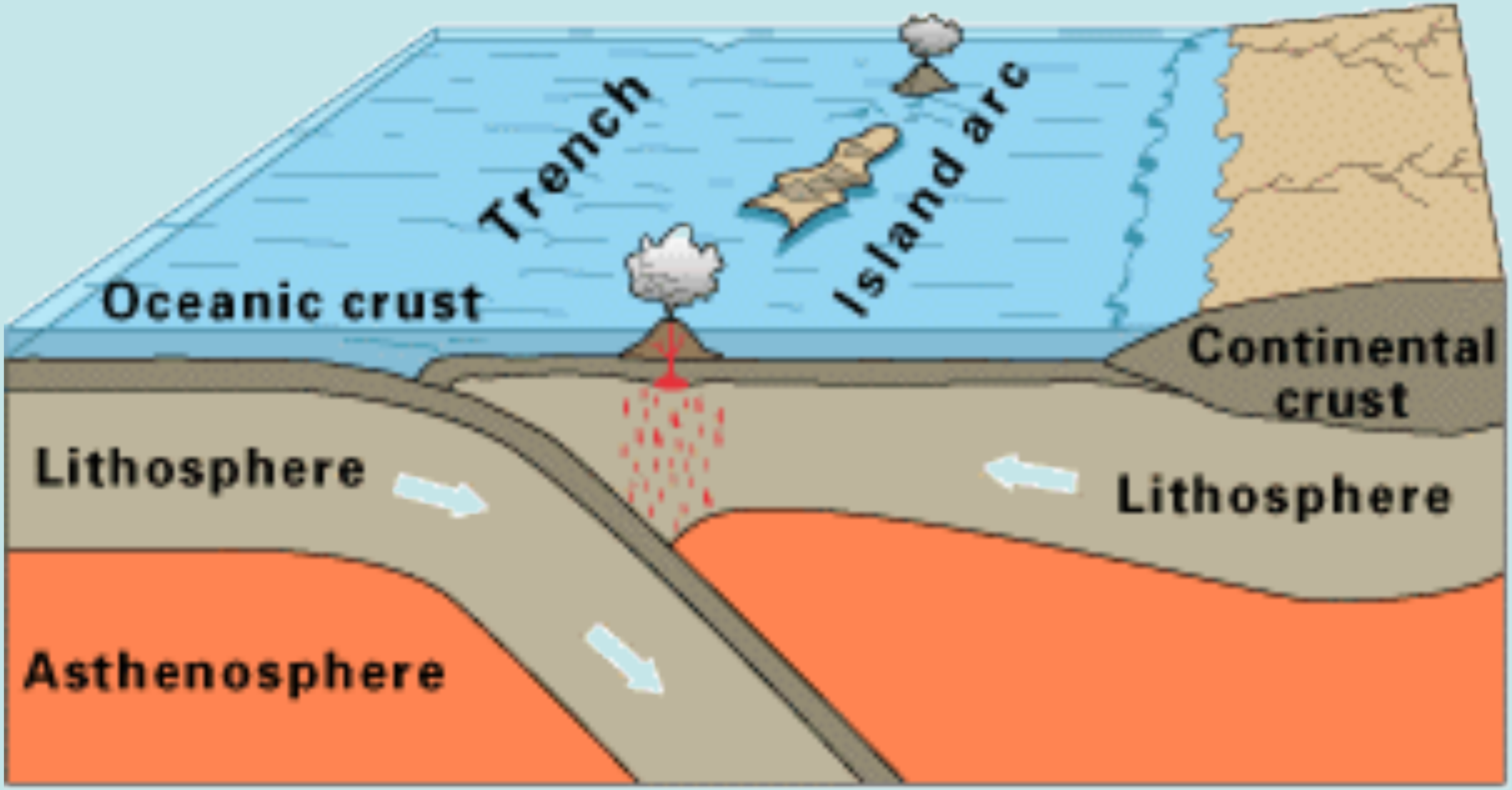
Plate boundary zones—Broad belts in which deformation is diffuse and boundaries are not well defined.

Selected prominent hotspots

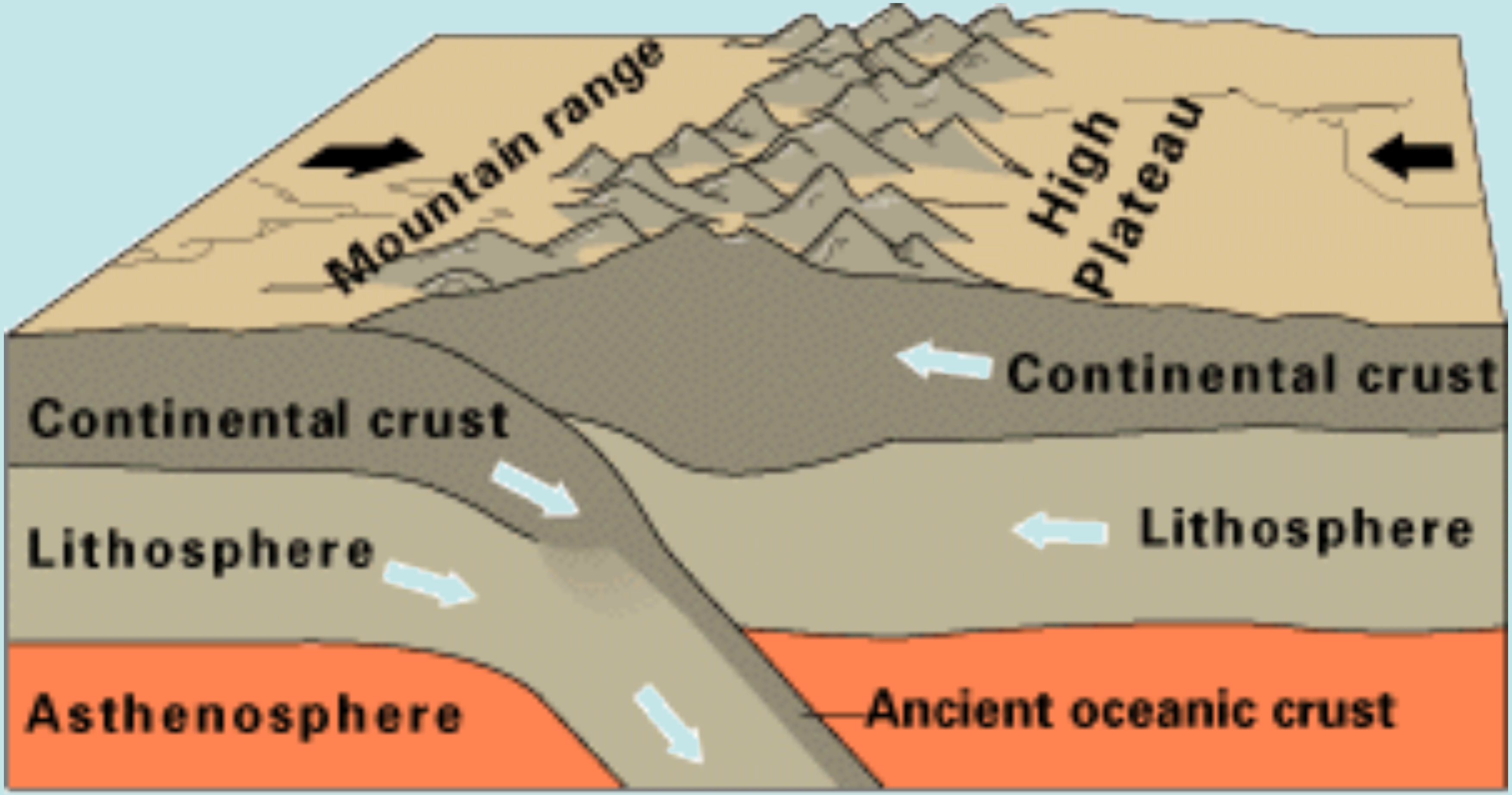




Oceanic-continental convergence



Oceanic-oceanic convergence

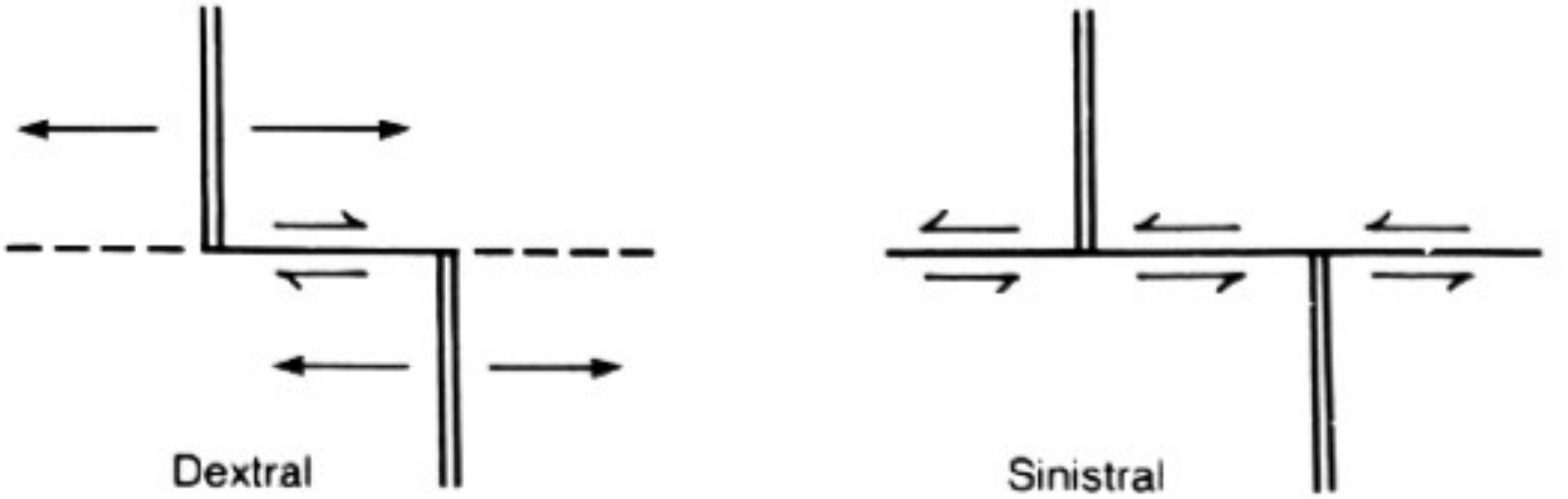


Continental-continental convergence

- **A maioria das bordas das placas estão sob a água , sendo estudadas por métodos indiretos (sísmica, magnetometria, fluxo de calor etc..)**
- **Uma exceção, é a exposição de um sistema de Falhas complexas conhecida como ”Falha de San Andreas” que corta a zona terrestre na região oeste e sul da Califórnia.**
- **Vista áerea da paisagem que bordeja esta falha mostra uma topografia linear tendo na base rochas fraturadas crustais que foram forçadas para cima em montanhas com penhascos ou para baixo na forma de vales fragmentados.**
- **Terremotos intensos e poderosos caracterizam a área com falhamentos tipo grab (diretos) ou mesmo transformantes (como aqueles entre as placas que derivam em sentido contrário no eixo das cordilheiras meso-oceânicas).**
- **A razão para esta atividade tectônica, é que este sistema de falha de 1300 Km de comprimento representa o limite das placas (limite de transformação) que separa a placa Pacífica da Norte-Americana**

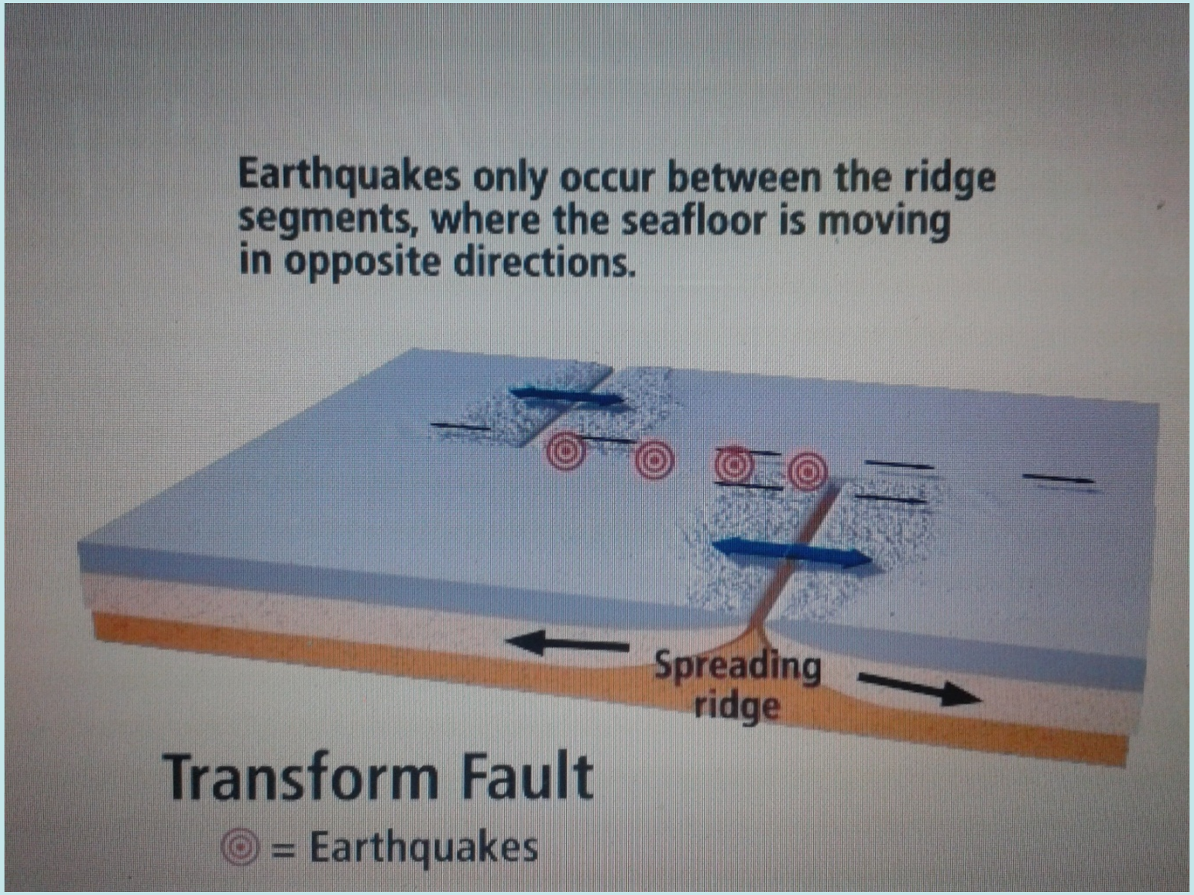
- A falha de San Andreas é uma falha de transformação longa que junta dois centros de espalhamento ,um localizado no Golfo da Califórnia e outro no noroeste dos EUA e sudoeste do Canadá

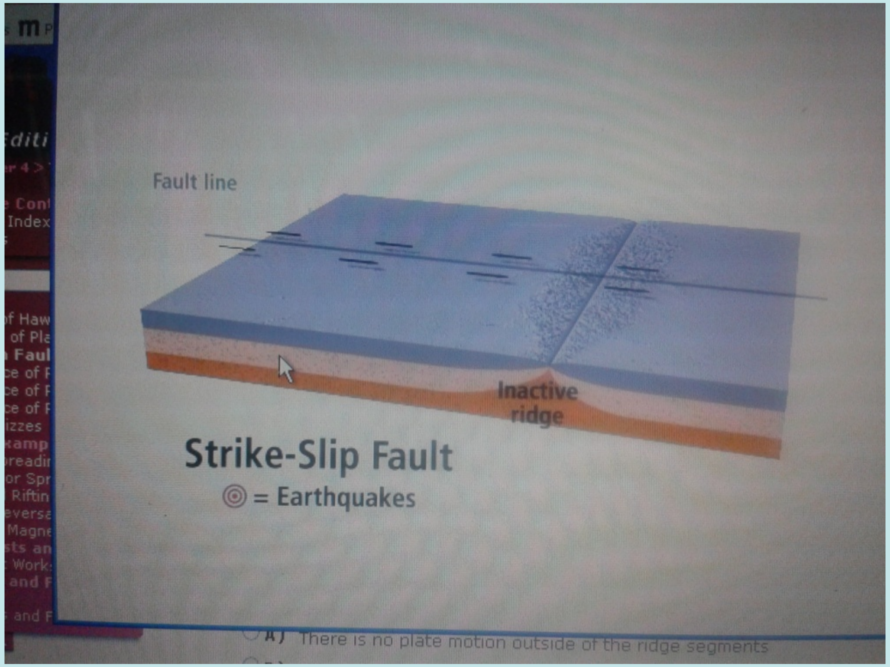
Koyukuk terrane
ALASKA
Aleutian Trench
Wrangellia terrane
PACIFIC PLATE
CANADA
Alexander terrane
JUAN DE FUCA PLATE
Cascadia Trench
EXPLANATION
Island arc
Submarine deposits
Ancient ocean floor
Attached fragments
Ancient continental interior (craton)
Divergent boundary
Convergent boundary
Transform boundary
NORTH AMERICAN PLATE
Sonoma terrane
SAN ANDREAS FAULT
UNITED STATES
Salton Trough
Guerrero terrane
MEXICO
East Pacific Rise

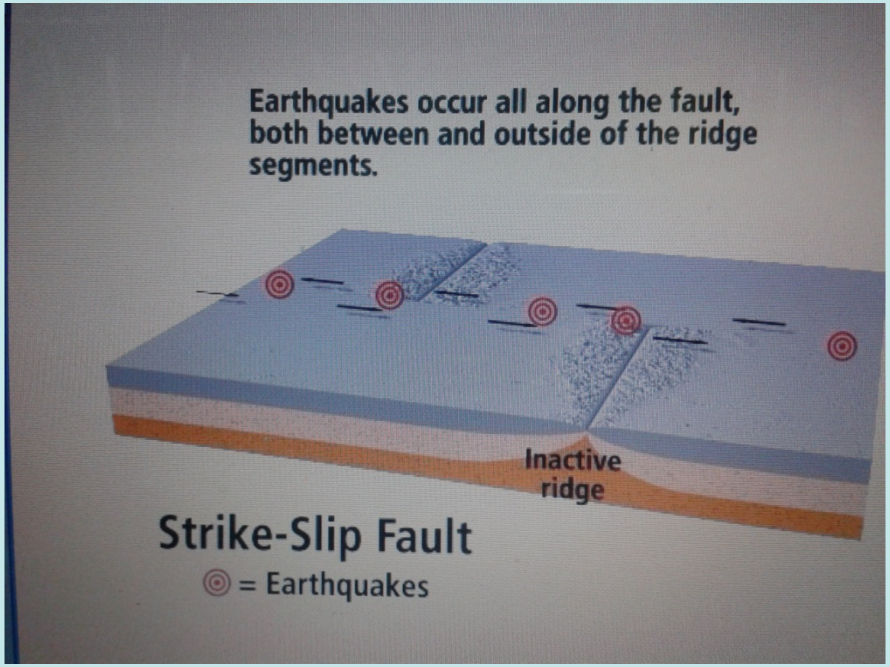


(a) Transform fault

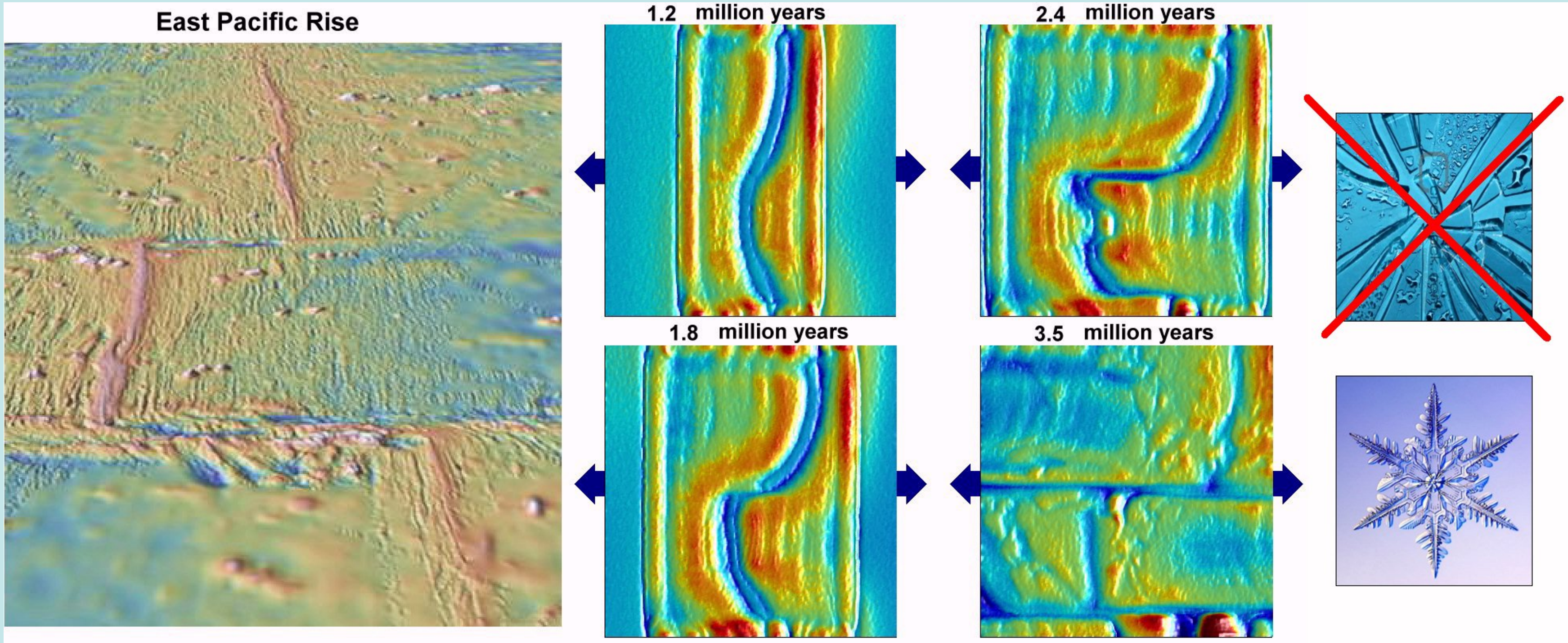
(b) Transcurrent fault

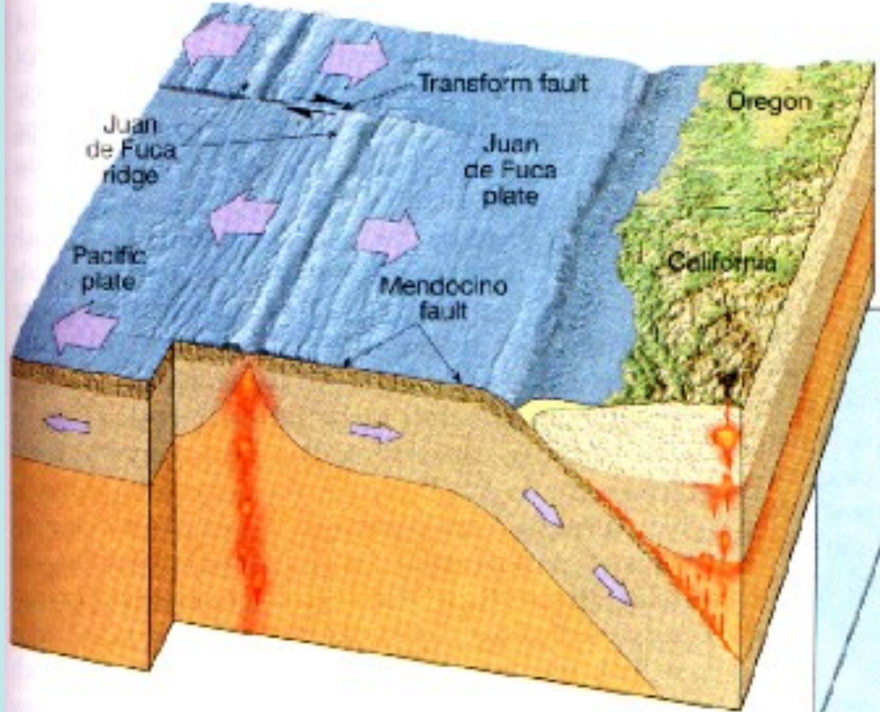

Earthquakes only occur between the ridge segments, where the seafloor is moving in opposite directions.
Spreading ridge
Transform Fault
= Earthquakes

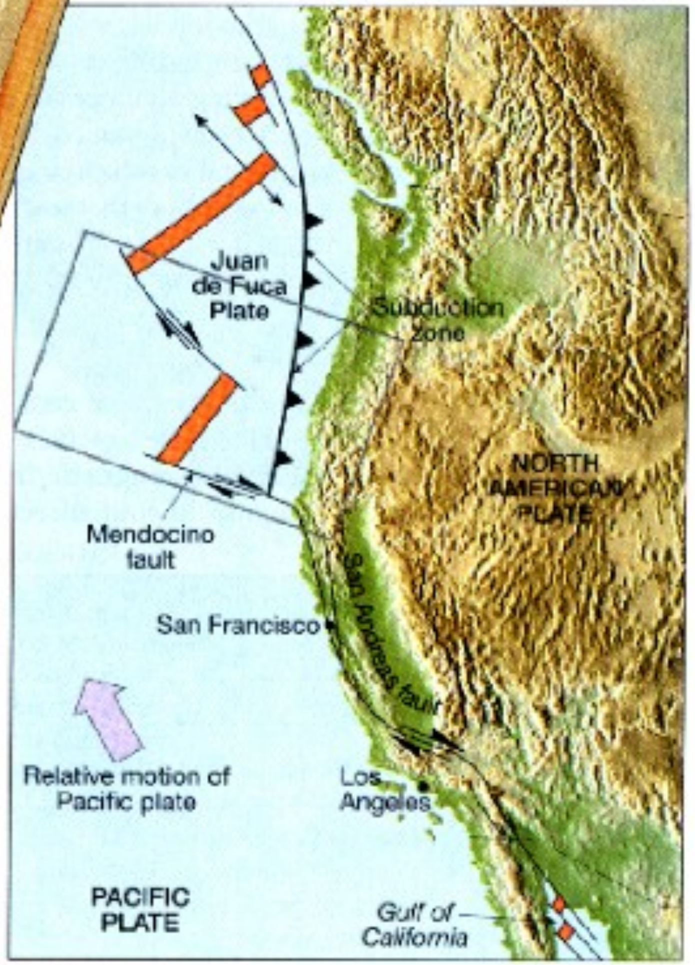

Fault line
Inactive ridge
Strike-Slip Fault
= Earthquakes
A) There is no plate motion outside of the ridge segments

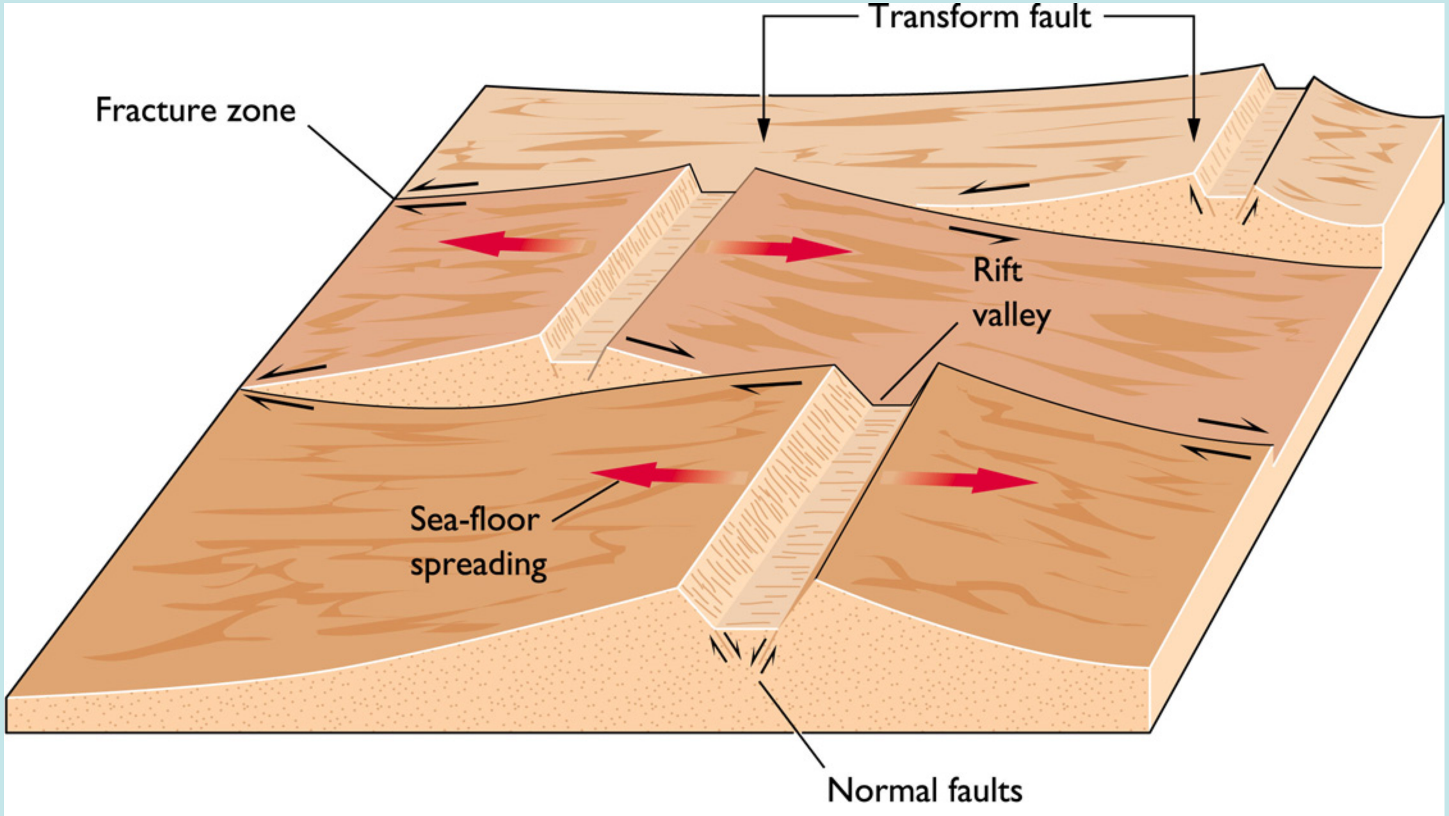

Earthquakes occur all along the fault, both between and outside of the ridge segments.
Inactive ridge
Strike-Slip Fault
= Earthquakes

transform faults at mid-ocean ridges are considered to be the products of plate fragmentation under imposed tectonic and thermal contraction forces.
New theory published in Science **suggests that transform faults are actually plate growth structures and result from dynamical thermomechanical instability developing at mid-ocean ridges.**
Mid-ocean ridges dissected by **transform faults** are one of the most striking, yet enigmatic features of terrestrial **plate tectonics**. The **transform faults** are considered to be the inherited product of preexisting structures resulting from initial plate fragmentation (**break-up**). Ridge offsets along these faults therefore should remain constant with time.
Recent high-resolution 3D numerical models suggest, however, that **transform faults** are actively developing and result from **dynamical instability** of **constructive plate boundaries**, irrespective of previous structure.
Boundary instability from asymmetric plate growth can spontaneously start in alternate directions along successive ridge sections; the resultant curved ridges become **transform faults** within a few million years.
The new theory thus suggests that **transform faults** are originally **plate growth and not plate fragmentation structures**. Similarly snowflakes differ from fragments of broken glass.

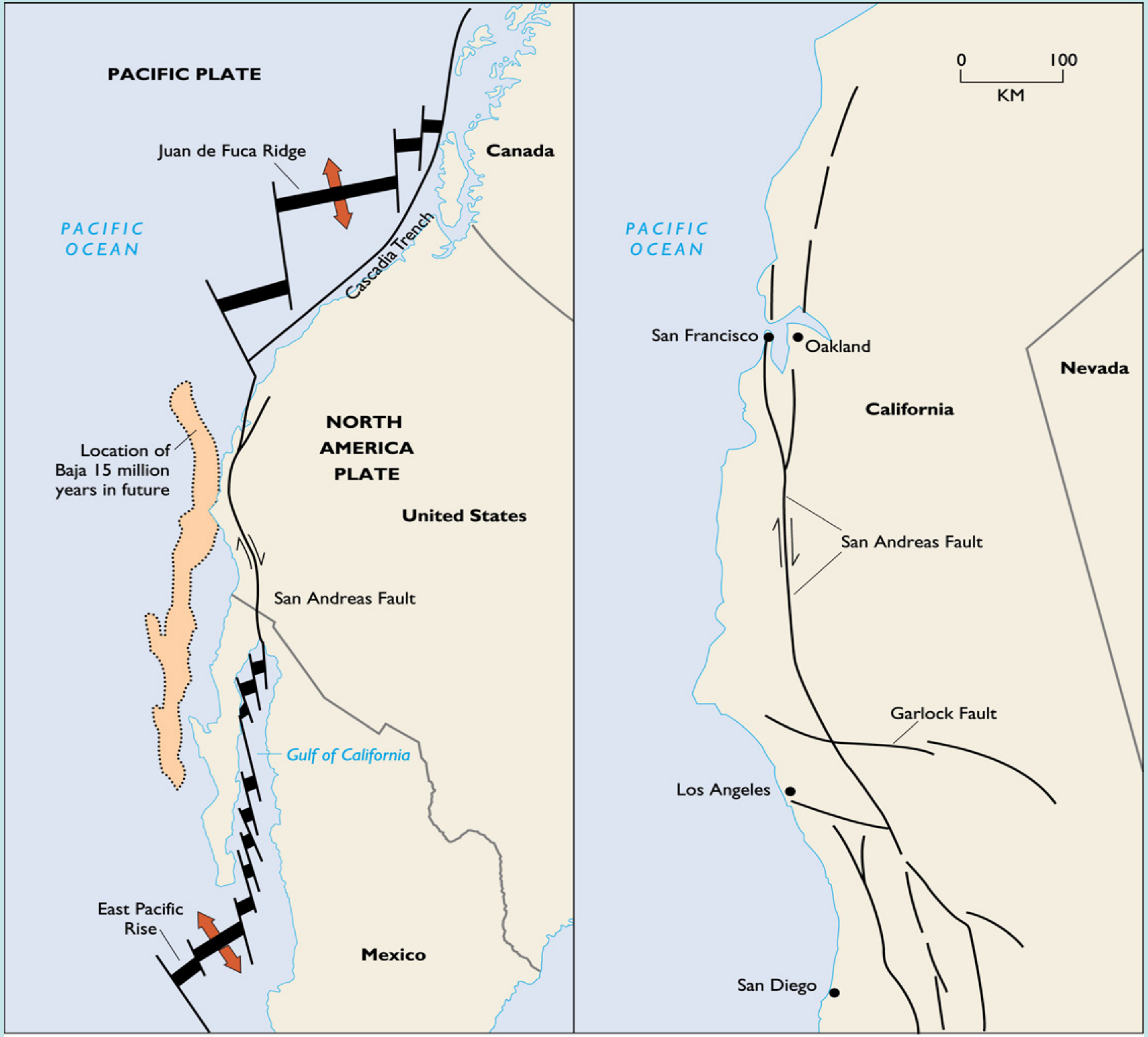

East Pacific Rise
1.2 million years
2.4 million years
1.8 million years
3.5 million years


Transform fault
Juan
de Fuca
ridge
Juan
de Fuca
plate
Oregon
Pacific
plate
Mendocino
fault
California

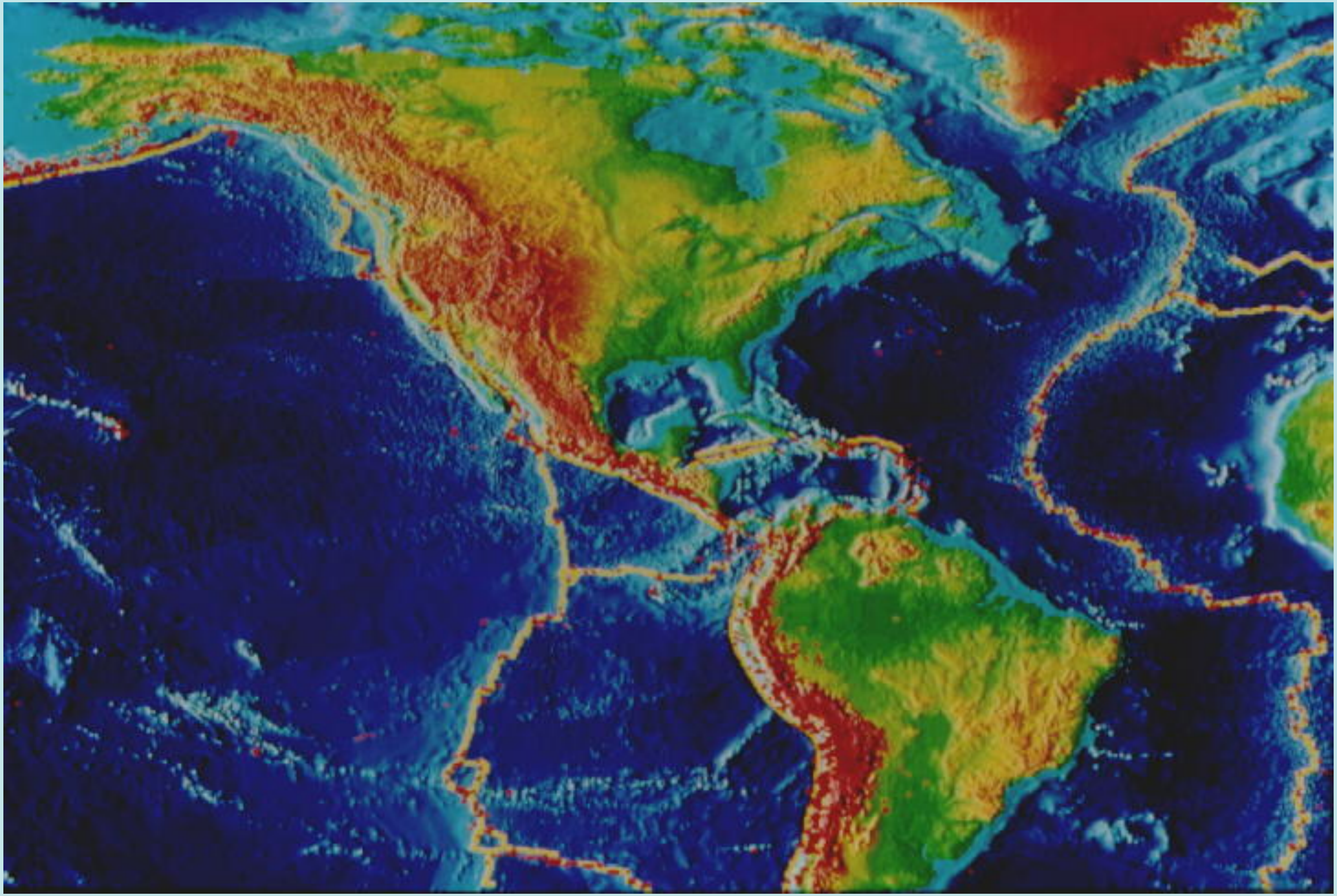

Juan
de Fuca
Plate
Subduction
zone
NORTH
AMERICAN
PLATE
Mendocino
fault
San Francisco
San Andreas fault
Relative motion of
Pacific plate
Los
Angeles
PACIFIC
PLATE
Gulf of
California



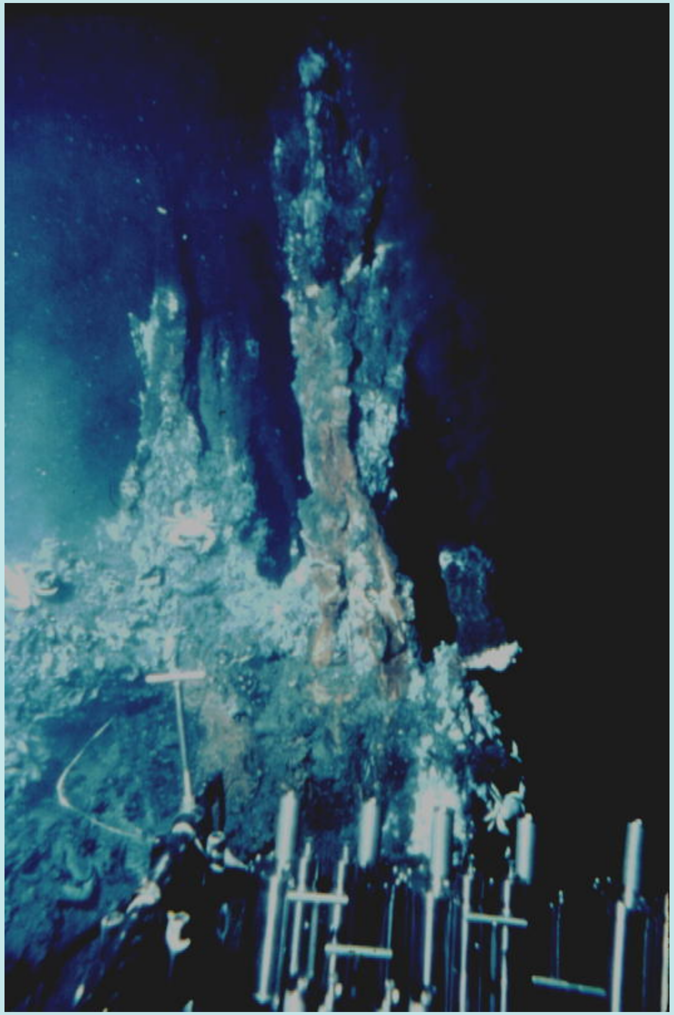
(a) SEGMENTED OCEAN RIDGE

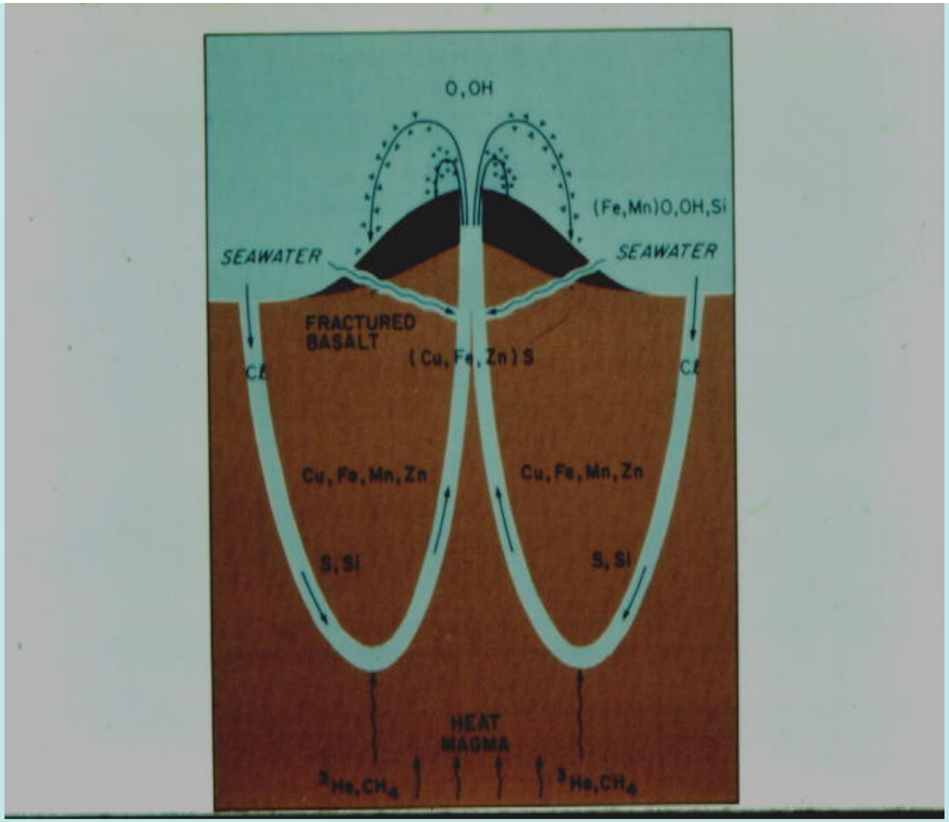


(a) PLATE BOUNDARY (b) SAN ANDREAS FAULT



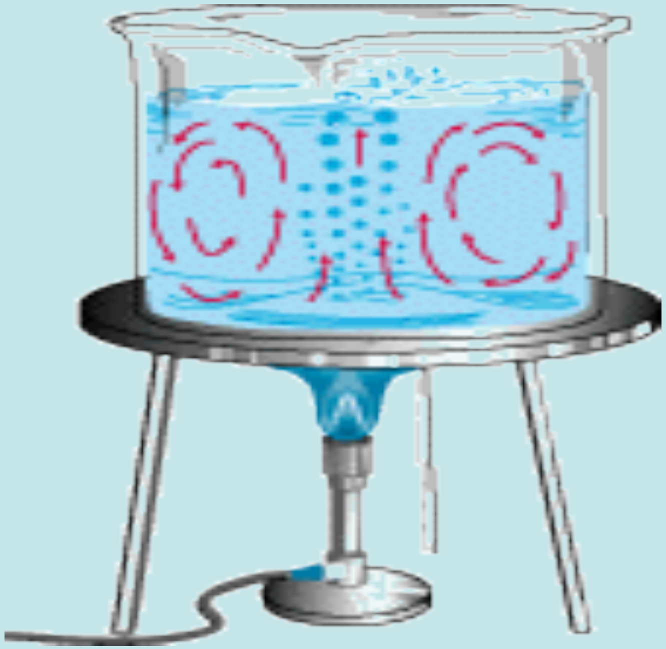

NUEVA YORK
TUCSON
HERMOSILLO
CHIHUAHUA
SAN ANTONIO
HOUSTON
NUEVA ORLEANS
GUAYMAS
LOS MOCHIS
MC ALLEN
MIAMI
LA PAZ
MAZATLAN
GUADALAJARA
AGUASCALIENTES
LEON
PUERTO VALLARTA
MERIDA
CANCUN
MORELIA
MANZANILLO
CD. MEXICO
IXTAPA, ZIHUATANEJO
ACAPULCO

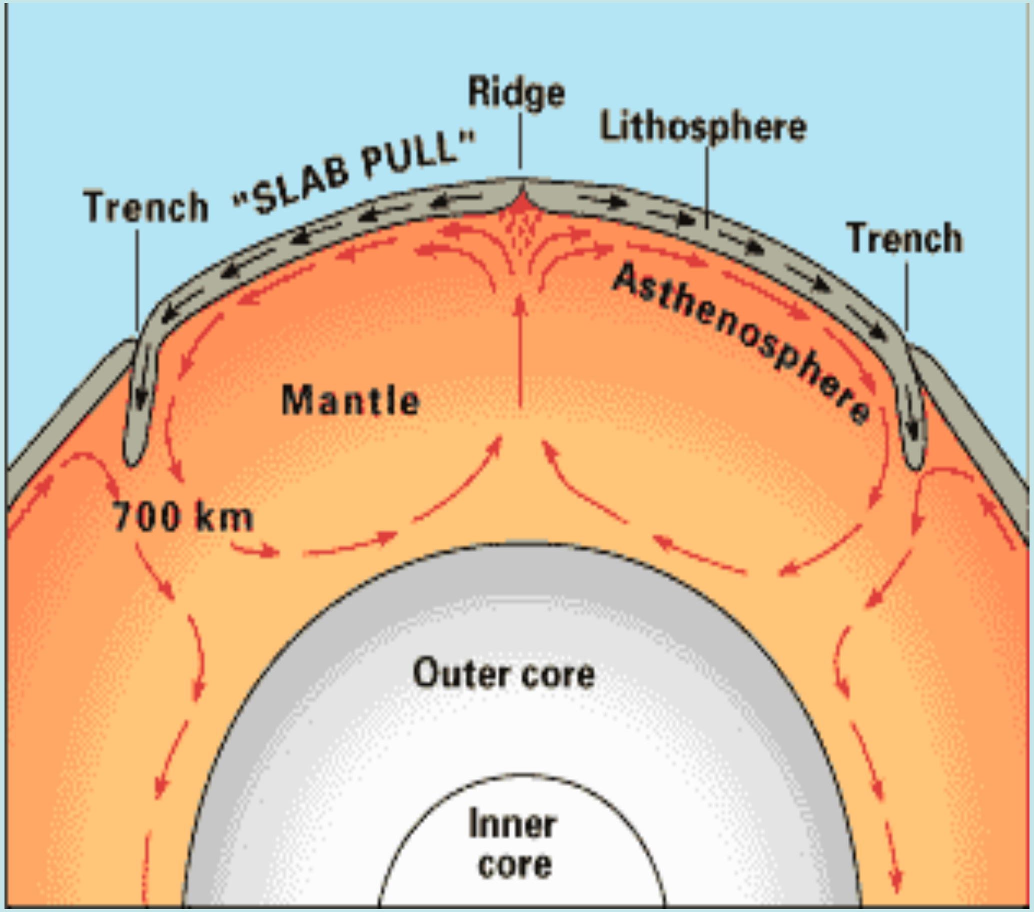


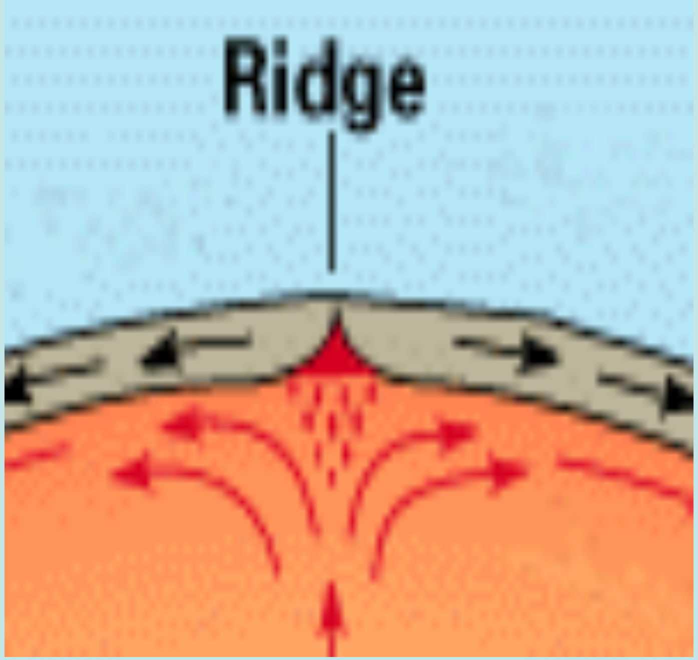


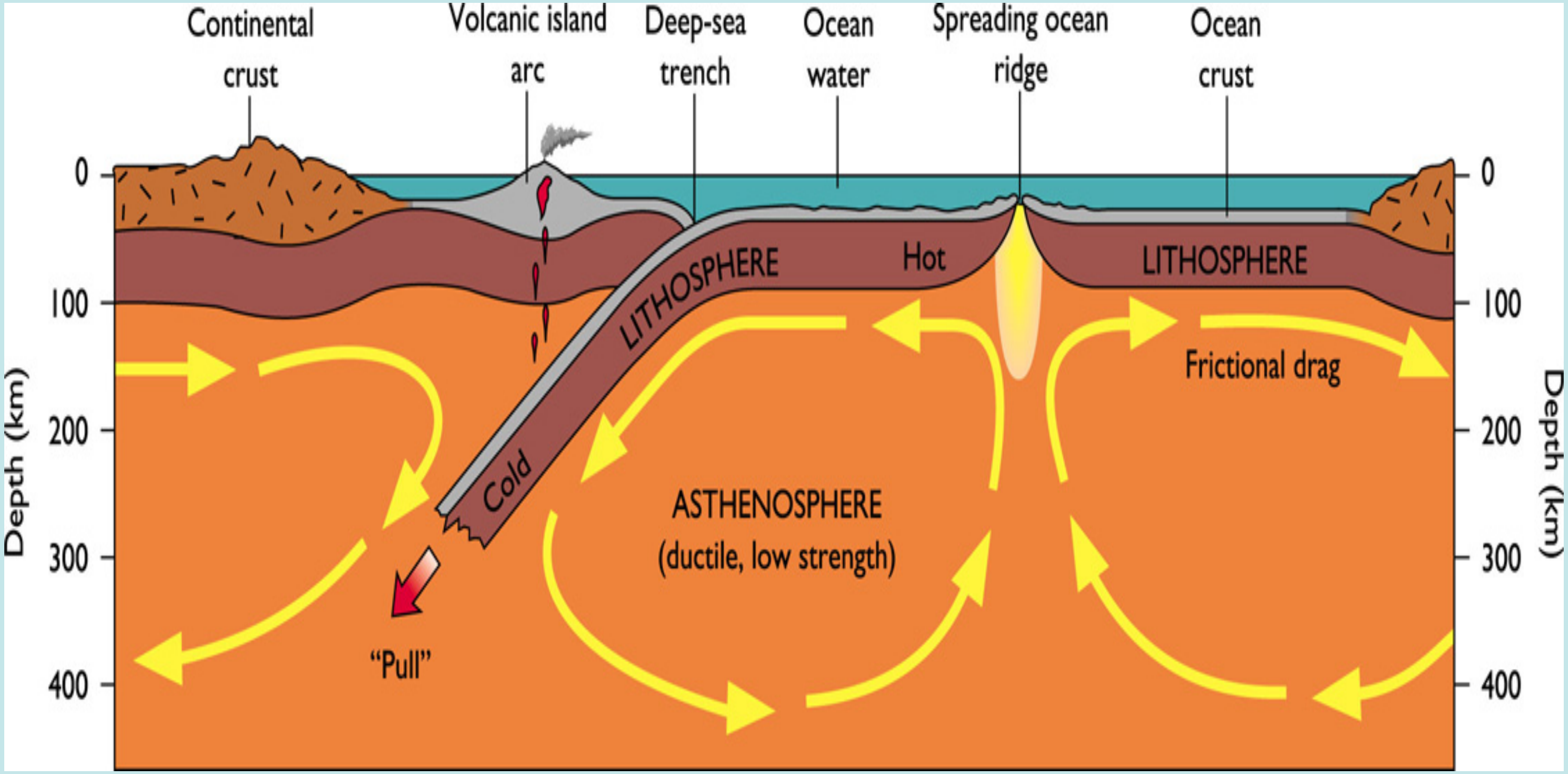
Centro do Golfo da Califórnia
Evidências

- Embora o mecanismo atual que causa a movimentação das placas esteja ainda sendo estudado, existe pouca dúvida de que a CONVECÇÃO TÉRMICA (transferência de calor por movimento de fluídos) das rochas “quase plásticas”da astenosfera desempenha um papel importante. A medida que o calor aumenta no interior da Terra, as rochas da astenosfera tornam-se menos densas que as de cima e sofrem convecção ascendendo. O processo é mais óbvio nos centros de espalhamento



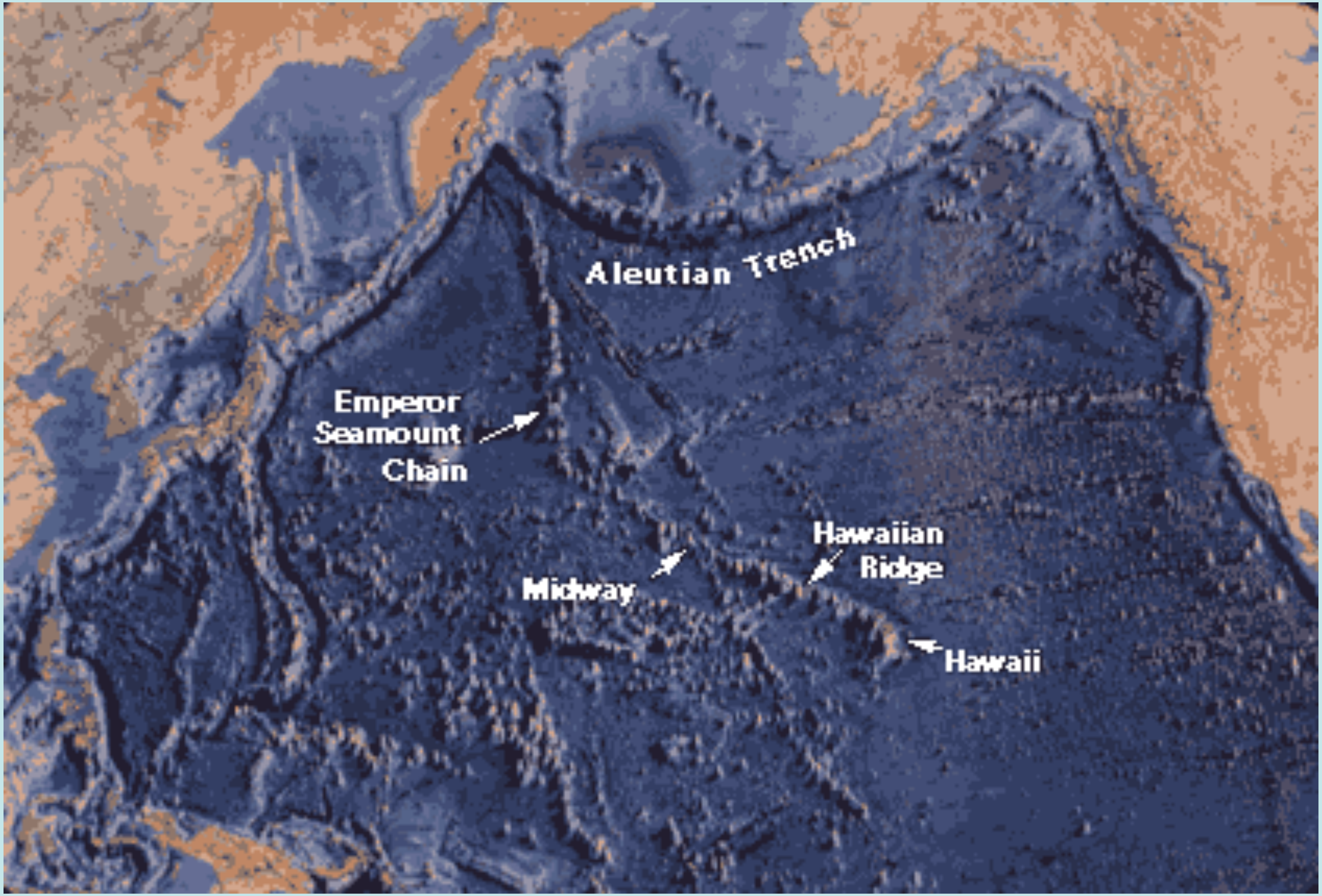

Ridge
Lithosphere
Trench
"SLAB PULL"
Trench
Asthenosphere
Mantle
700 km
Outer core
Inner
core

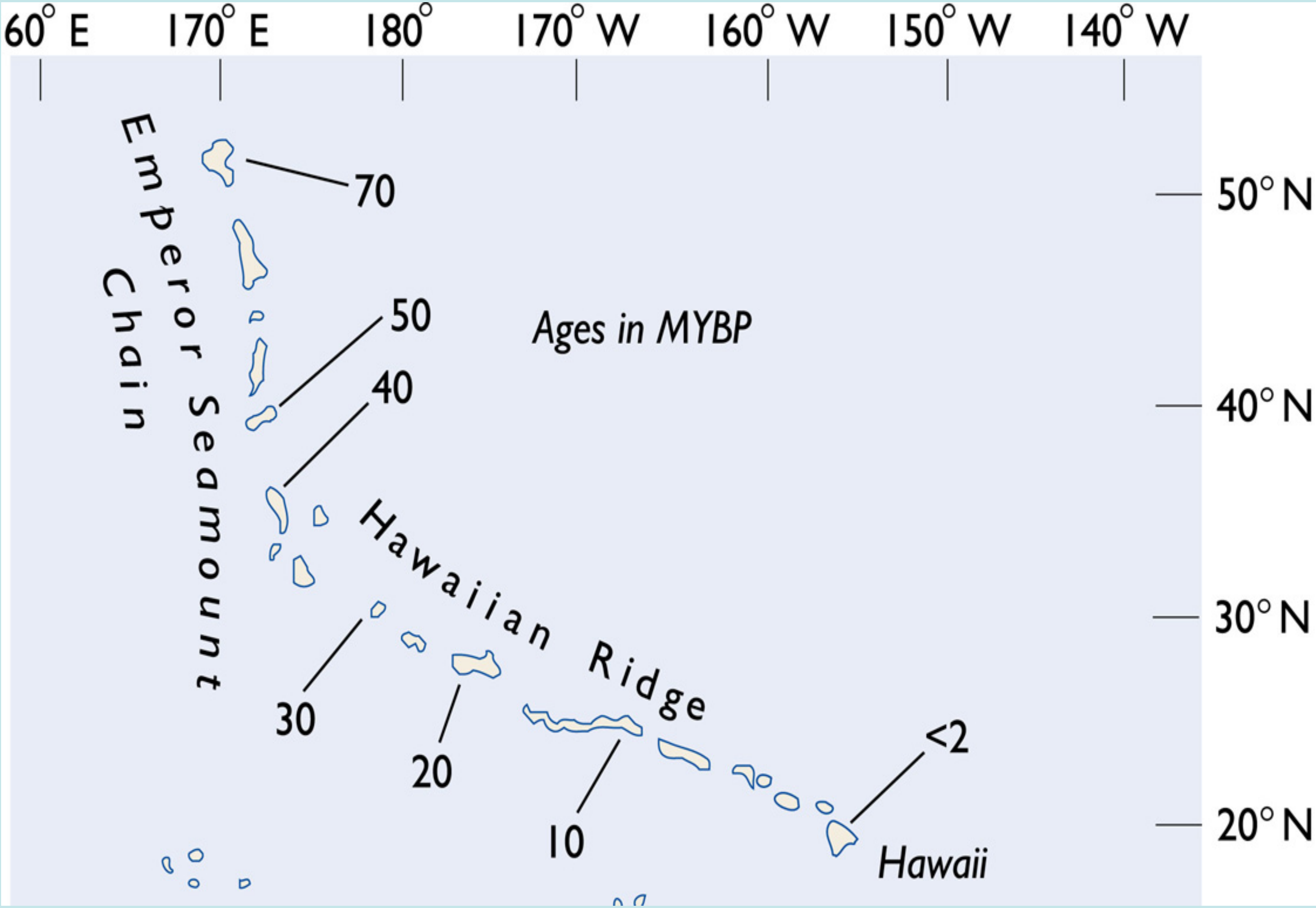

Ridge

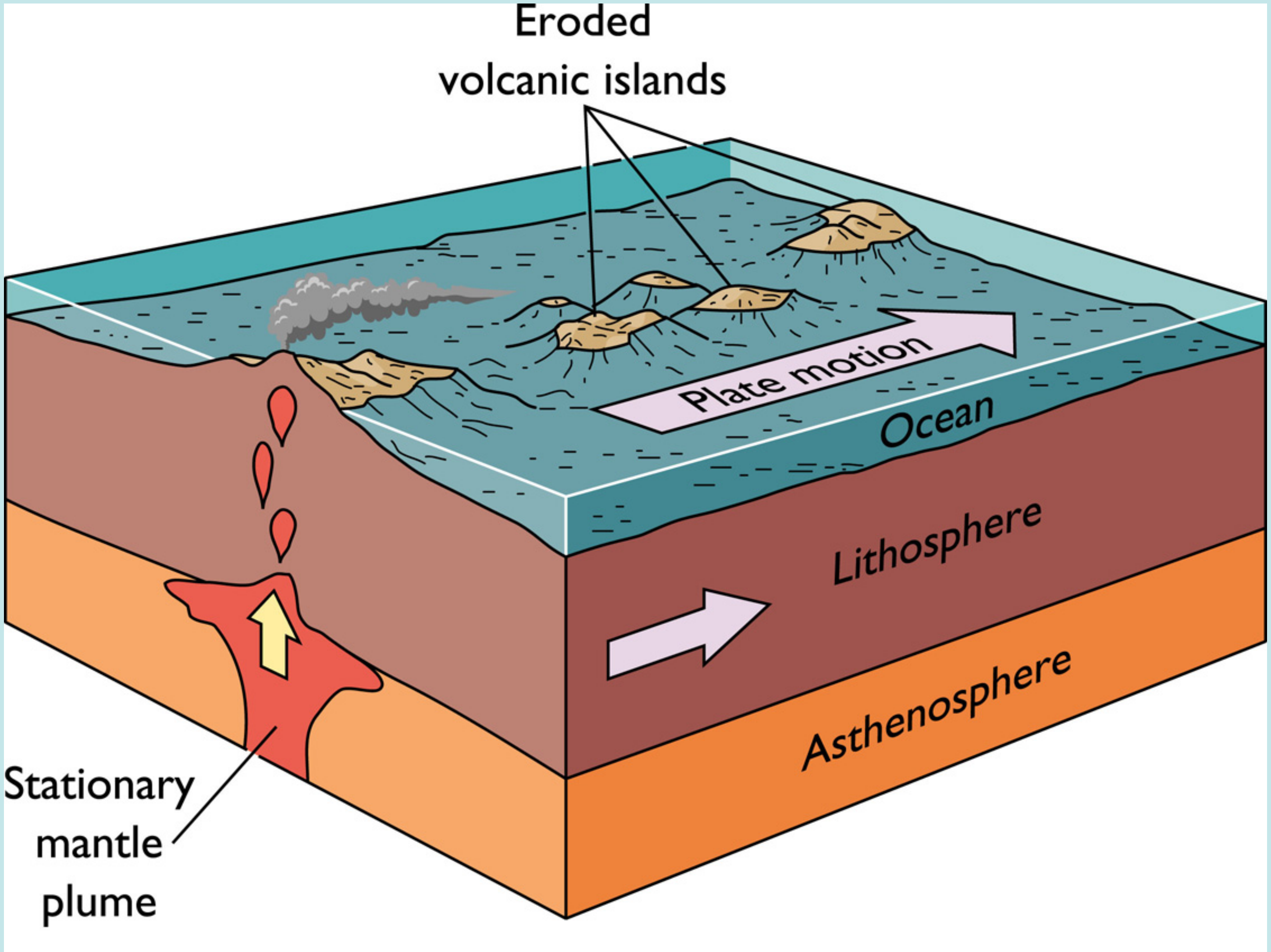


Continental crust
Volcanic island arc
Deep-sea trench
Ocean water
Spreading ocean ridge
Ocean crust
0
100
200
300
400
Depth (km)
LITHOSPHERE
Hot
LITHOSPHERE
Frictional drag
Cold
ASTHENOSPHERE
(ductile, low strength)
"Pull"

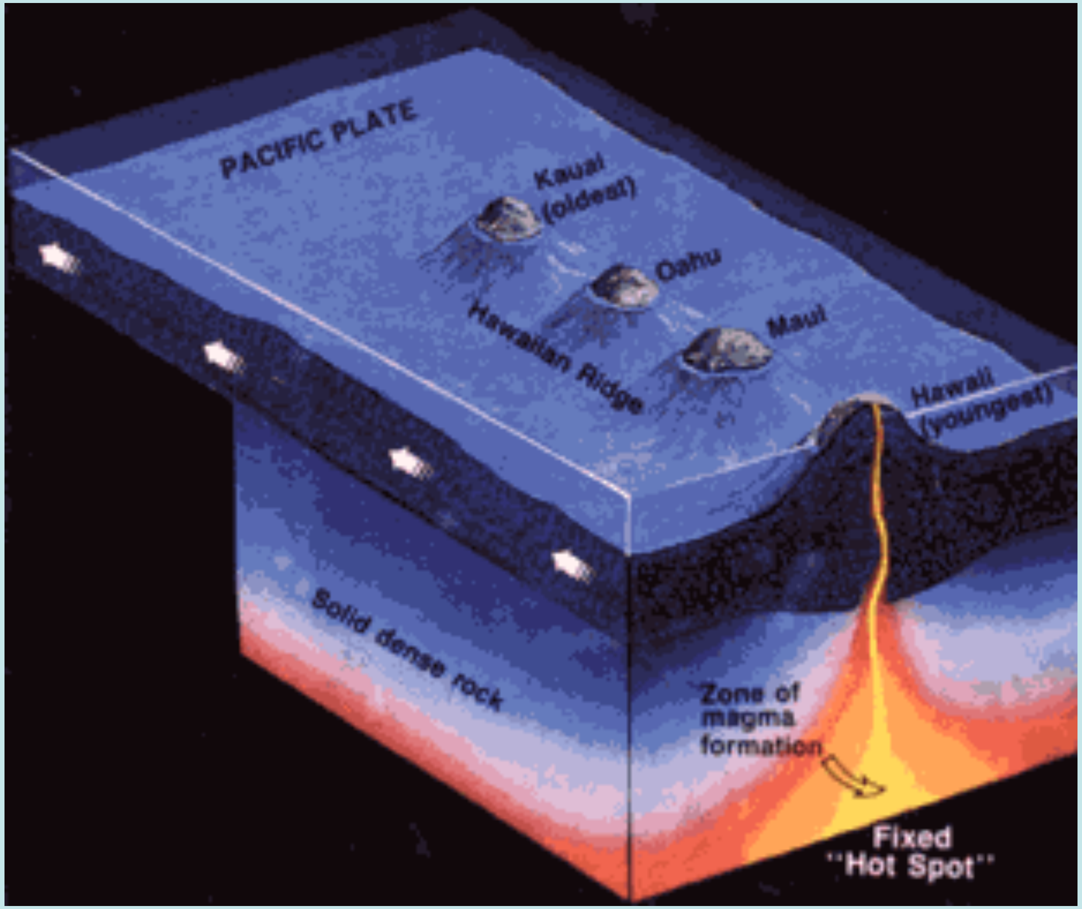
- **A maioria das extrusões vulcânicas ocorre no limite das placas: lava basáltica nos centros de divergência e lava andesítica nos locais de subducção, ENTRETANTO, menos comum mas saídas de lava impressionantes ocorre no centro de algumas placas, distante a milhares de quilômetros das suas bordas. São os PONTOS QUENTES (HOT SPOTS).**
- **Local mais estudado: Cadeia linear com direção Oeste-noroeste localizada no centro da Placa Pacífica –as Ilhas Hawai —Cadeias de montanhas vulcânicas criadas a medida que a Placa Pacífica deriva vagarosamente sobre um HOT SPOT profundo tipo uma “pluma do manto”.**

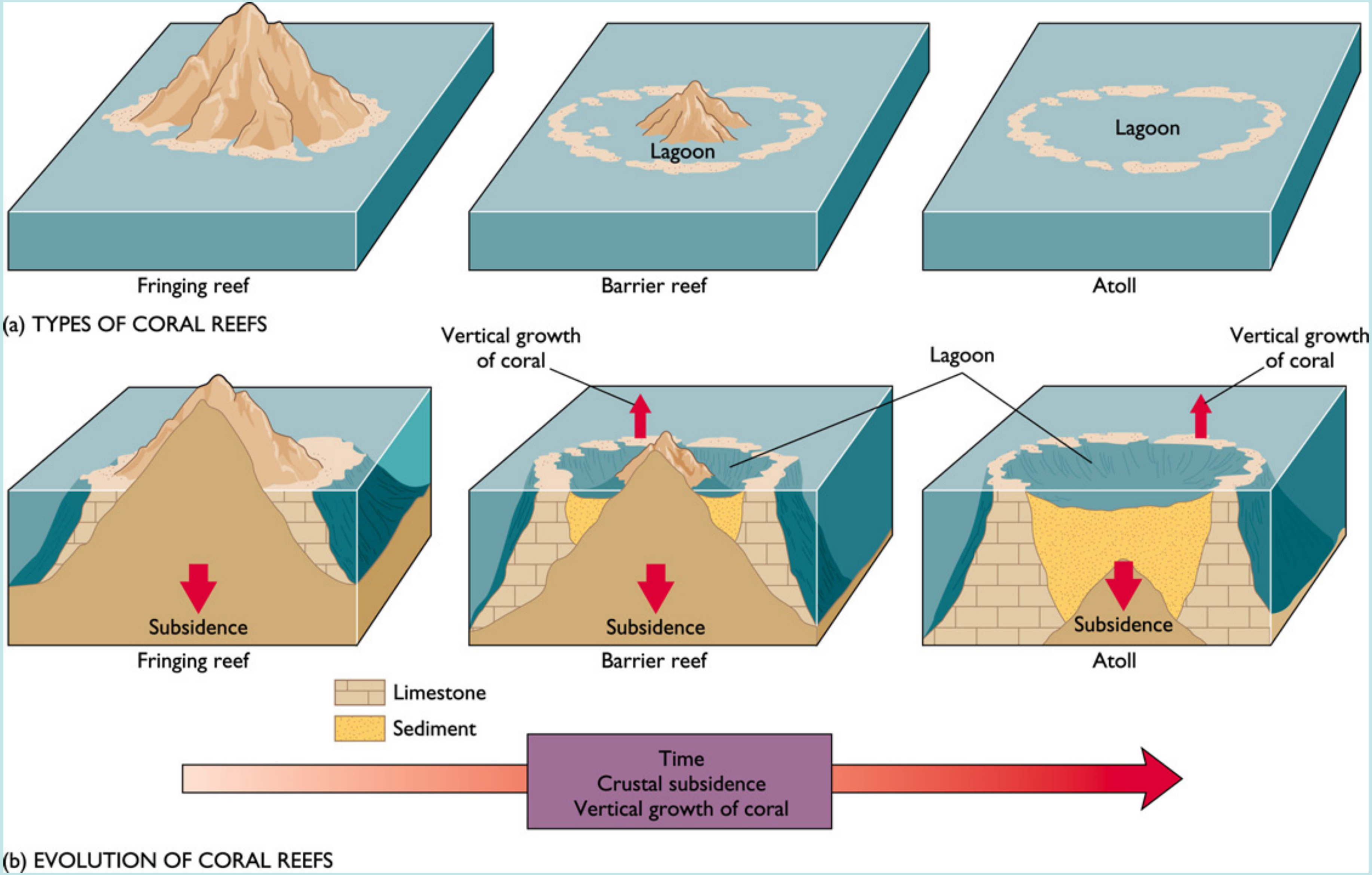

Aleutian Trench
Emperor
Seamount
Chain
Midway
Hawaiian
Ridge
Hawaii


60° E
170° E
180°
170° W
160° W
150° W
140° W
50° N
40° N
30° N
20° N
Emperor Seamount Chain
Hawaiian Ridge
Ages in MYBP
70
50
40
30
20
10
<2
Hawaii

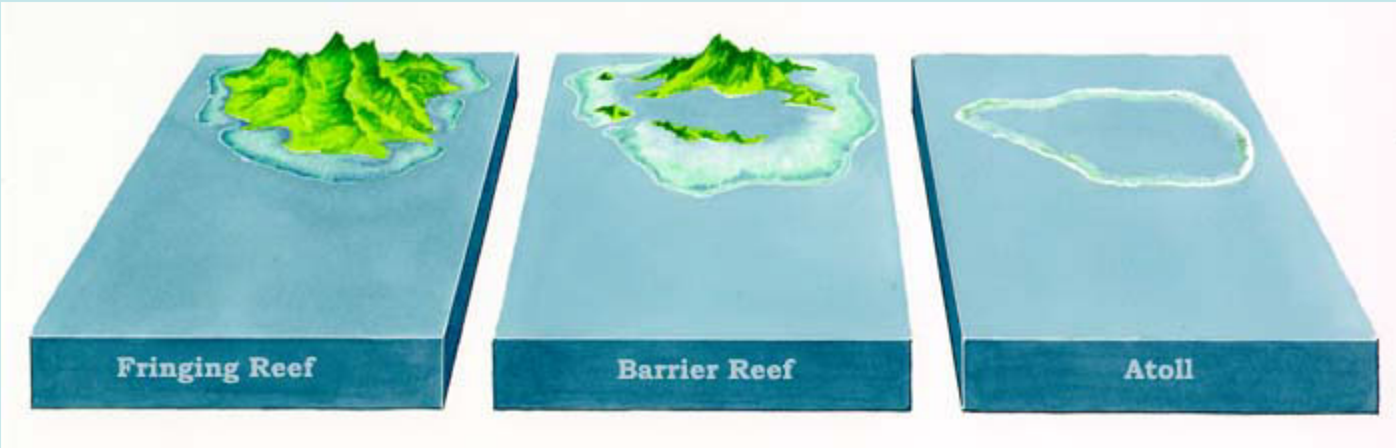


(c) MANTLE PLUME


PACIFIC PLATE
Kauai
(oldest)
Oahu
Hawaiian Ridge
Maui
Hawaii
(youngest)
Solid dense rock
Zone of
magma
formation
Fixed
"Hot Spot"



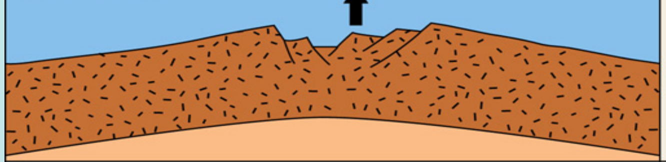
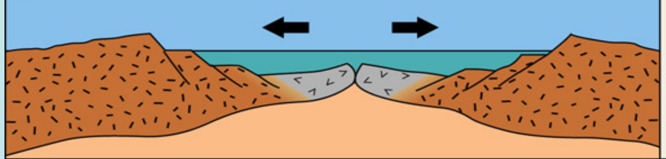
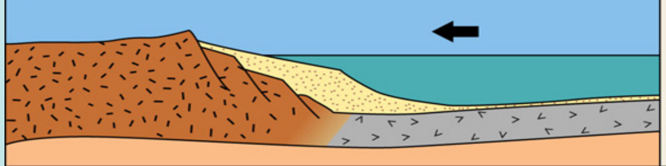
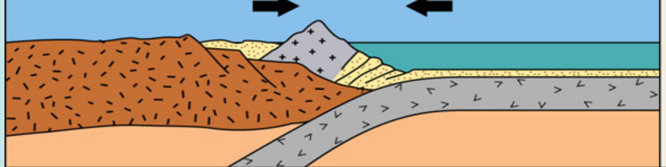
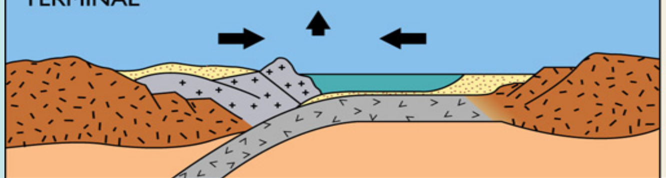
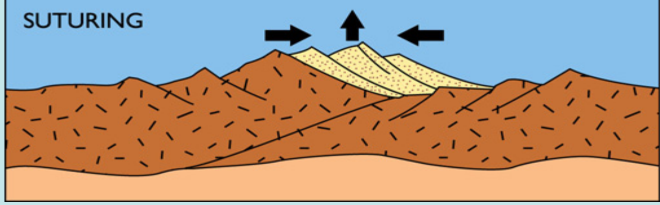
Fringing reef
Lagoon
Barrier reef
Lagoon
Atoll
(a) TYPES OF CORAL REEFS
Vertical growth of coral
Lagoon
Vertical growth of coral
Subsidence
Fringing reef
Subsidence
Barrier reef
Subsidence
Atoll
Limestone
Sediment
Time
Crustal subsidence
Vertical growth of coral
(b) EVOLUTION OF CORAL REEFS

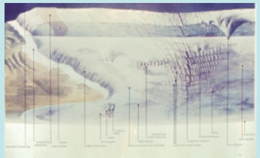

Fringing Reef
Barrier Reef
Atoll

Evolução das bacias oceânicas, abertura e fechamento

- Durante o curso de várias centenas de milhões de anos, as bacias oceânicas evoluiram através de estágios distintos que estão diretamente ligados a tectônica de placas global.
- O estágio inicial no **“ciclo de Wilson”** da evolução começa com a separação da crosta granítica dos continentes. Isto resulta na formação de vales longos e lineares, processo hoje ocorrente no leste da África. **A bacia neste estágio é embriônica**. O continente é então fraturado por um sistema de falhas normais e basalto “escapa”para a superfície e se espalha no assoalho do rift valley.
- No estágio seguinte, **uma bacia oceânica juvenil** ocorre quando os continentes são separados em duas massas independentes. Crosta basáltica se forma entre eles ao longo de um centro de espalhamento de uma cordilheira oceânica. O estágio atual é o **mar Vermelho**
- Com a continuação do EFO o esse oceano estreito alarga-se formando então um **estágio maturo,** tipo o atual Oceano Atlântico

- Continuação da expansão leva eventualmente a instabilidade e a placa larga se rompe onde a litosfera é velha e suporta uma grande carga de sedimentos –geralmente nas margens continentais devido a tremenda espessura de sedimentos que aí se acumula.
- **Subducção** começa quando um lado da placa fragmentada,cavalga a outra. A bacia oceânica entra então no **estágio de declínio** a medida que a litosfera oceânica e até o próprio centro de espalhamento sofre subducção e desaparece da face da Terra, uma situação a qual está atualmente ocorrendo na "East Pacific Rise".
- A medida que a subducção progride a bacia atinge o **estágio terminal.** Continentes e zonas de subducção em cada lado da bacia, colidem, dobrando e soerguendo os depósitos sedimentares marinhos da bacia em cinturões de cadeias montanha dobrados e falhados—Mar Mediterrâneo)
- Finalmente as duas massas continentais em colisão **sofrem sutura (fusão)** se juntam e os depósitos sedimentares mais a crosta oceânica são forçados para cima formando uma majestosa cadeia de montanhas –Himalaias onde rochas sedimentares com fósseis marinhos atestam o tempo quando estavam submersos na bacia oceânica pré-existente entre a Índia e o continente Asiático.

STAGE	MOTION	PHYSIOGRAPHY	EXAMPLE
EMBRYONIC 	Uplift	Complex system of linear rift valleys on continent	East African rift valleys
JUVENILE 	Divergence (spreading)	Narrow seas with matching coasts	Red Sea
MATURE 	Divergence (spreading)	Ocean basin with continental margins	Atlantic, Indian, and Arctic oceans
DECLINING 	Convergence (subduction)	Island arcs and trenches around basin edge	Pacific Ocean
TERMINAL 	Convergence (collision) and uplift	Narrow, irregular seas with young mountains	Mediterranean Sea
SUTURING 	Convergence and uplift	Young to mature mountain belts	Himalayas




Tripoli
Tehran
Baghdad
Jerusalem
Cairo
ARABIA
Riyadh
New Delhi
THAR DESERT
Karachi
Bombay
SAHARA
Khartoum
LAKE CHAD
N'Djamena
AFRICA
Douala
CONGO
Nairobi
Kinshasa
Luanda
Lusaka
Salisbury
KALAHARI DESERT
Pretoria
KERGUELEN ISLANDS
LENA GUYOT
HEARD


Nicósia
Chipre
Síria
Líbano
Beirute
Damasco
Amã
Jerusalém
Dead Sea
Marcador sem título
Faixa de Gaza
Israel
Jordânia
Alexandria
Lago Mareotis
Cairo
Al Jawf
Al Hudud ash Shamali
Golfo de Aqaba
Golfo de Suez
Tabuk
Ha'il
Google
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© 2012 ORION-ME
Map Data © 2012 AND

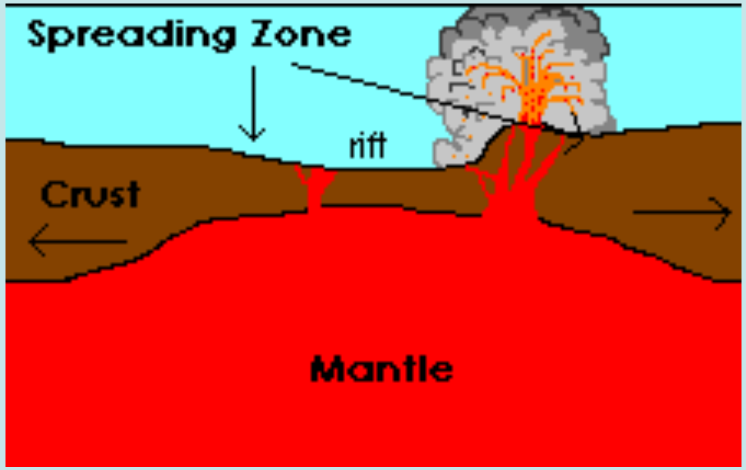

72°F / 22°C
72°F / 22°C
66°F / 19°C
72°F / 22°C
68°F / 20°C
68°F / 20°C
Dead Sea
72°F / 22°C
Marcador sem título
72°F / 22°C
© 2012 Cnes/Spot Image
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Google
31°31'10.35" N 35°27'22.61" L
elev 0 m
Altitude do ponto de visão 140.88 km

Awesome Stats

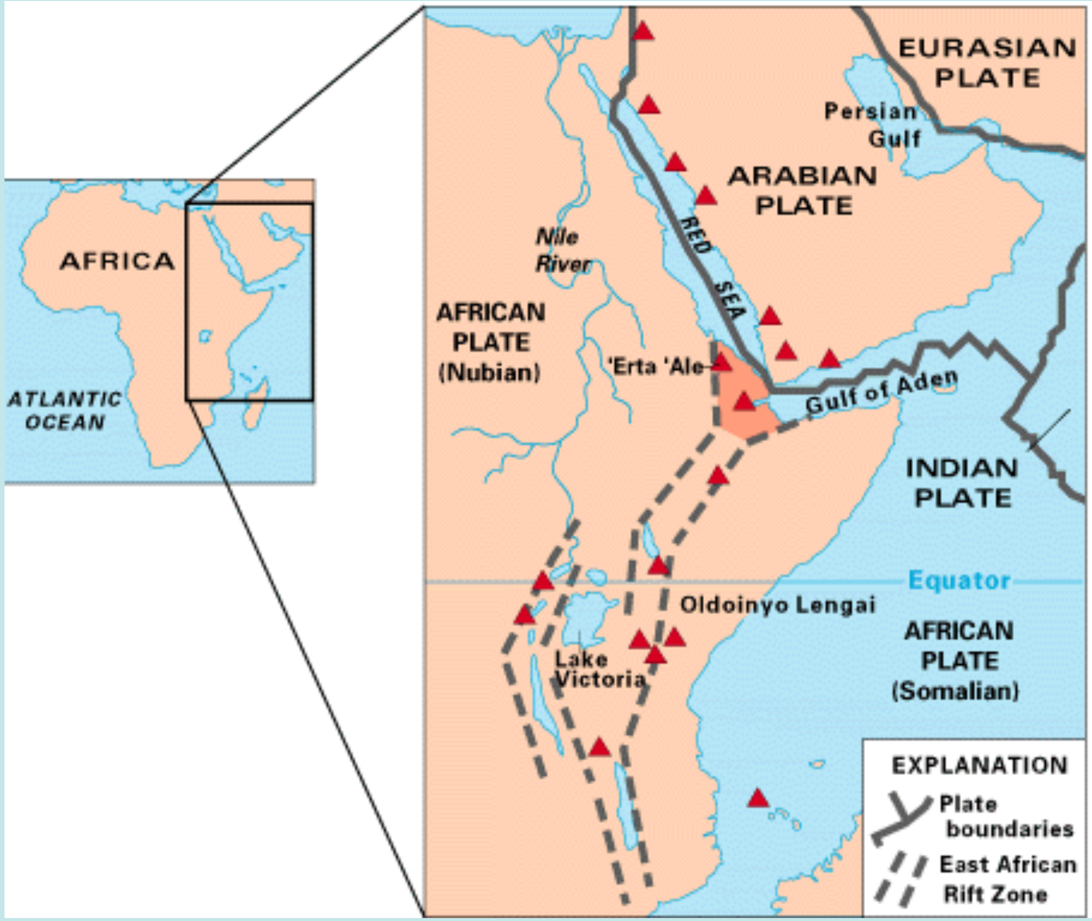
Location: The Middle East, between Jordan and Israel. Check out the map.

Stats: The surface of the Dead Sea is over 1,300 feet below sea level. The very bottom of the sea, in the deepest part, is over 2,300 feet below sea level.

The Scientists who study this cool stuff? Geologists, Biologists, Geochemists, Hydrologists, Zoologists.



Placa **Africana** dividindo-se em duas: Nubian e Somalian ambas se
Afastam da placa da Arábia a medida que o mar vermelho encontra o golfo de Aden



- Map of East Africa showing some of the historically active volcanoes(red triangles) and the Afar Triangle (shaded, center) -- a triple junction where three plates are pulling away from one another: the Arabian Plate, and the two parts of the African Plate (the Nubian and the Somalian) splitting along the East African Rift Zone (USGS).

- ETriple Junctions
- Rarely, a group of three plates, or a combination of plates, faults, and trenches, meet at a point called a triple junction. The East African Rift Zone is a good example of a triple plate junction. The African plate is splitting into two plates and moving away from the Arabian plate as the Red Sea meets the Gulf of Aden. Another example is the Mendocino Triple Junction, which occurs at the intersection of two transform faults (the San Andreas and Mendocino faults) and the plate boundary between the Pacific and Gorda plates.

- A triple junction is the point where the boundaries between three tectonic plates, and three plate margins, meet. At the triple junction a boundary will be one of 3 types - a ridge, trench or transform fault and triple junctions can be described according to the types of plate margin that meet at them. Of the many possible types of triple junction only a few are stable through time.
- The triple junction concept was developed in 1968 by W. Jason Morgan, Dan McKenzie, and Tanya Atwater. The term has traditionally been used for the intersection of three divergent boundaries or spreading ridges. These three divergent boundaries ideally meet at near 120° angles. In plate tectonics theory during the breakup of a continent, one of the divergent plate boundaries would fail (see aulacogen) and the other two would continue spreading to form an ocean. The opening of the south Atlantic Ocean began with a triple junction in the present Gulf of Guinea. The failed arm of this junction is occupied by the rift system under the Niger Delta area and the volcanic Cameroon line.
-
- Map of East Africa showing some of the historically active volcanoes(red triangles) and the Afar Triangle (shaded, center) -- a triple junction where three plates are pulling away from one another: the Arabian Plate, and the two parts of the African Plate (the Nubian and the Somalian) splitting along the East African Rift Zone (USGS).
- The junction of the Red Sea, the Gulf of Aden and the Great Rift Valley of East Africa centered in the Afar Triangle is an example of a triple junction (the Afar Triple Junction). This is the only Ridge-Ridge-Ridge triple junction above sea level. Another example of a triple junction is the junction between the Arabian Plate , the African Plate , and the Indo-Australian Plate.
- Another active example is the R-R-R triple junction where the Nasca, the Cocos, and the Pacific Plates meet. The East Pacific Rise extends north and south from this junction and the Galapagos Rise goes to the east. This example is made more complex by the Galapagos Microplate which is a small separate plate on the rise just to the southeast of the triple junction.
- Further north on the west coast of North America another unstable triple junction is to be found offshore of Cape Mendocino. There the San Andreas Fault, a strike-slip fault and transform plate boundary, approaches from the south. The San Andreas Fault separates the Pacific Plate and the North American Plate. To the north lies the Cascadia subduction zone, where the section of the Juan de Fuca Plate called the Gorda Plate is being subducted under the margin of the North American Plate at a plate boundary called a trench (T). Another transform fault runs along the boundary between the Pacific Plate and the Gorda Plate called the Mendocino Fault (F). Where the three intersect is a seismically active F-F-T triple junction called the Mendocino Triple Junction.
- The North Sea is located at a triple junction of three continental plates formed during the Palaeozoic: Avalonia, Laurentia and Baltica.
- The properties of triple junctions are most easily understood from the purely kinematic point of view where the plates are rigid and moving over the surface of the Earth. No knowledge of the Earth's interior or the geological details of the crust are then needed. Another useful simplification is that the kinematics of triple junctions on a flat Earth are essentially the same as those on the surface of a sphere: despite describing plate motions as involving relative rotations about poles and plate motions on a flat surface being defined by vectors. The relative motions at the triple junction are the

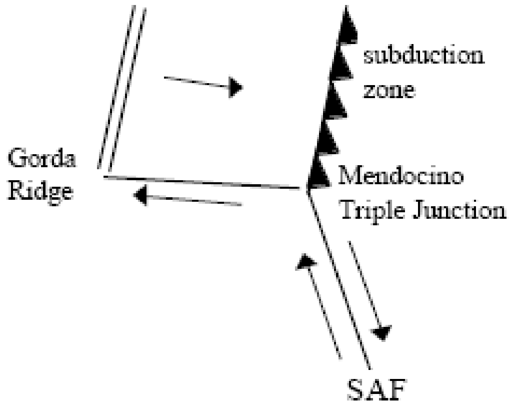


Figure 4.8. Diagram of the Mendocino Triple Junction. SAF - San Andreas Fault.

- Another example is the Mendocino Triple Junction, which occurs at the intersection of two transform faults (the San Andreas and Mendocino faults) and the plate boundary between the Pacific and Gorda plates.

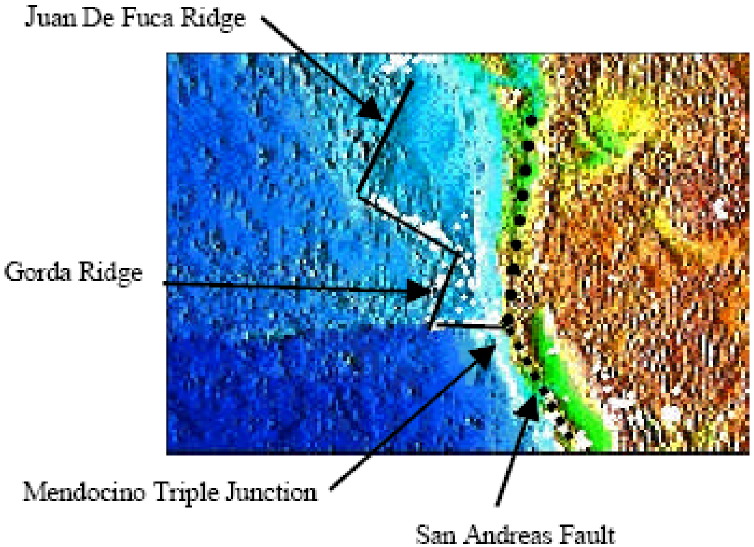
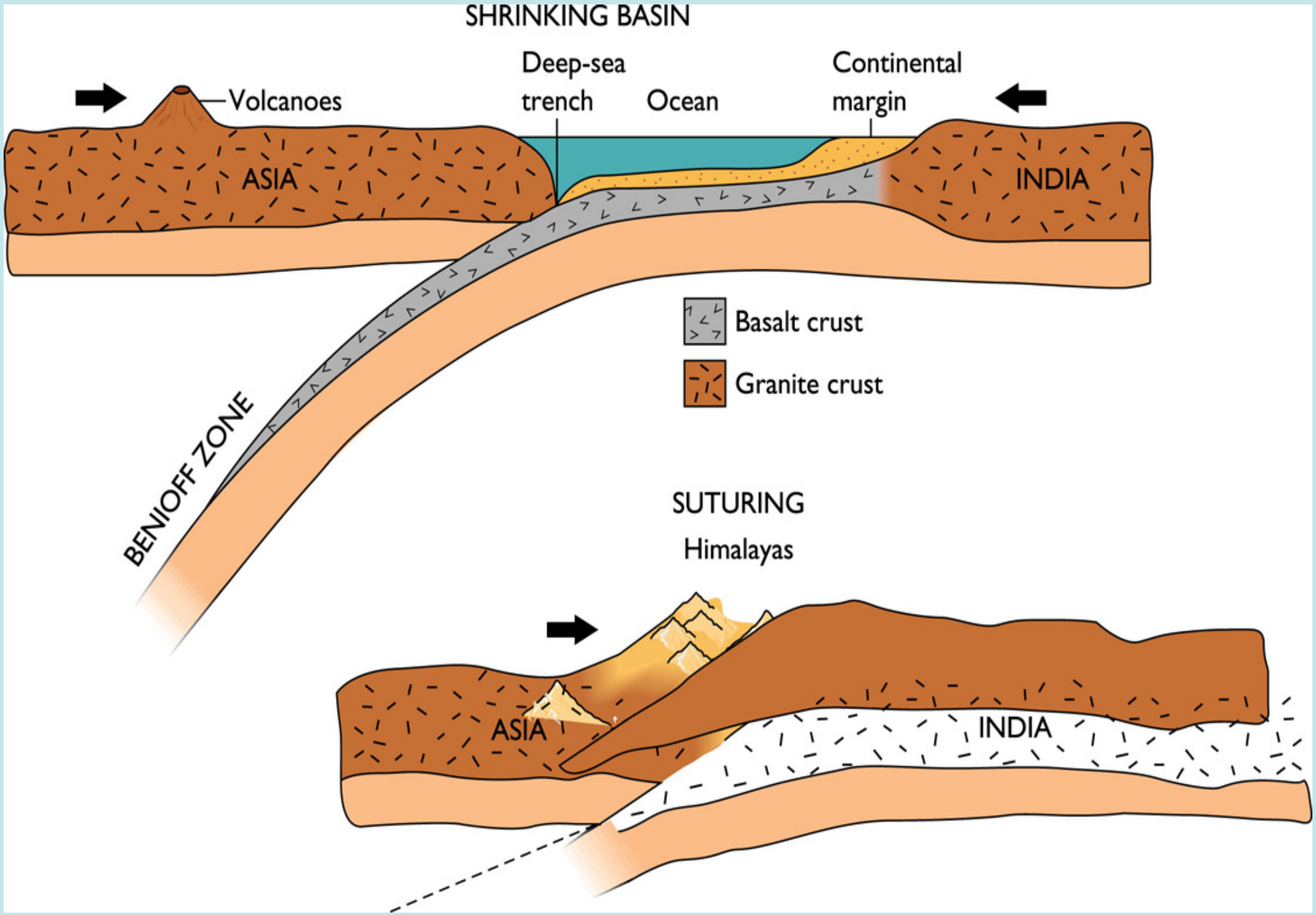
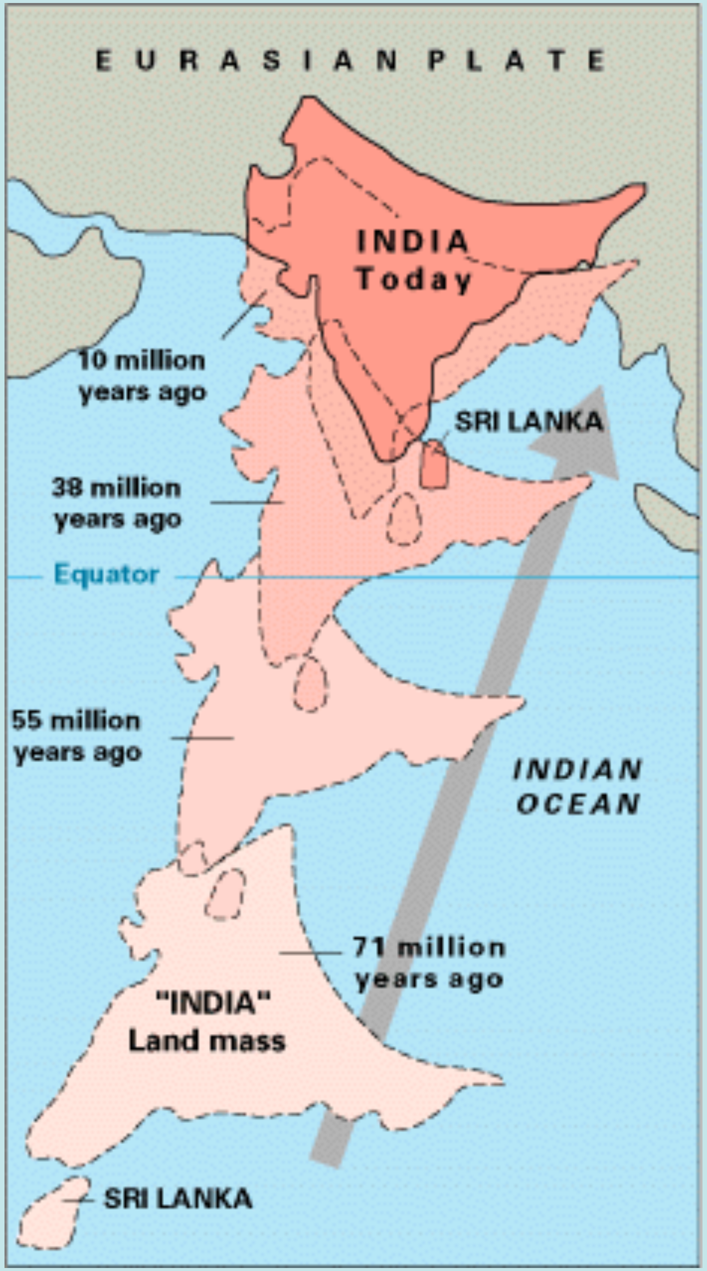


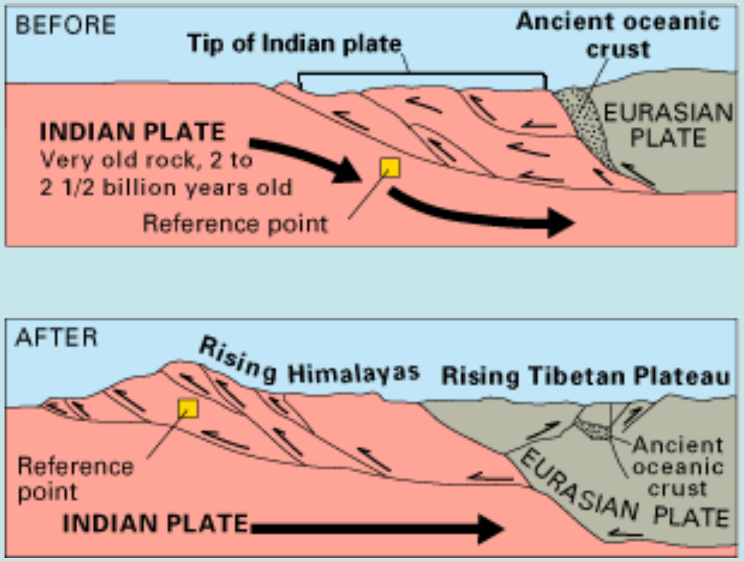
Figure 4.9. Example of a triple junction.

Figure 4.9, at the left, is a map captured from the "Our Dynamic Planet" CD, showing topography and quakes of the Mendocino Triple Junction area.
The dotted line along the Oregon/Washington coast is the subduction zone. Contrary to the previous statement about transform faults always being at right angles to the spreading center, the transform fault that trends east-west from the southern end of the Gorda Ridge is not at a right angle. Notice also that there are many quakes to the east of the Gorda Ridge, indicating that deformation is occurring in a region that, in the ideal case, is fairly quake free. It turns out that this region is deforming and rotating, so the occurrence of quakes within the plate is not surprising.


SHRINKING BASIN
Volcanoes
Deep-sea trench
Ocean
Continental margin
ASIA
INDIA
Basalt crust
Granite crust
BENIOFF ZONE
SUTURING
Himalayas
ASIA
INDIA


EURASIAN PLATE
INDIA
Today
10 million
years ago
SRI LANKA
38 million
years ago
Equator
55 million
years ago
INDIAN
OCEAN
71 million
years ago
"INDIA"
Land mass
SRI LANKA

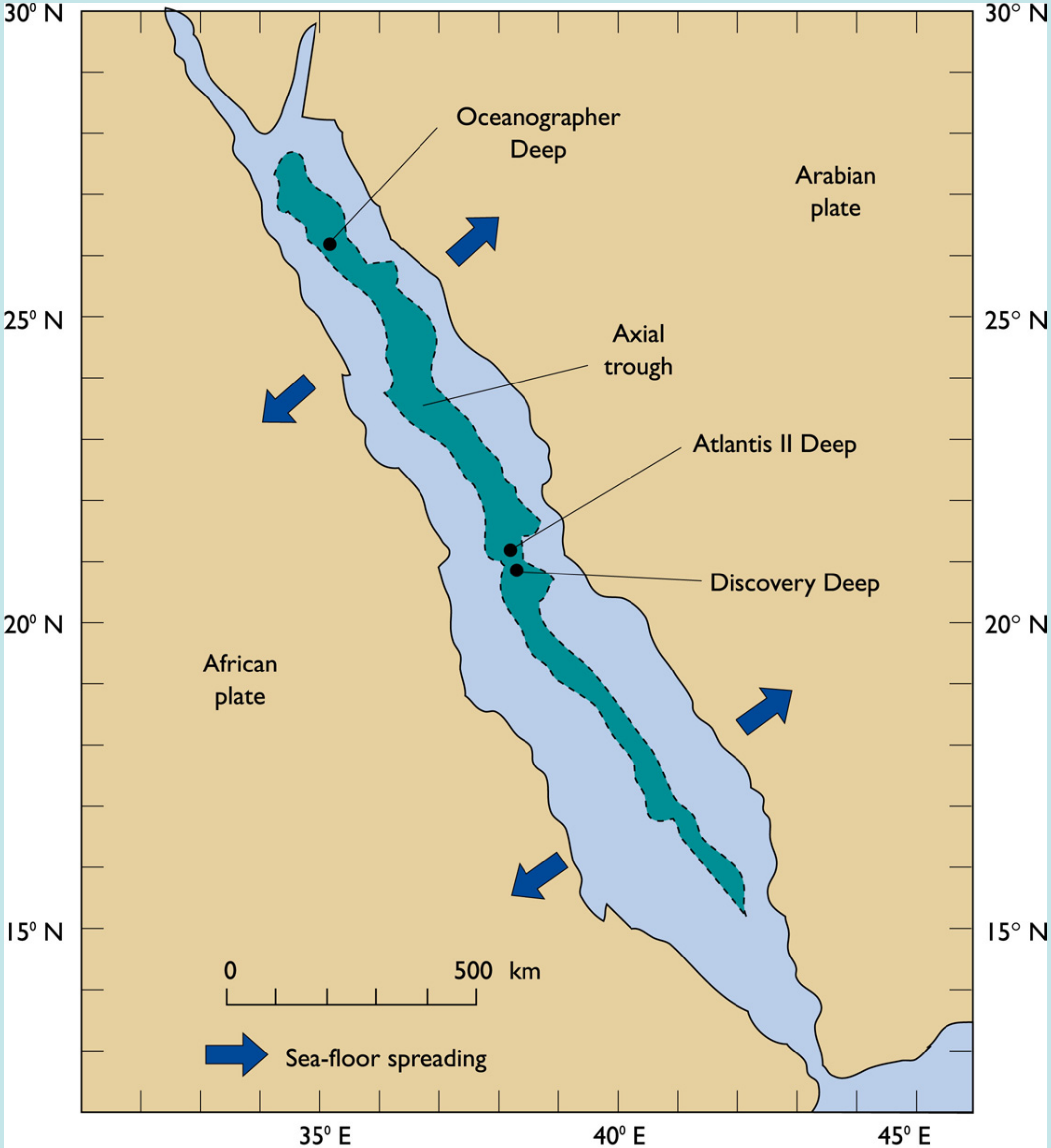

EURASIAN
PLATE
Tibetan
Plateau
Himalayas
Ganges Plain
Mt. Everest
INDIAN
PLATE
INDIAN OCEAN


BEFORE
Tip of Indian plate
Ancient oceanic
crust
EURASIAN
PLATE
INDIAN PLATE
Very old rock, 2 to
2 1/2 billion years old
Reference point
AFTER
Rising Himalayas
Rising Tibetan Plateau
Reference
point
Ancient
oceanic
crust
EURASIAN PLATE
INDIAN PLATE

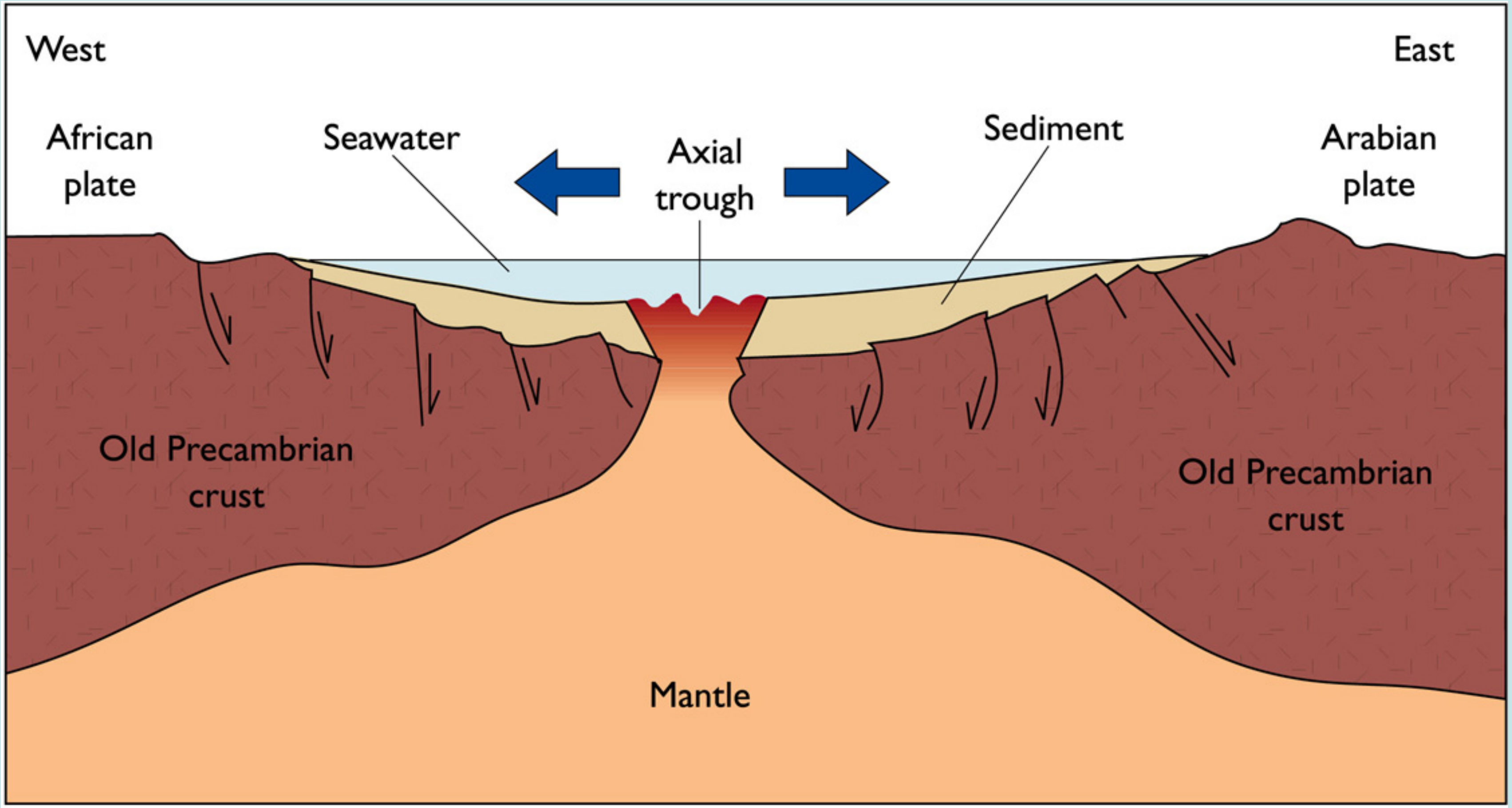

30
20
10
Sea level
Altitude, in Km
Stratosphere
Mt. Everest
Tropopause
AIR TRAFFIC
Troposphere

O MAR VERMELHO: Uma bacia oceânica em estado juvenil

- Bacia longa, quase retangular:Comprimento: 1.900 Km: Largura 300 Km. A maior parte do fundo marinho é raso (média de 490 m) mas com depressões profundas 2850 m.
- Ao longo do centro do Mar Vermelho, existe uma cava profunda com uma profundidade média de 1000 m. Crosta oceânica basáltica vem sendo injetada nessa fossa axial profunda a media que a Árabia se separa da África. Na verdade o Mar Vermelho é um oceano em miniatura uma bacia oceânica juvenil clássica que está se abrindo lentamente devido ao EFO.Processo semelhante ao que foi responsável pela abertura do Atlântico.
- Aparentemente a bacia do Mar Vermelho começou a desenvolver-se cerca de 20 a 30 milhões de anos atrás quando a crosta granítica do leste da África e Árabia sofreu distensão e se rompeu através de um sistema de falhas diretas (normais).
- Estas falhas, dividiram a crosta granítica espessa em blocos grandes. Os sedimentos que atapetam o fundo incluem depósitos de sal com cerca de 7 Km de espessura.



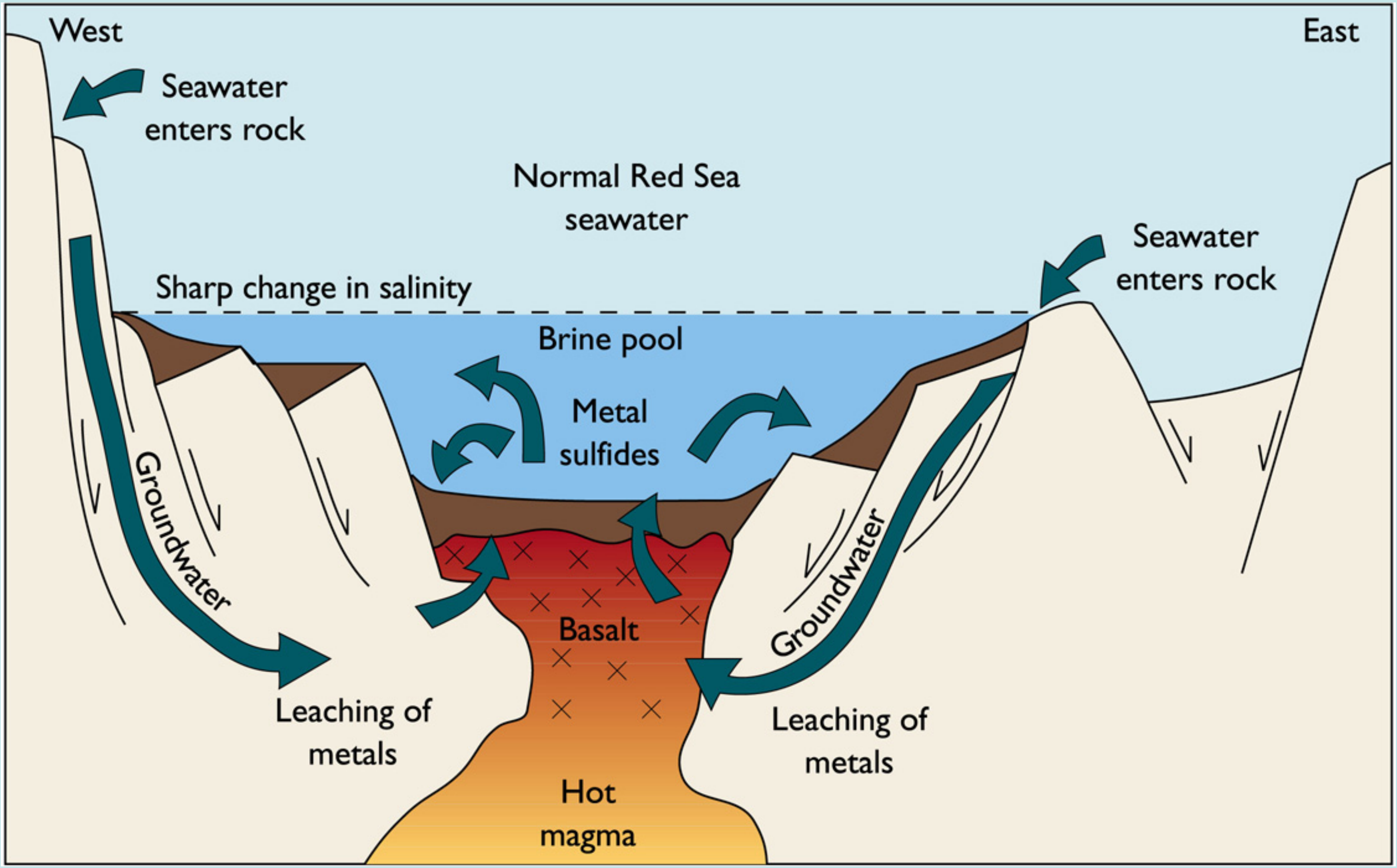
(b) THE RED SEA SPREADING CENTER

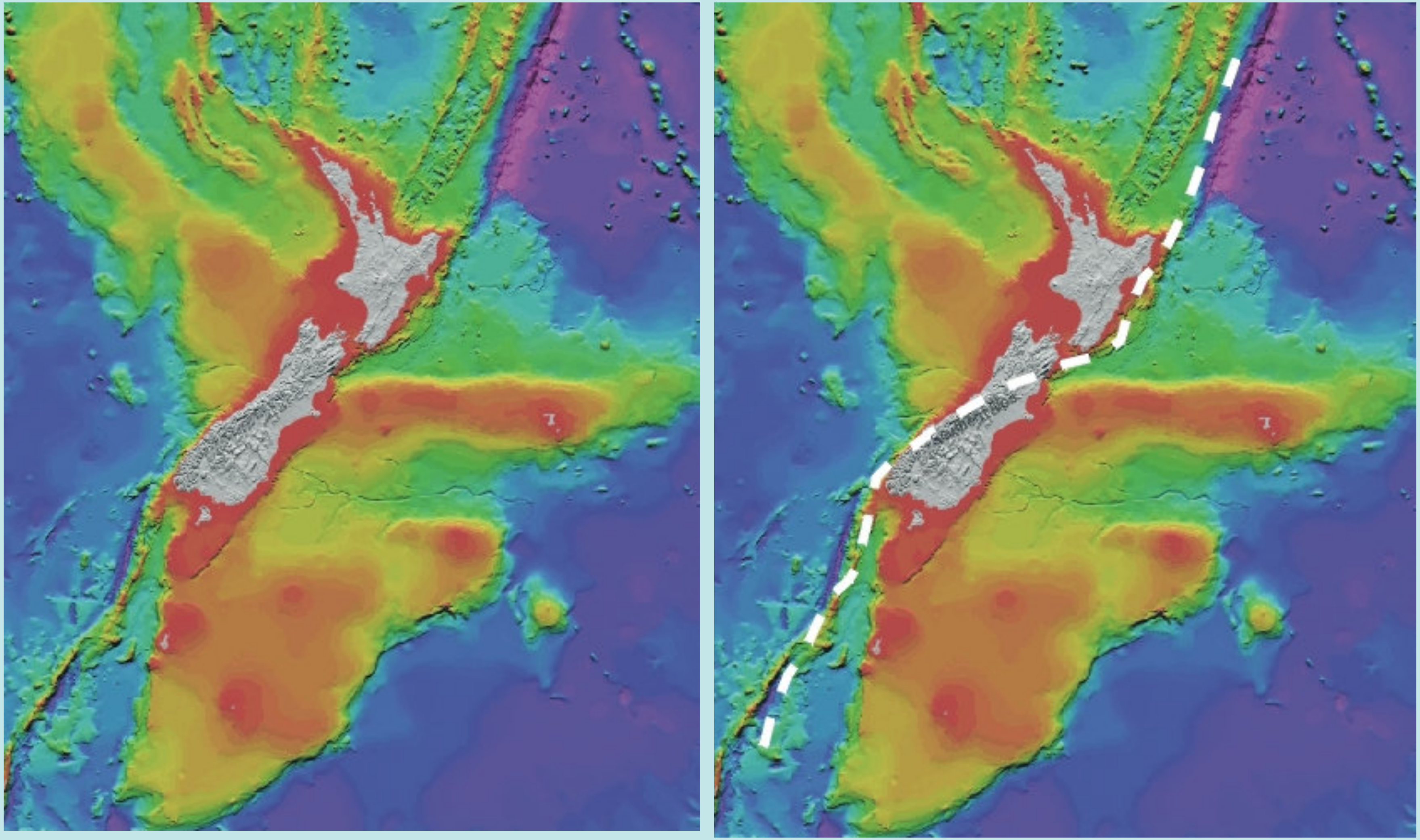


(c) GEOLOGIC (WEST–EAST) CROSS SECTION

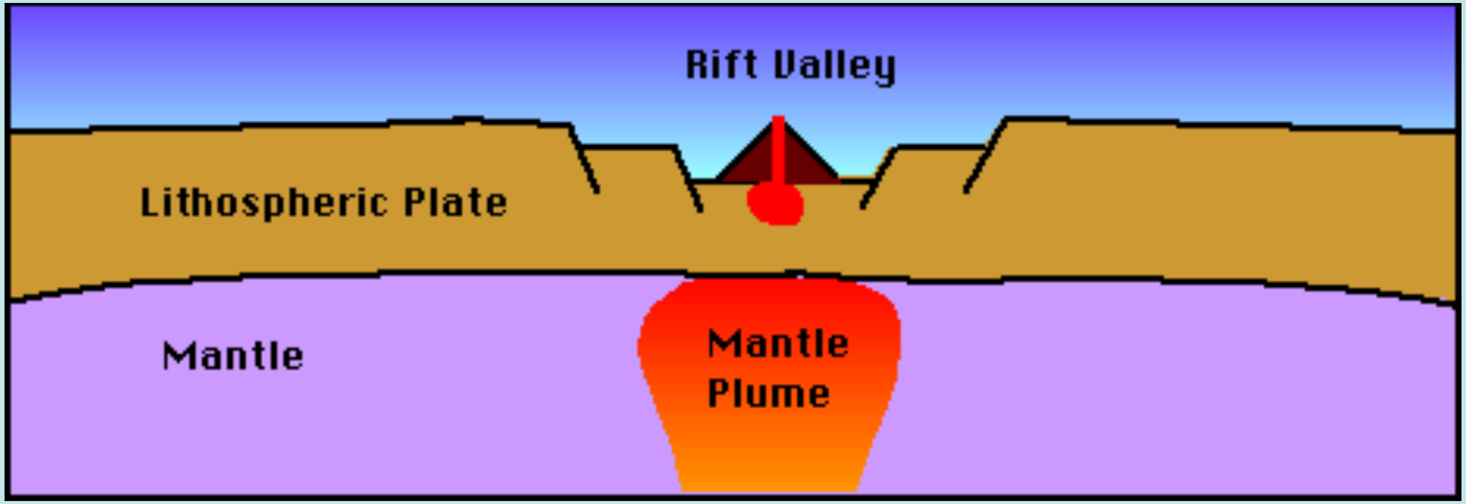
- Restrição basinal: A presença de sal indica que a maior parte do oceano secou períodicamente a medida que a água evaporava e depósitos (EVAPORITOS) salinos formavam-se .
- Não somente existem evaporitos no fundo, mas a água nas depressões mais profundas (Atlantis II, Discovery Deep e Oceanographer deep) é usualmente mais salgada (salmouras quentes—HOT BRINES). Essas salmouras atingem temperatura de 50 a 60 ^{0}C e estão cheia de metais (SULFETOS METÁLICOS) . A fonte tanto do sal como dos metais é o fluxo de água subterrânea através de fraturas das rochas subjacentes. Essa água/salmoura é então aquecida a medida que passa através da crosta aquecida, torna-se corrosiva e lixivia os metais das rochas basalticas, sendo então descarregada ao longo das depressões, falhas e fraturas do fundo, onde permanece devido a SUA ALTA DENSIDADE.
- A medida que o nível dos metais dissolvidos aumenta (ferro, manganes, cobre, chumbo e zinco) aumenta, muitos precipitam com depósitos de sulfetos dando brilho e coloração aos sedimentos.
- Pesquisas geoquímicas indicam que os depósitos da Atlantis II são suficientemente concentrados para serem explotados comercialmente.

- Jatos de água através de mangueiras poderosas baixadas de navios, poderiam transformar os depósitos em lama densa os quais poderiam então ser bombeados para a superfície a uma taxa aproximada de **200.000 toneladas por dia**. Esses depósitos seriam então processados a bordo do navio de mineração.--- Economicamente deveria ser processado no oceano---o problema é o rejeito da mineração----metais pesados---engenheiros vem trabalhando em técnicas de processamento para minimizar os impactos ambientais.


West
East
Seawater enters rock
Normal Red Sea seawater
Seawater enters rock
Sharp change in salinity
Brine pool
Metal sulfides
Groundwater
Groundwater
Basalt
Leaching of metals
Leaching of metals
Hot magma

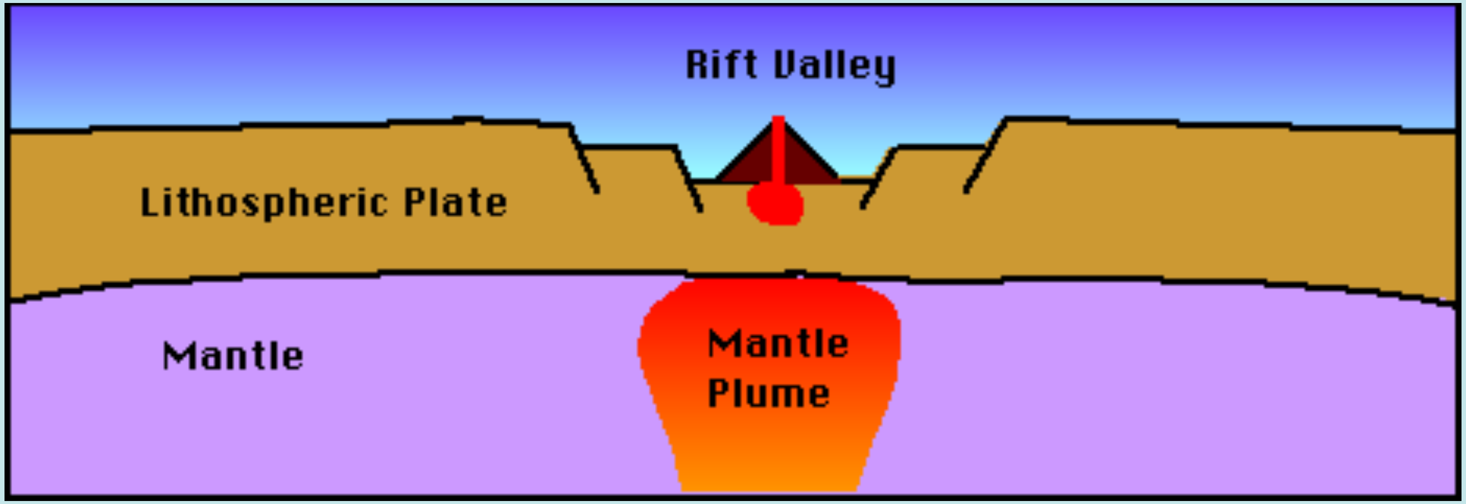


The Wilson Cycle: 1. Formation of rift



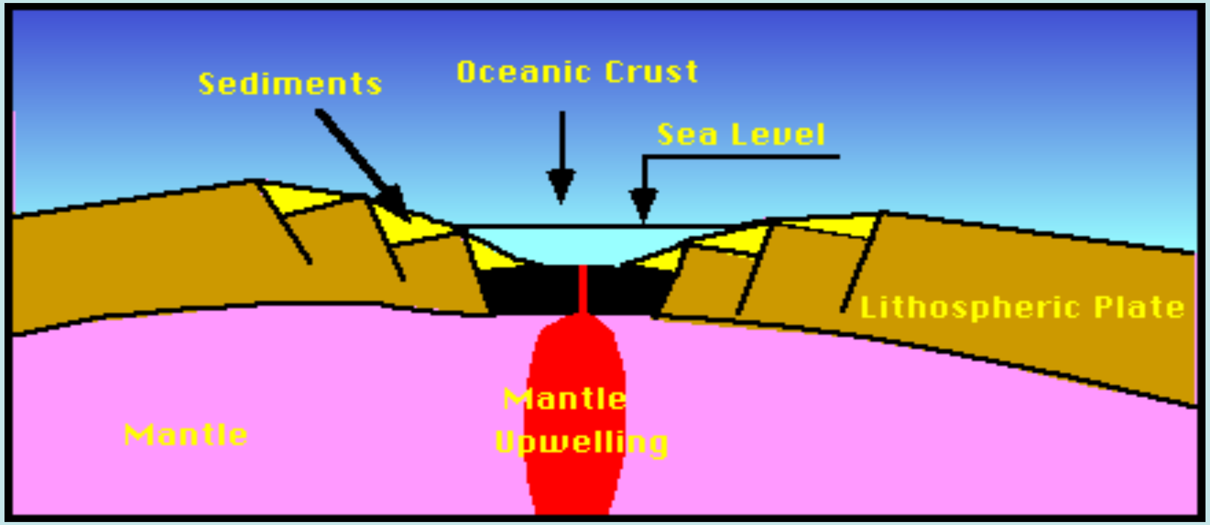
- plates tend to aggregate over cold downwellings in the mantle and act as an insulating blanket
- mantle below heats up as a result, alters convection pattern
- asthenosphere upwells, continental crust bulges
- continent splits in response to intraplate tension
- break-up of the continent produces rift valleys
- current example: East African Rift.

2. Extension, formation of rift valleys



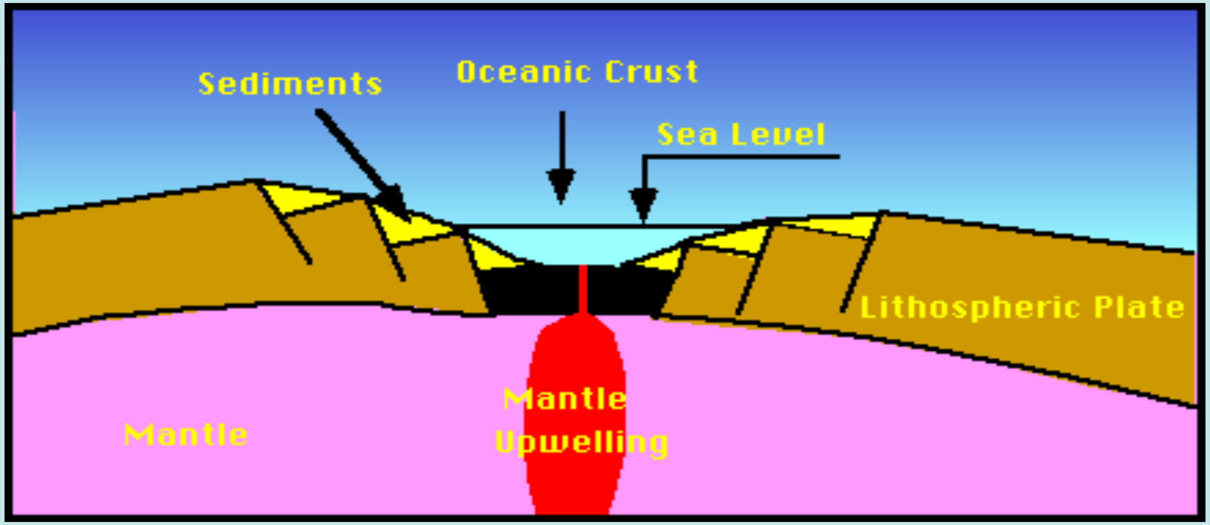
- plates begin to "slide off" upwelled mantle bulge
- rifts evolve into extensional valleys
- continental sediments get deposited in grabens or half-grabens
- initial continental sedimentation gets replaced by marine
- initial drainage away from rift limits sediment input
- sabkha and evaporite deposits in warm dry climates (restricted communication with open ocean water)
- reef limestones develop (slow subsidence, little terrestrial input).

2. Extension, formation of rift valleys



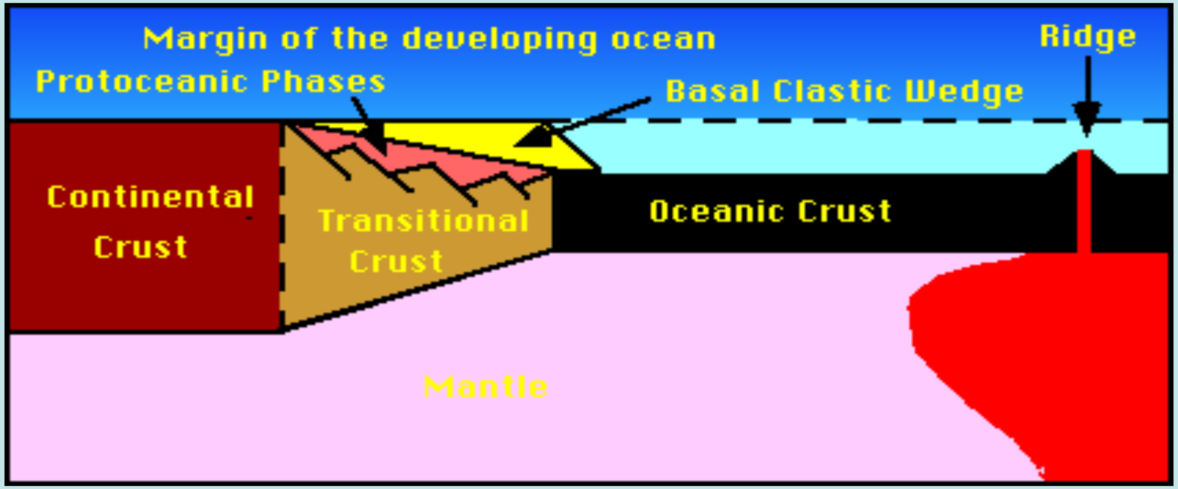
- anaerobic conditions + sapropelic sediment → good source rocks for petroleum
- potential structural traps (faults, salt domes) → good traps
- continental tholeiite magma leaks to the surface along dykes and forms flows (e.g., Fundy Group)
- eventually oceanic crust begins to form
- rifting may be symmetrical or asymmetrical.

3. Young ocean basin stage



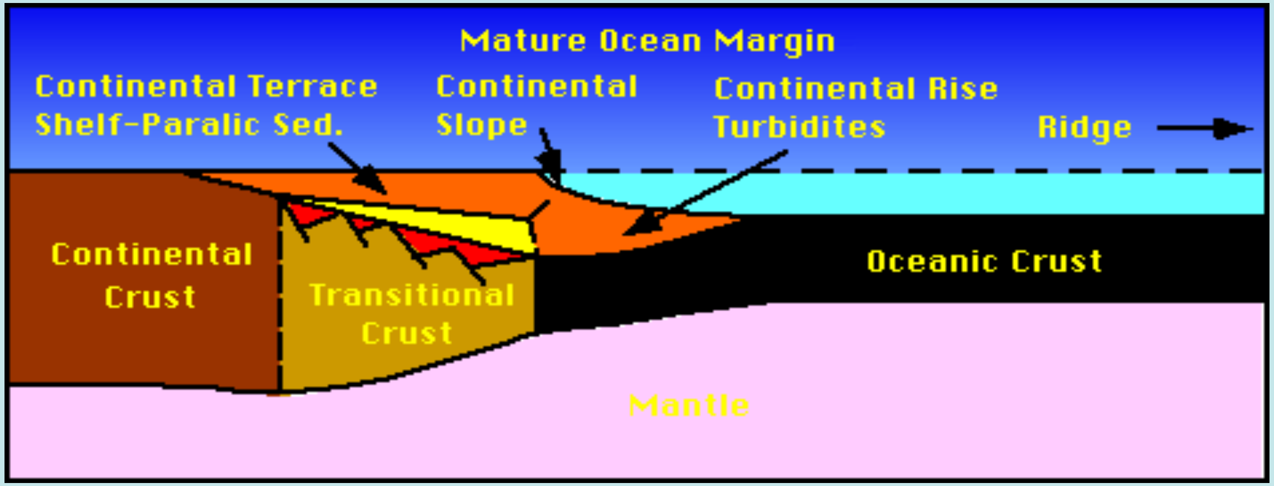
- ocean crust begins to form (sea-floor spreading)
- magnetic stripes start to develop
- the central rise divides the ocean in two halves with separate depositional histories
- usually initially fairly symmetrical
- basal terrigenous wedge at periphery reflects rapid thermotectonic subsidence
- accelerated spreading may lead to a global transgression.

3. Young ocean basin stage



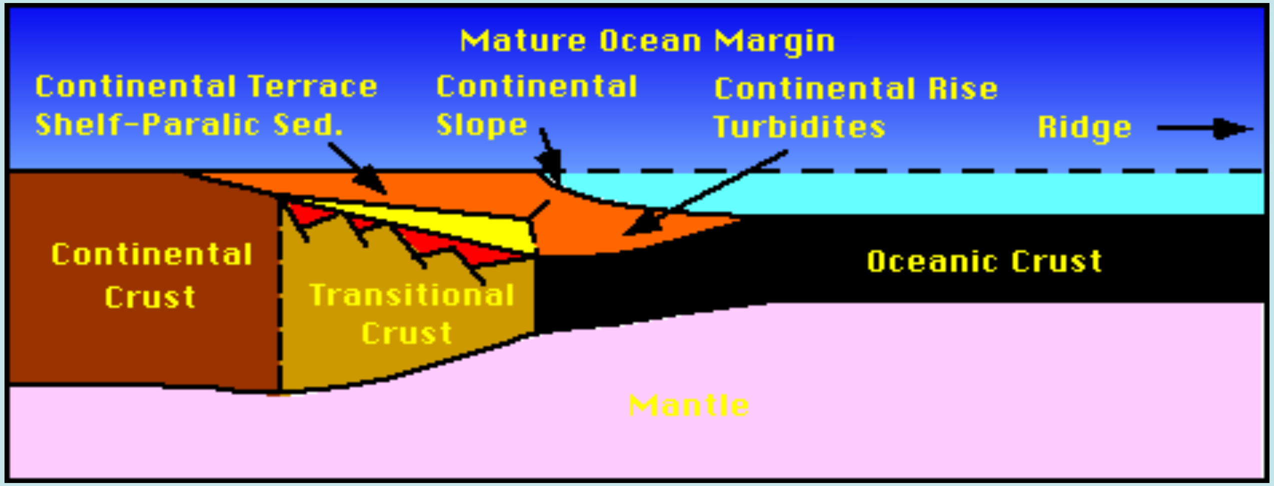
- terrigenous clastic wedge grades landward into fluvio-lacustrine complex
- clastic wedge grades seaward into turbidites of continental rise
- calcareous sediments restricted to zones above the CCD (central parts of ocean, margins)
- deeper water characterized by red clays, ooze
- burial of earlier sapropelic deposits by clastic sediments create favourable environments for formation of hydrocarbons
- world's main mass of sediment.

4. Mature ocean basin



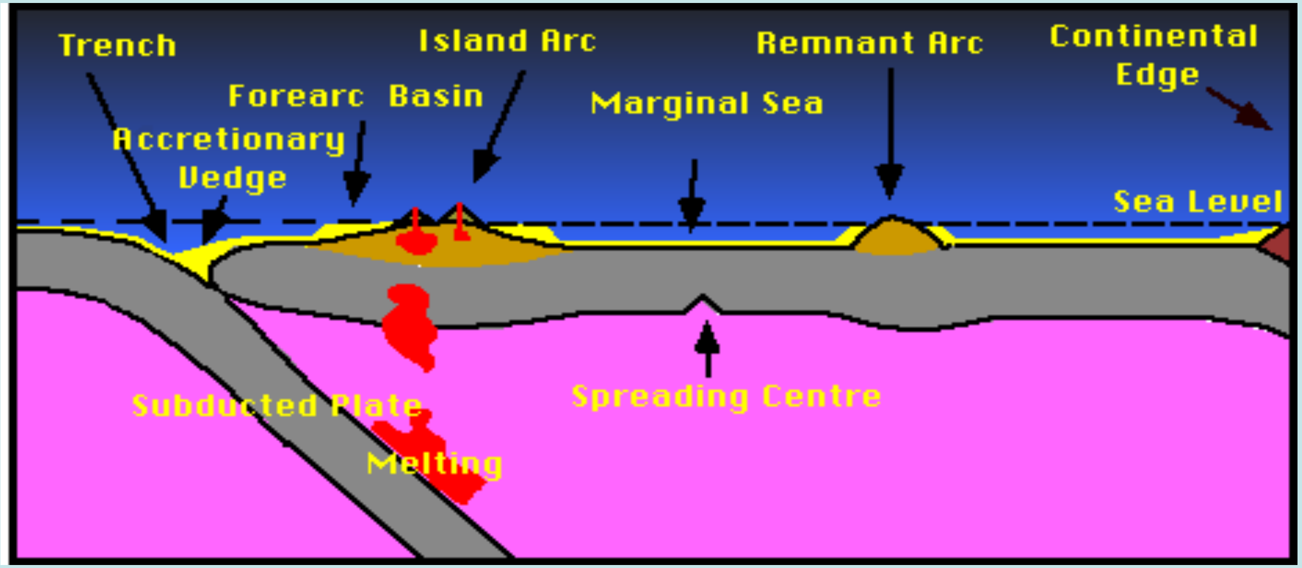
- continuous production of oceanic crust → ocean widens
- "passive margins" exist on both sides
- these are not plate boundaries
- passive margins have unrelated depositional histories
- may be asymmetrical
- weight of sediment results in flexural subsidence
- subsidence rates are much slower than earlier; carbonate platforms may develop (e.g., Bahamas).

4. Mature ocean basin



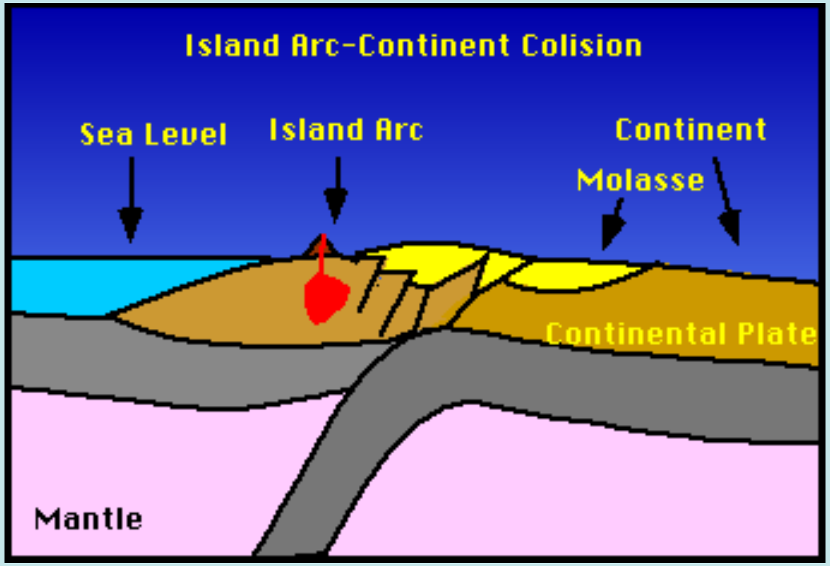
- fine-grained continental sediment (deltaic, lacustrine, shelf) builds up on the basal clastic wedge
- turbidite currents transport sediment down slope to rise
- very slow sedimentation on abyssal plains
- e.g., east coast, North America
- open ocean water depth at its greatest (outside trenches) because older ocean floor is colder, and subsides.

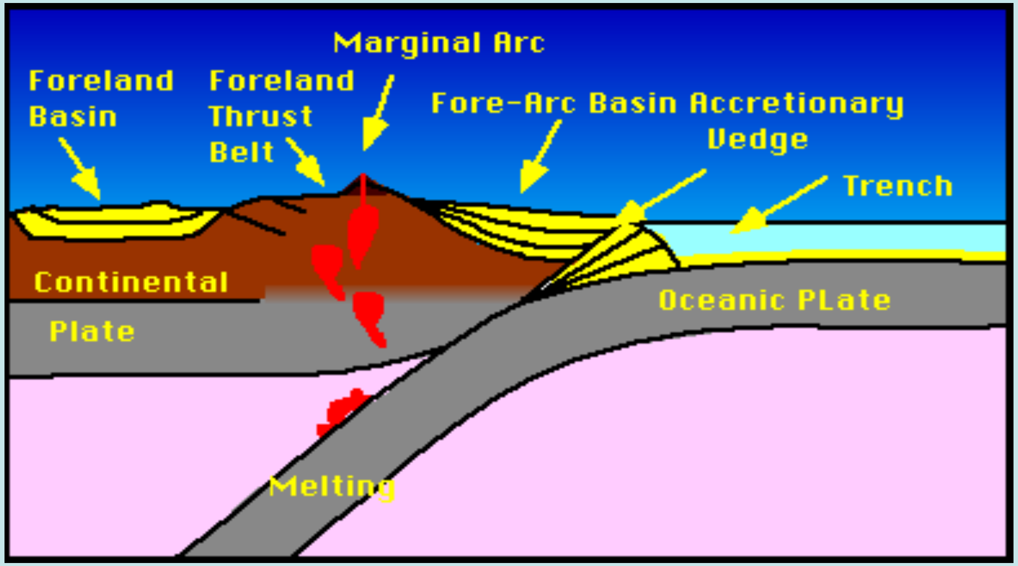
5. Closing of the ocean basin



- new ocean crust production is balanced by ocean crust consumption by subduction (island arc forms)
- as ocean floor ages, it cools, and eventually becomes dense (cool) enough to sink, e.g., West Pacific
- if the rate of subduction exceeds the rate of sea-floor spreading, the ocean begins to close
- buoyant material (oceanic islands, sediment, various junk) may not subduct, and gets scraped off into an ***accretionary wedge***.

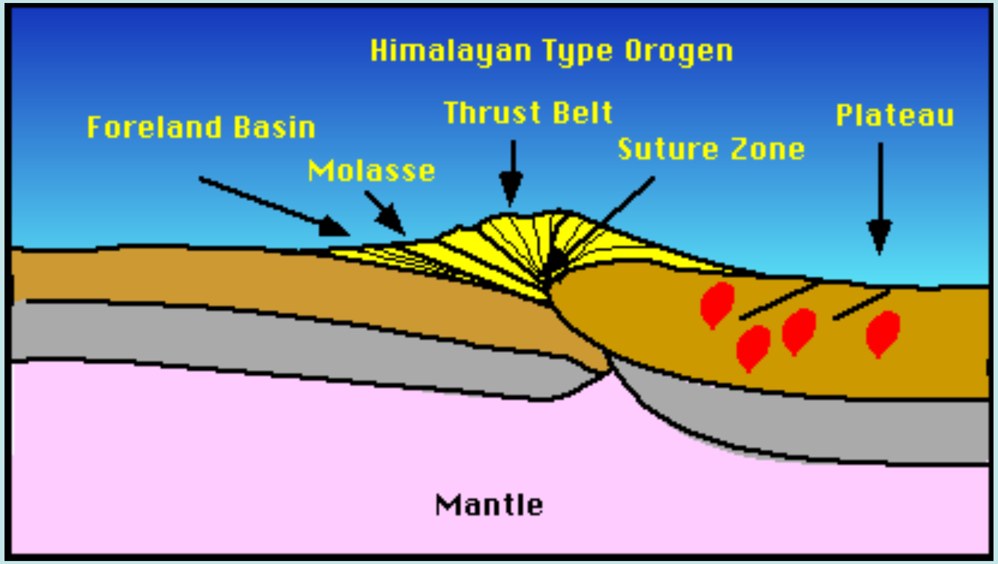
6a. Arc-Continent Collision





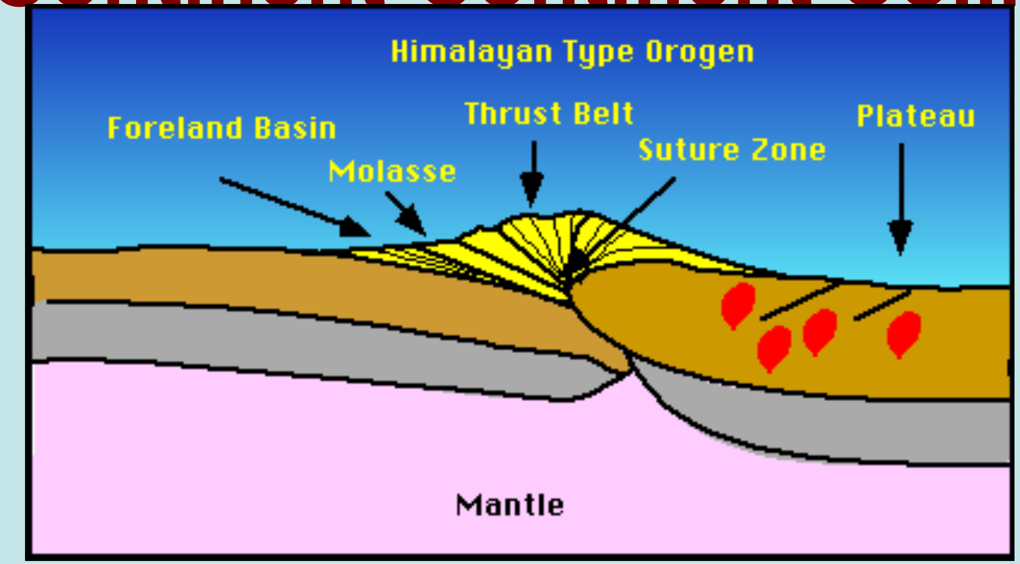
- as ocean crust is subducted, ultimately a continent will arrive
- arc-continent collision occurs: crustal shortening, folding, thrusting, metamorphism, intrusion
- accretionary wedge and fragments of ocean floor may be driven up on to a continental margin
- oceanic lithosphere continues to be subducted under the continent
- oceanic lithosphere always subducts
- e.g., Andes

6b. Continent-Continent Collision



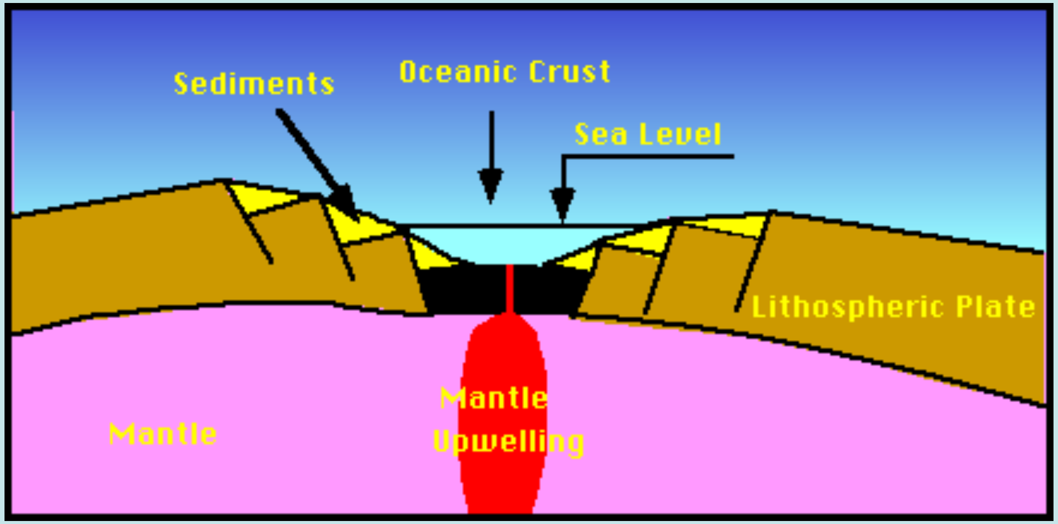
- **continental crust is too buoyant to subduct on both sides**
- **major crustal shortening, thrusting, metamorphism, upheaval**
- **movement is slowed or halted**
- **remainder of subducting oceanic lithosphere is detached and sinks into asthenosphere**
- **new mountain range forms, locus of collision is called *suture*.**
- **eventually a second continent will be pulled to the subduction zone (e.g., India to Asia)**

6b. Continent-Continent Collision

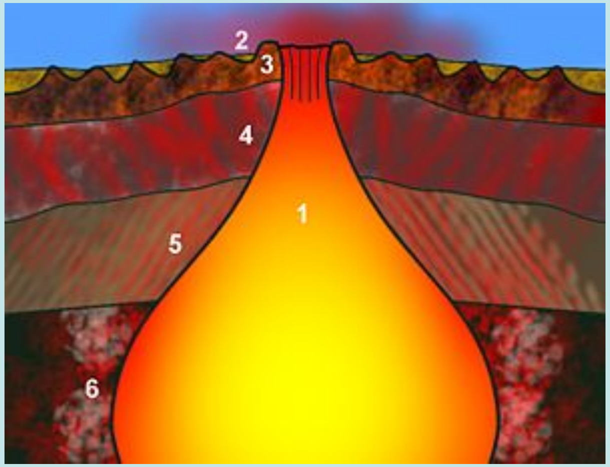


- ophiolites may be preserved along the suture, or thrust out and preserved as klippen
- uplift results in weathering and erosion
- *molasse* (deposited on continent or shallow water) and *flysch* (deposited in deep water, usually farther away) form
- geographic restriction of ocean basins commonly result in isolated basins (e.g., Caspian Sea)
- continued collision may result in indentation one continent by the other.

7. Renewed Break-up



- eventually collision ends, plate motions adjust, and a new larger continent exists
- heat builds up underneath, the mantle swells
- rifting begins…
- where does rifting occur?
  - could be at the "peak" of the swell
  - could be along a line of weakness (former suture)
  - e.g., Iapetus Ocean, Atlanic Ocean.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