TECTONIC PLATES, A GLOBAL THEORY

TEMA 2

BIOLOGÍA Y GEOLOGÍA 4ºE.S.O.

1. HISTORICAL BRACKGROUND

Teorías fijistas ⟷ *Teorías movilistas*.

The first historical data:

The cartographers of the 16th and 17th centuries, who noticed the similarity of the coasts of South America and Africa. They considered that earthquakes and floods had separated them.

In the nineteenth century Alexander von Humboldt said that not only did the geographical boundaries coincide, but so did several geological formations.

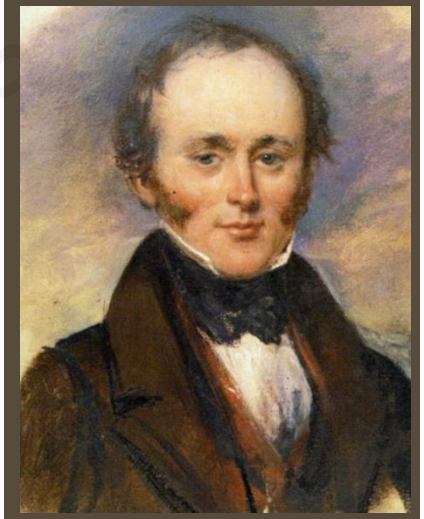
- At the end of the 19th century, Austrian geologist Edward Suess proposed that the continents that are in the southern hemisphere in the past were united in a single supercontinent, Gondwana.

TRIASSIC
200 million years ago

2. VERTICAL MOVEMENTS: ISOSTASY

The vertical movements of the continents were known since ancient times and were accepted by fixists and mobilists

Templo Serapis de Pozzuoli

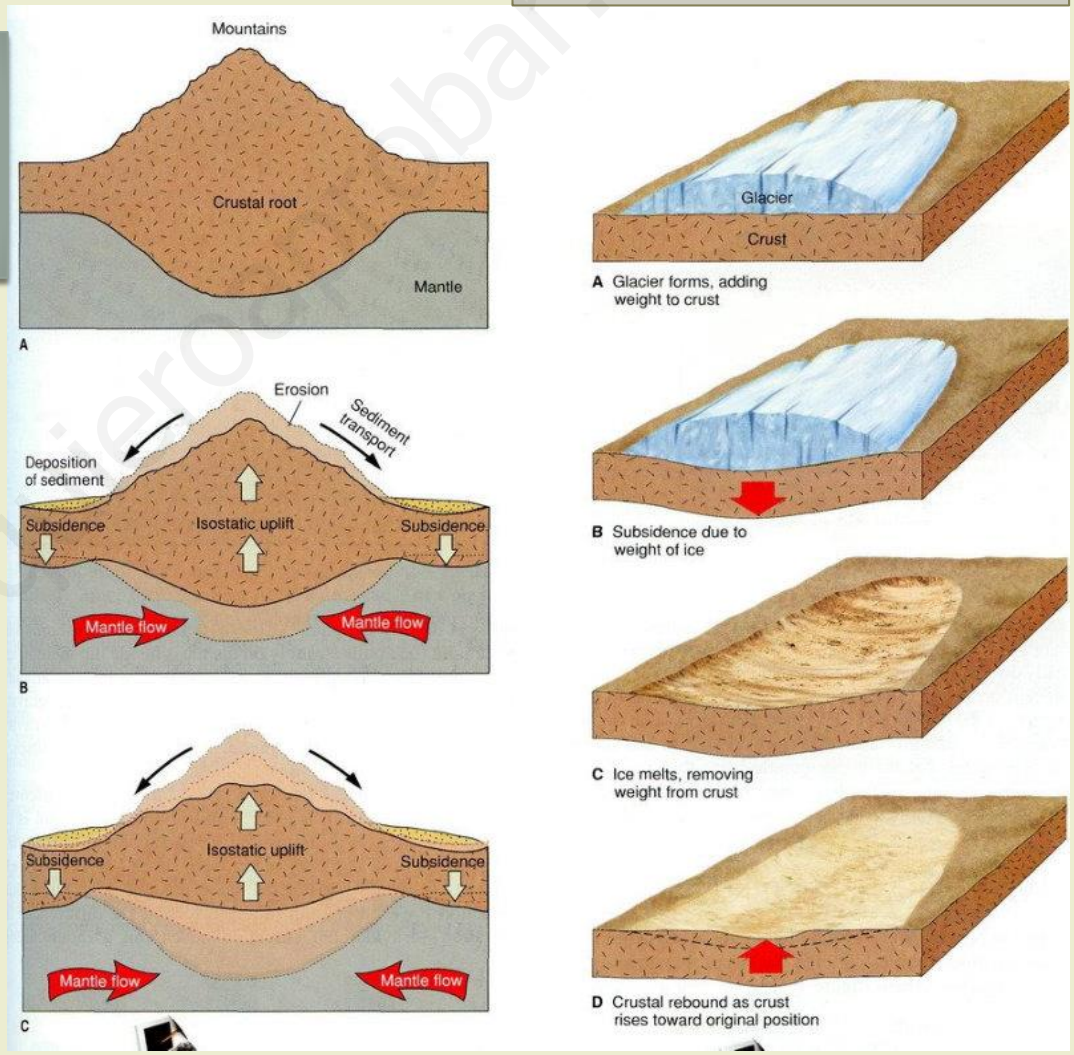


Ancient water lines were known inside the continent and that the estuaries and fjords are formed by flooding valleys by sinking the continent.

- A simplification could be made by stating that the lithosphere "floats" over the asthenosphere so that:

✔ If its mass decreases, erosion, melting of glaciers ...
✔ It "rises" over the asthenosphere.

✔ If it increases its mass, due to sediment accumulation, formation of a glacier layer ...
✔ It "sinks" into the asthenosphere.



- Isostasia is called movements that seek gravitational balance with the mantle, so that it rises when it is discharged and sinks when it is overloaded.

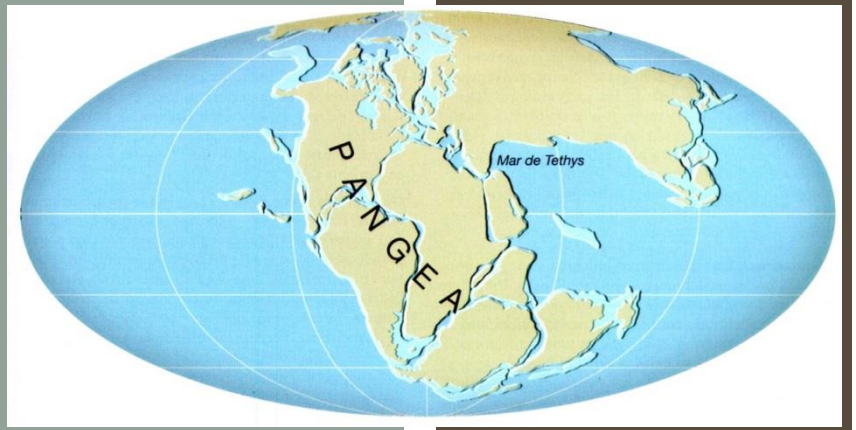
- They are slow movements that stop when the isostatic equilibrium is reached.

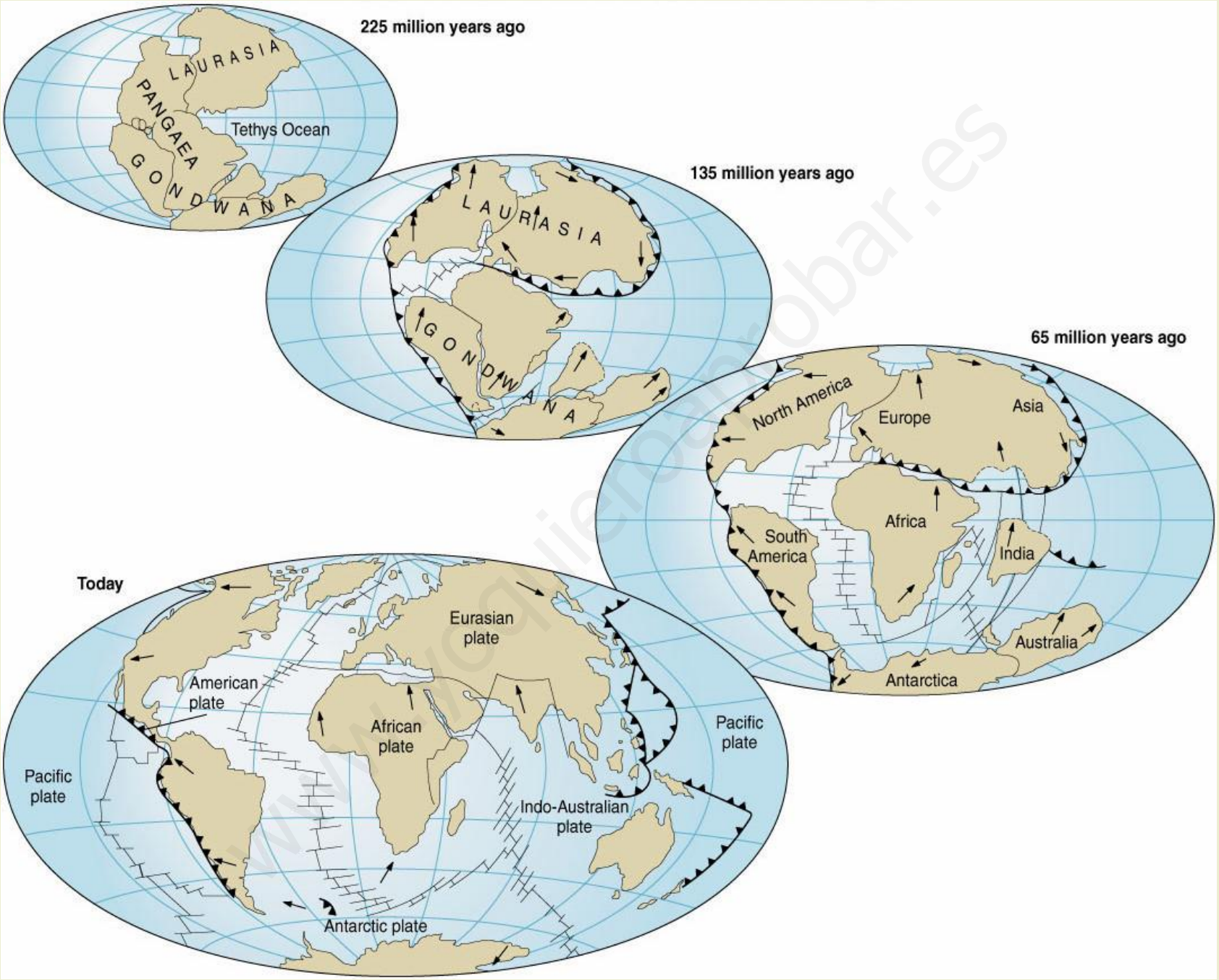
3. ALFRED WEGENER: THE CONTINENTAL DERIVA

At the beginning of the 20th century, Alfred Wegener developed the theory of continental drift

In 1915 he published The origin of the continents and the oceans,

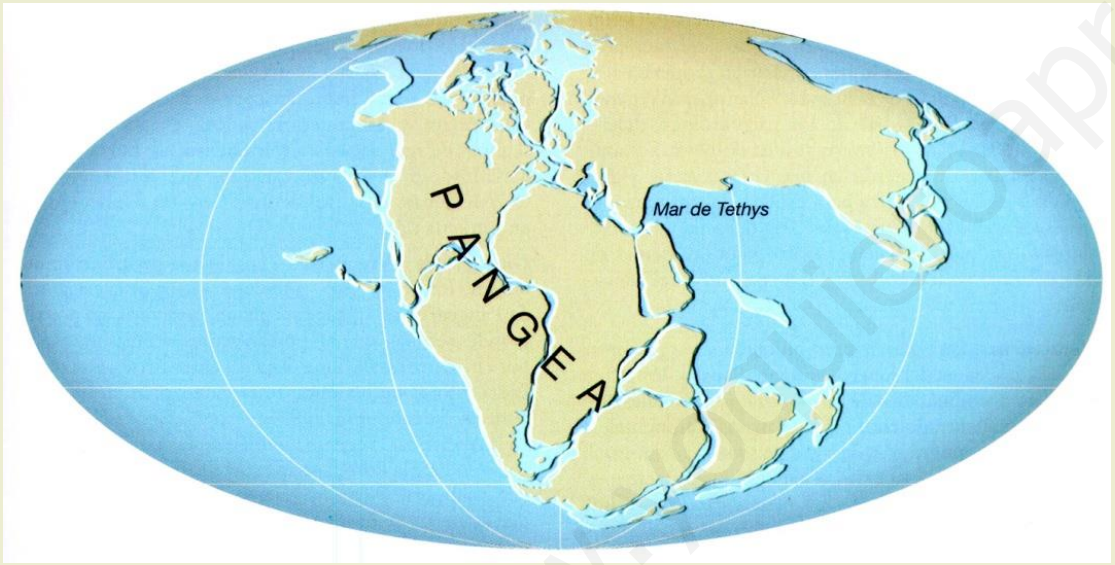
- The theory states that:
- In the past there had been a single supercontinent, which he called Pangea,
- 200 million years ago it began to dismember giving rise to a series of minor fragments that suffered a series of horizontal displacements, "drifting",
- This movement caused continental collisions,
- They would be responsible for the folding and lifting of the mountain ranges.

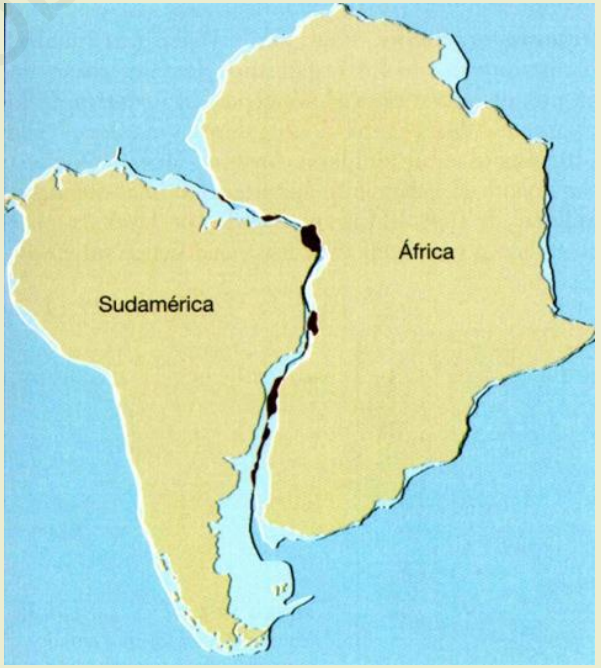



225 million years ago
LAURASIA
PANGAEA
Tethys Ocean
GONDWANA
135 million years ago
LAURASIA
GONDWANA
65 million years ago
North America
Europe
Asia
Africa
South America
India
Australia
Antarctica
Today
Eurasian plate
American plate
African plate
Pacific plate
Pacific plate
Indo-Australian plate
Antarctic plate

GEOGRAPHICAL TESTS

- The edges of the continents fit quite well when reconstructing the old supercontinent proposed by Wegener

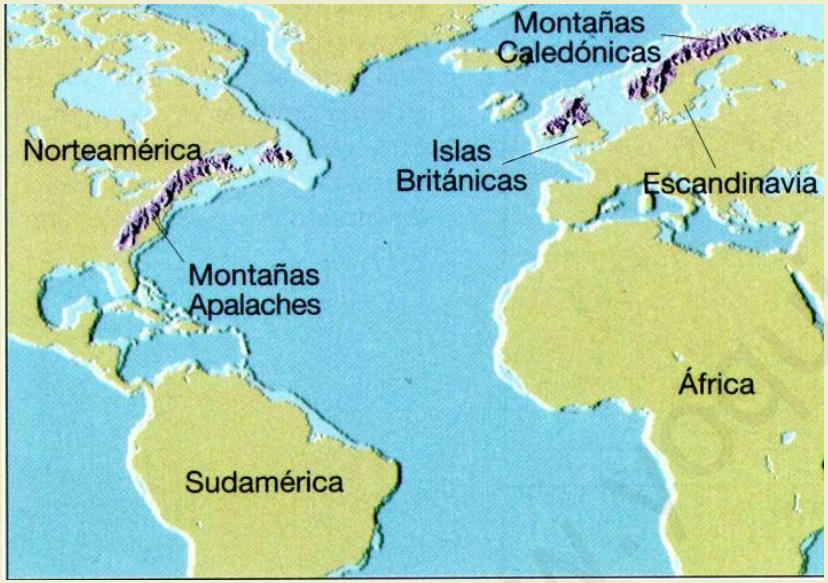




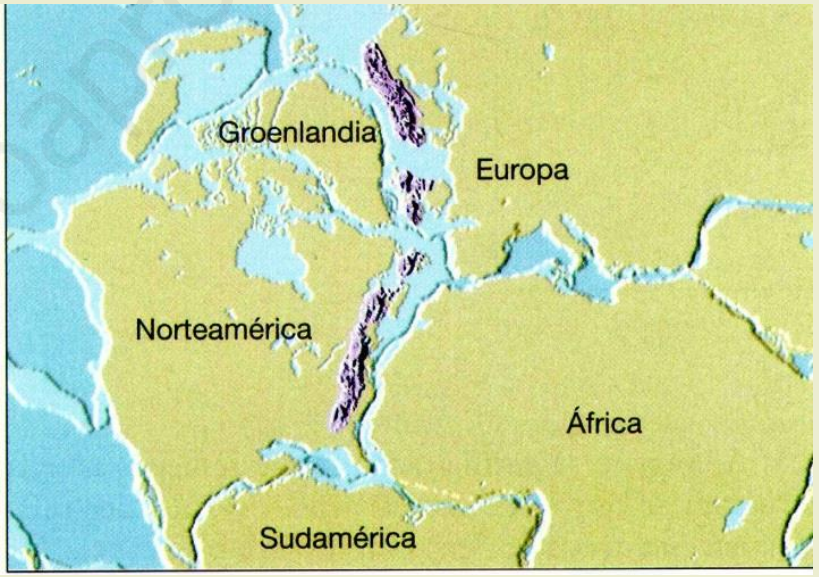
- This lace is better if we consider the edges of the continental shelf

GEOLOGICAL TESTS

- When reconstructing Pangea, there is a coincidence between good and perfect of a great diversity of geological features: mountain chains, stratigraphic series, granitic massifs, basaltic effusions, etc. Moreover, these coincidences disappear sharply when Pangea ceases to be a single continent.

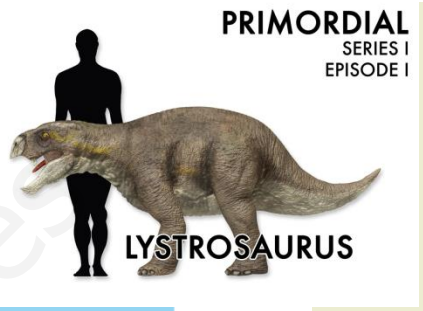


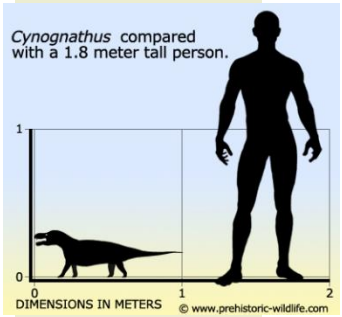
- The Appalachians extend along the eastern coast of North America and disappear on the coast of Newfoundland.
- There are comparable age and structure mountain ranges in the British Isles and Scandinavia

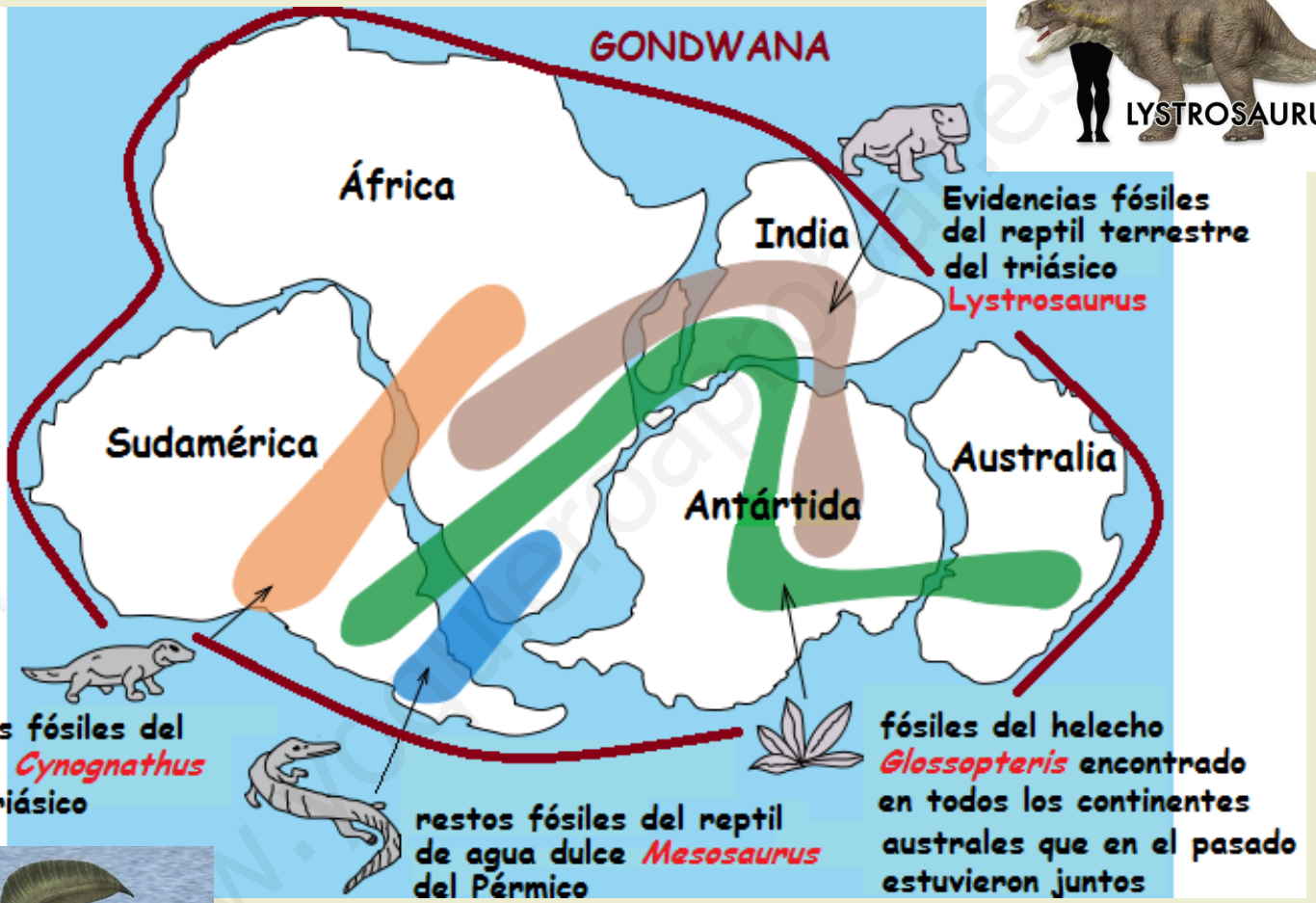


- By arranging the continents as it is believed that they were united in Pangea these mountain ranges form a continuous mountain range

PALEONTOLOGICAL TESTS







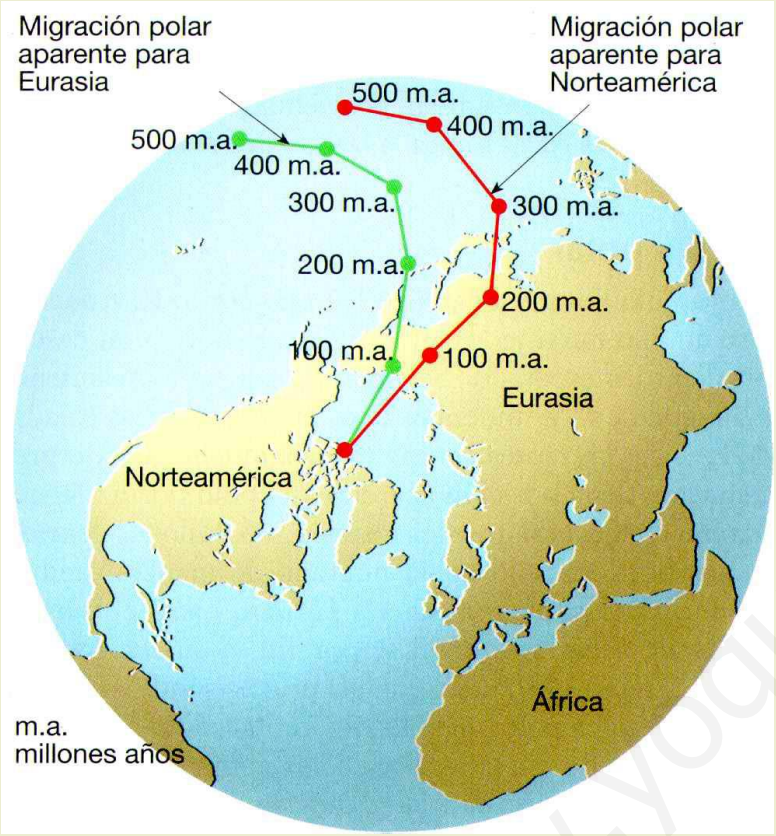
- It is very difficult to explain the distribution of certain fossils without counting on the displacement of the continents

➢ PALEOCLIMATIC TESTS

MOST OF PALEOCLIMATIC ANOMALIES ARE RESOLVED WHEN PANGEA IS RECONSTRUCTED

- There are contemporary glacial deposits in South America, Africa, Antarctica, Australia and India, the residue of a glaciation that took place 320-270 million years ago
- In the reconstruction of Pangea, these places, so far away today, are together and near the south pole. In that situation, the extension of the polar cap acquires a reasonable size and the flow direction of the ice fits perfectly.
- On the other hand, at the same time, there are hardly any glacial deposits in the northern hemisphere, which is logical considering that Greenland and North America were in a tropical position

PALEOMAGNETIC TESTS



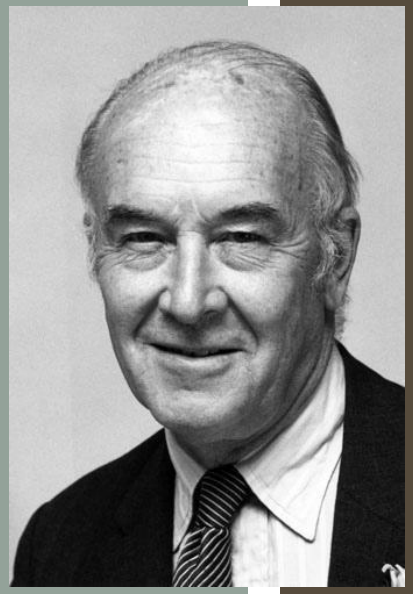
- With the information from rocks of different ages, a curve can be constructed that marks the change of position of the Earth's magnetic pole over time.
- This change of position may be due either to a real change of position of the pole or to a displacement of the continent with respect to it **(apparent polar drift).**

- The paleomagnetic data obtained in Eurasia allows to reconstruct the apparent migration path of the poles represented in green in the drawing on the left.

- The reconstruction made from paleomagnetic data obtained in North America is represented in red.

4. THE SCIENTIFIC REVOLUTION

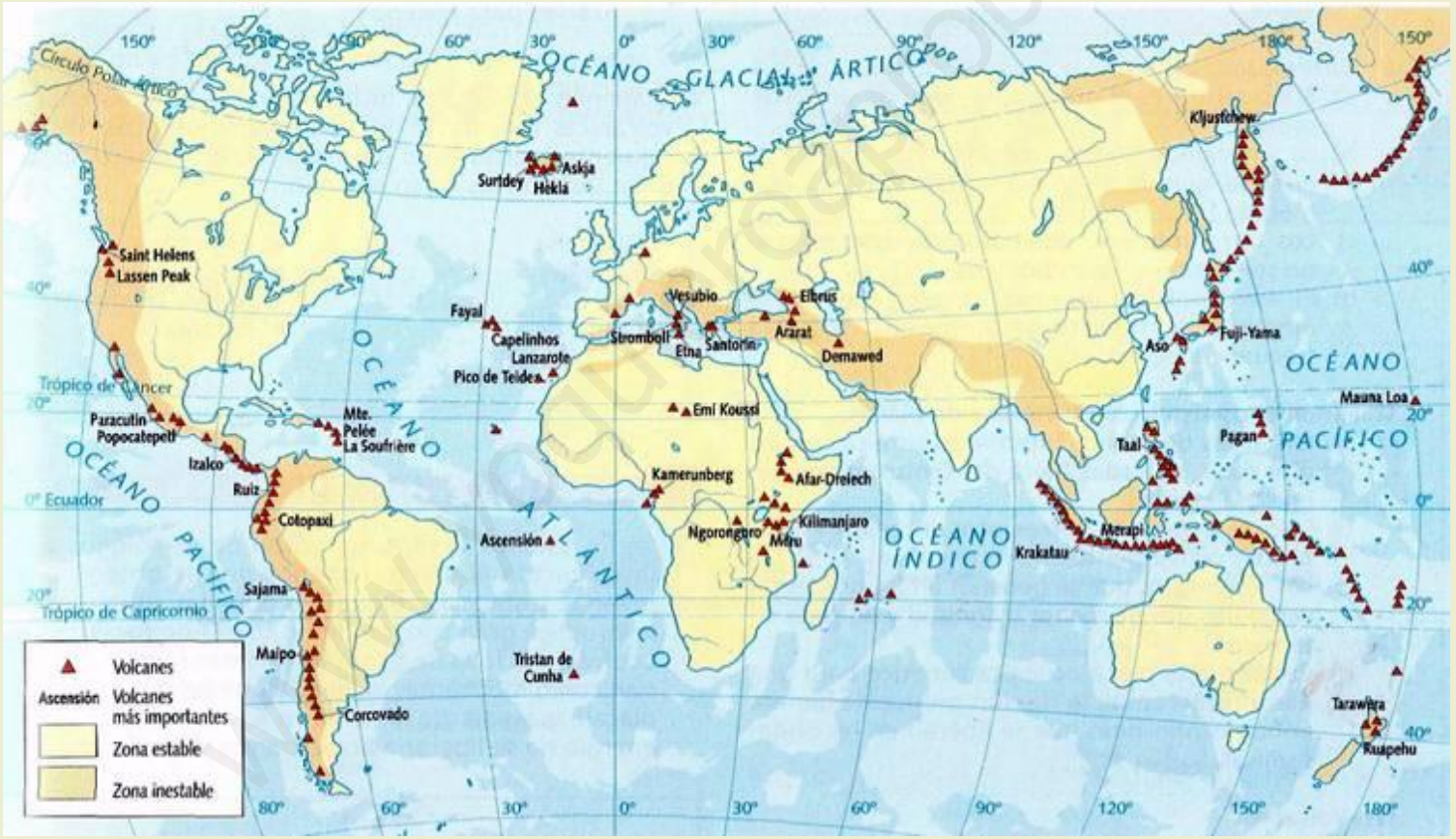
However, Wegener's theses were not accepted because he did not explain what the cause of the movement of the continents was.



Throughout the twentieth century, four major scientific and technological advances drove the formulation of a new theory, **plate tectonics:**

TESTS THAT EVALUATE THE TECTONICS OF PLATES

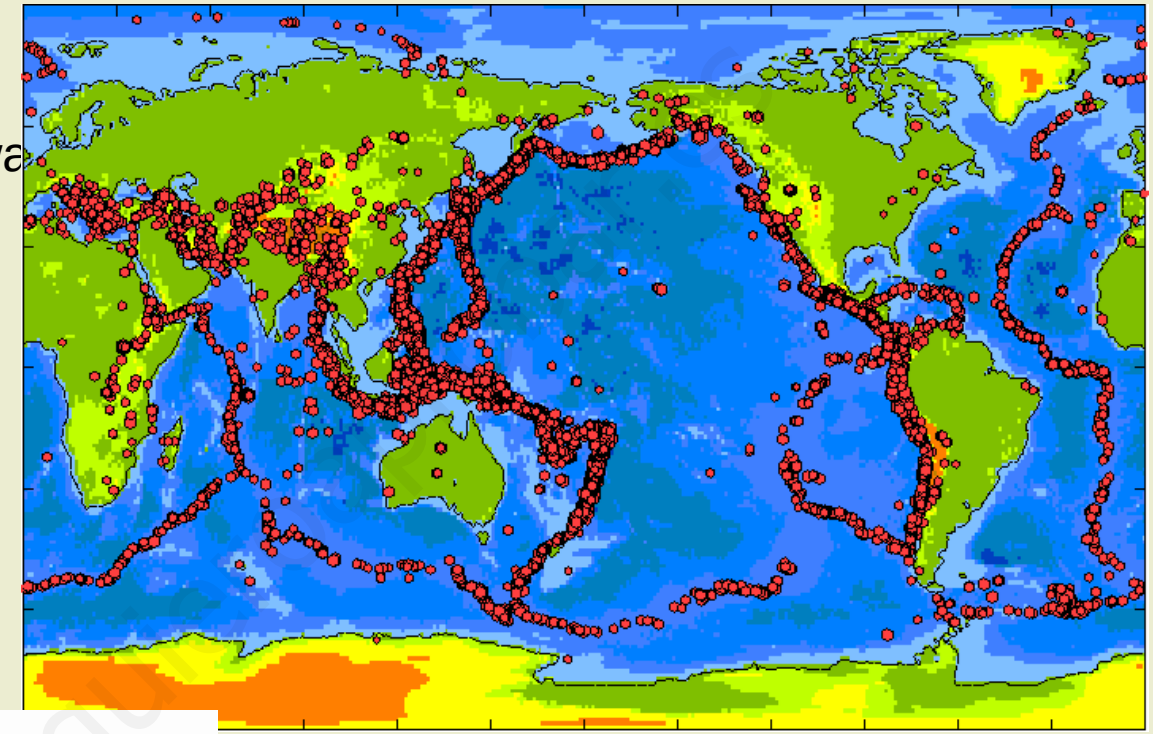
- **LOCATION OF SEISMIC AND VOLCANO FOCUSES**

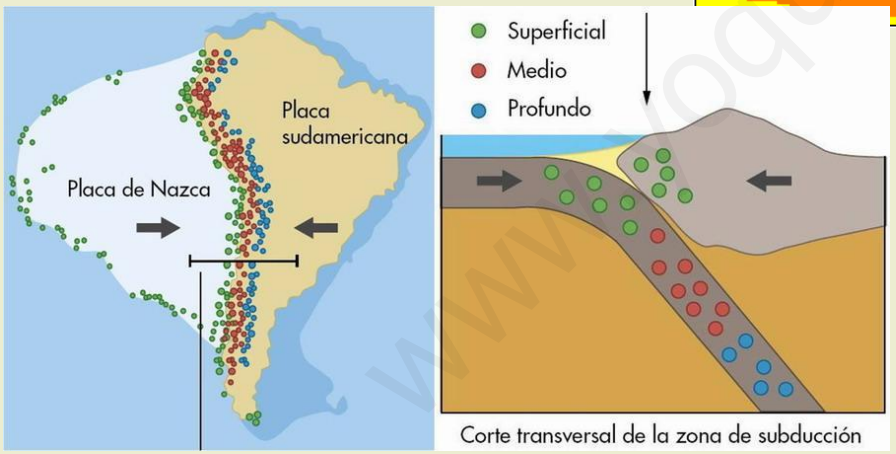


VOLCANO DISTRIBUTION

Seismic DISTRIBUTION

- Seismic studies in the cold wa
  detect nuclear explosions
- They contributed:
  - The distribution of earthquakes
  - Earthquakes indicated:
  - Distension (dorsals),
  - Compression (subduction) and
  - Shear (passive edges)



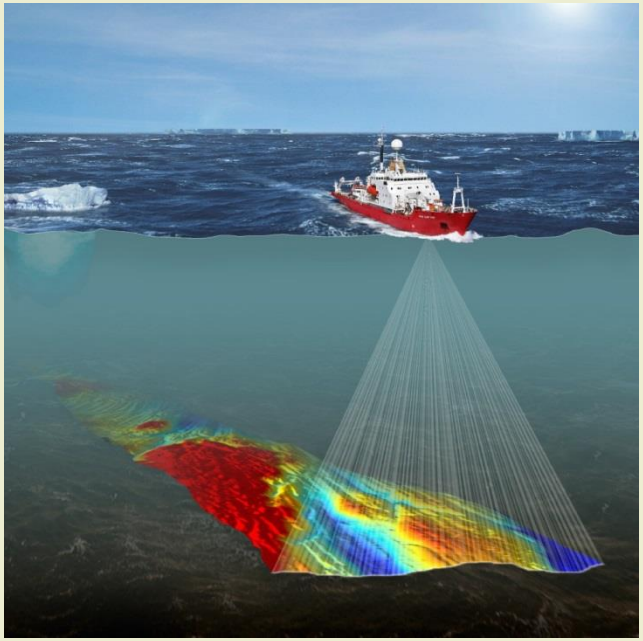


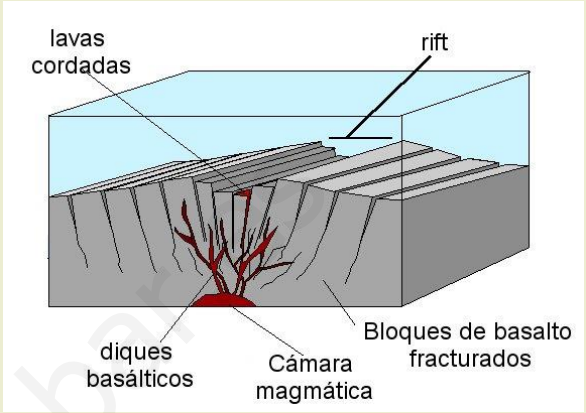
- The seismic foci inclined between 40 and 60 degrees with respect to the horizon in a plane called the Wadati-Benioff area

Enlace para página web USGS (US geological survey)

Ver archivo:
Placas tectónicas: volcanes y seísmos

STUDY OF THE OCEAN FUND





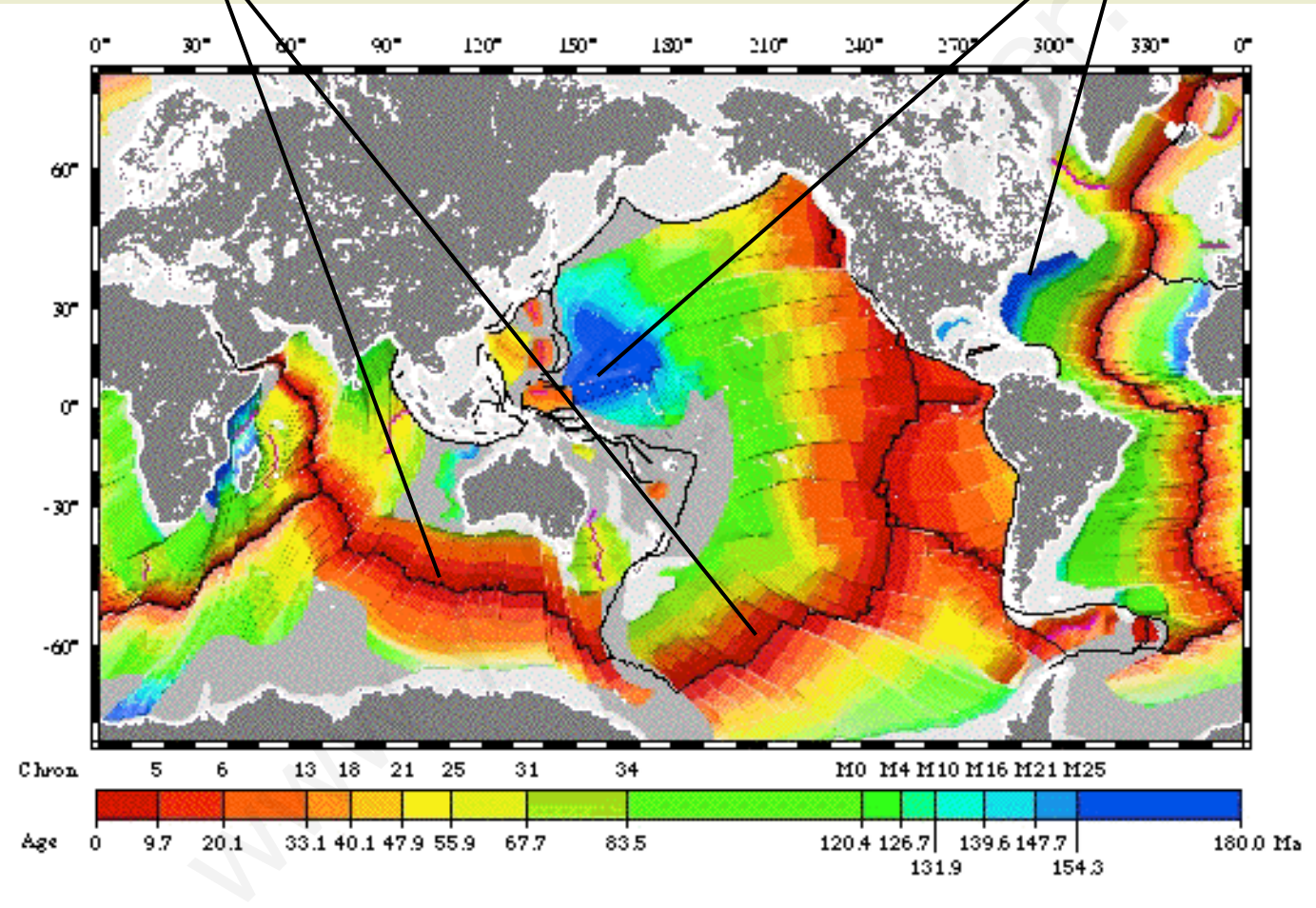
Oceanic dorsal: underwater mountain range, with more than 70,000 km in length and more than 1,000 km in width and a central valley, the rift

Ocean trenches

AGE OF OCEANIC BARK

The most recent cortex is located in the dorsals

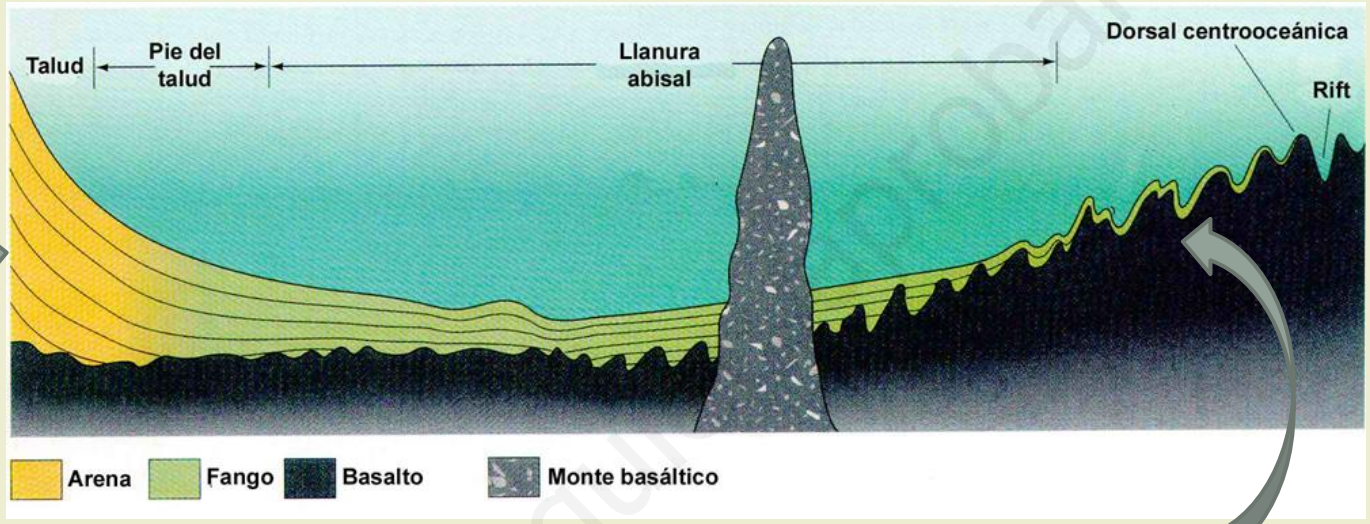
The oldest is near the coasts, far from the dorsals



THE AGE OF OCEAN COURT INCREASES AS WE GO AWAY FROM THE DORSALS

VOLUME AND DISTRIBUTION OF MARINE SEDIMENTS

- Assuming that the amount of sediments that currently reach the ocean basins has been similar in the past, and accepting about 4 billion years as the age of the oceans, there should be a minimum thickness of 17 km of compacted sediments in the ocean floor.



While on the continental edges there are thicknesses of up to 13 km.

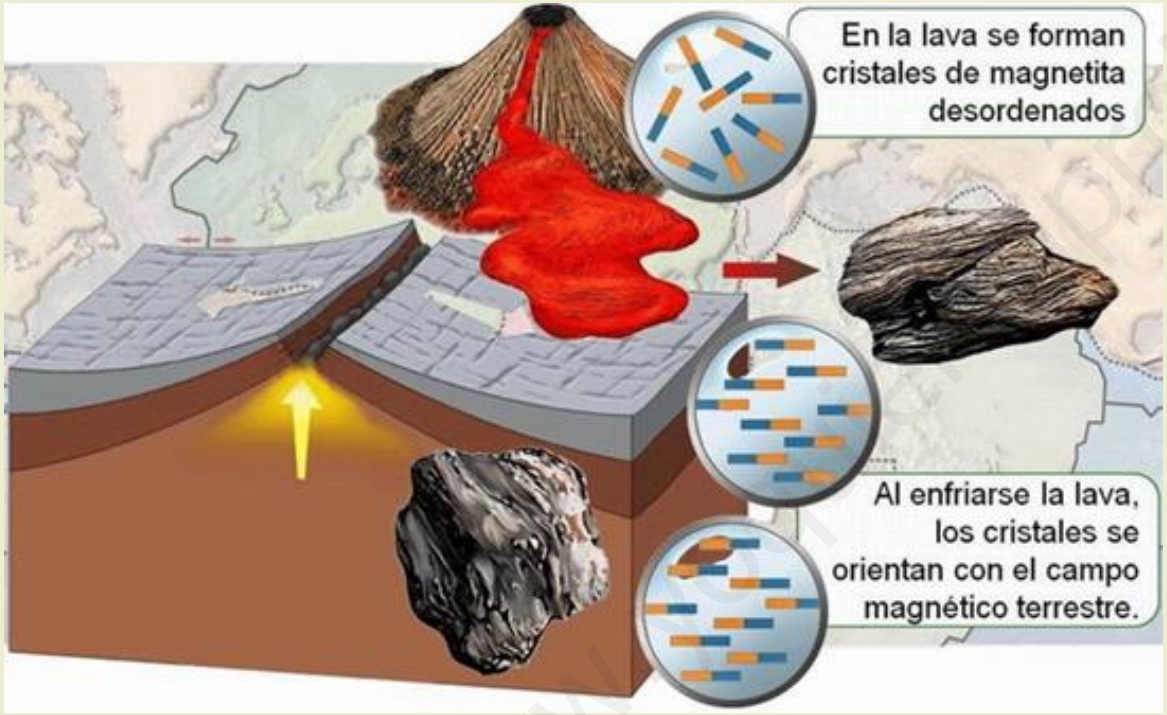
The actual average thickness (1.3 km) is only possible if the ocean floor has been continuously renewed.

- The dorsals in general have few sediments and, in some areas, lack them completely

The actual average thickness (1.3 km) is only possible if the ocean floor has been continuously renewed.

MAGNETIC BANDING-MAGNETIC INVESTMENTS

- Some rocks contain iron-rich minerals that can act as small compasses as they are capable of being oriented along the lines of the Earth's magnetic field.

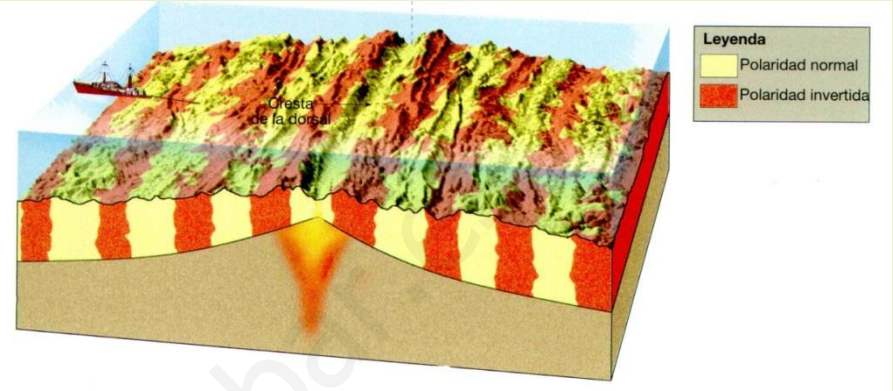


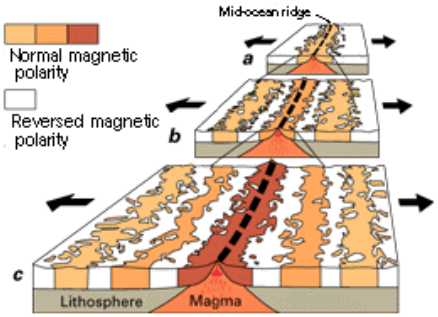
- When these iron-rich minerals heat up above a certain temperature, they lose their magnetism.
- However, when they cool again they magnetize again in a direction parallel to the lines of force of the magnetic field existing at that time.

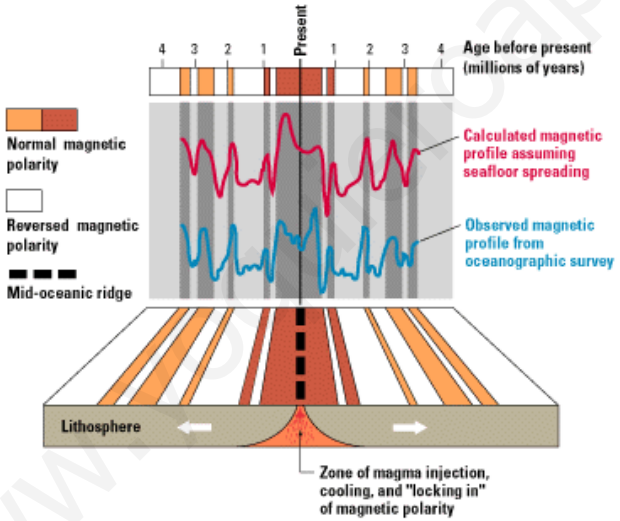
- This polarization represents a remnant magnetism, fossil magnetism or paleomagnetism. These rocks act like “fossil compasses.

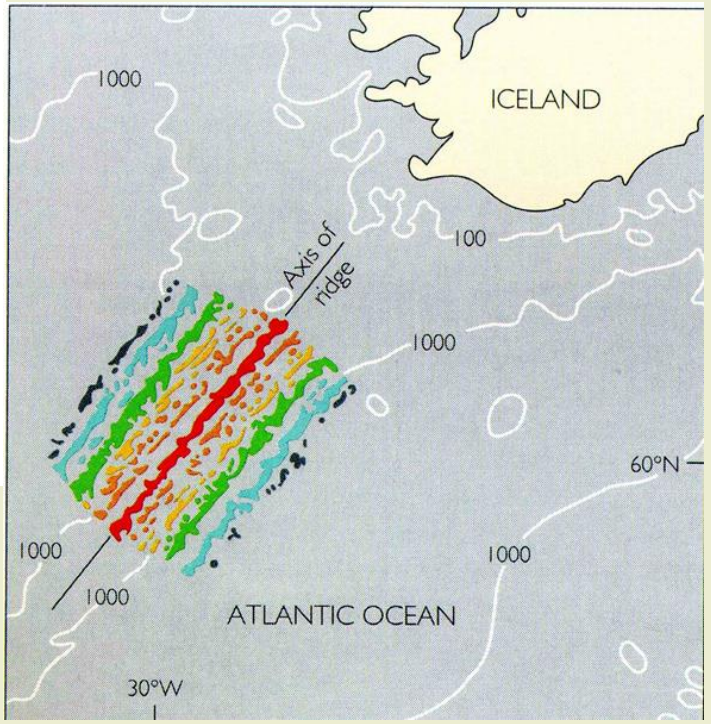
By dragging a magnetometer with a ship, the **paleomagnetic anomalies** of the ocean floor can be registered

- The color stripes show the areas where a normal polarity was registered (similar to that of the current magnetic field).
- The spaces between the strips show the areas where an inverse polarity was recorded







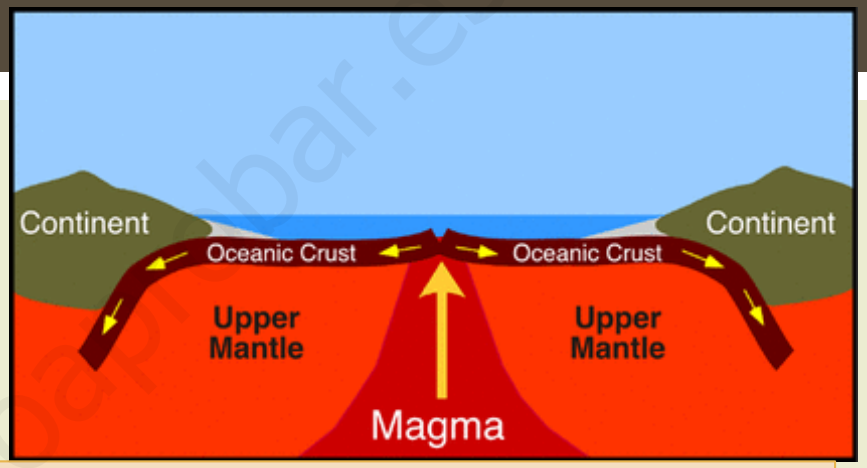


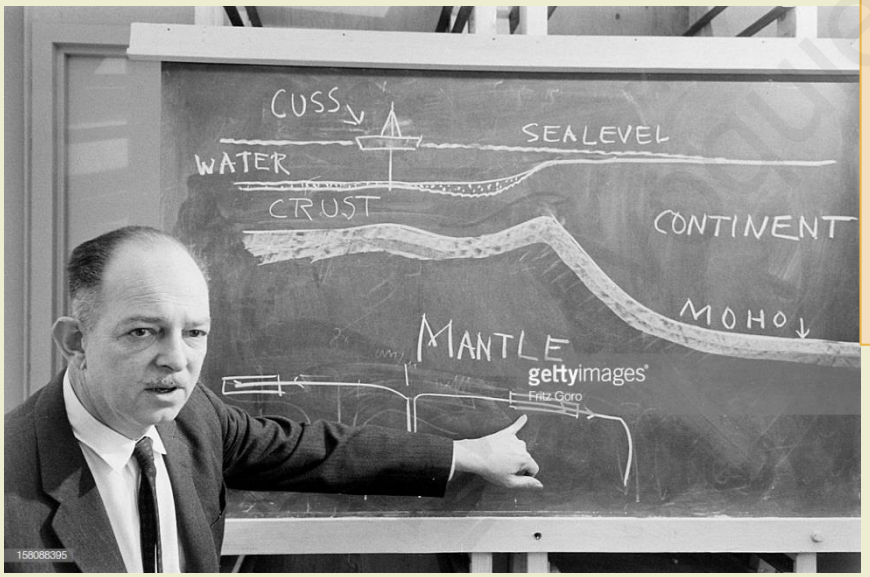
Symmetrical patterns are observed on the sides of the dorsal

Ver archivo:
Bandeado magnético

HYPOTHESIS: EXPANSION OF THE OCEAN FUNDS AND ITS RECYCLING IN SUBDUCTION AREAS

These findings led Harry Hess to propose the hypothesis of "Expansion of ocean floor and recycling in subduction zones."



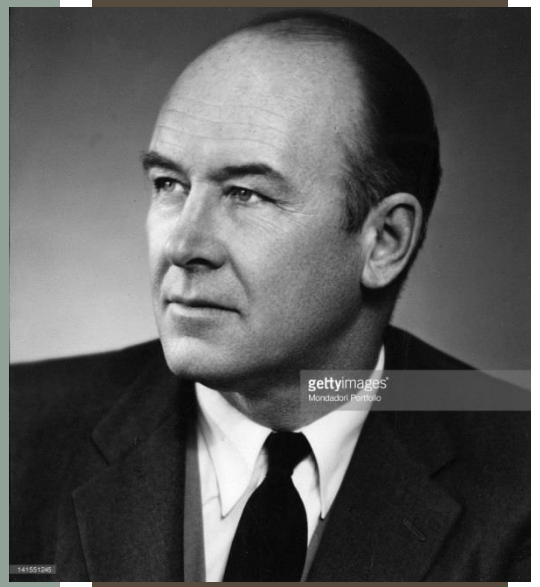


All the exposed considerations ended in a new scientific revolution, already anticipated by Wegener - for many with sufficient arguments - which was baptized with the name of Plate Tectonics Theory.

5. PLATE TECTONICS: LITHOSPHERIC PLATES

1968 Tuzo Wilson → Plate tectonics theory

It is an integrative theory that allows to explain globally the processes that occur on Earth



It states:

The lithosphere is divided into plates

The plates move relative to each other at different speeds (cm / year) and directions

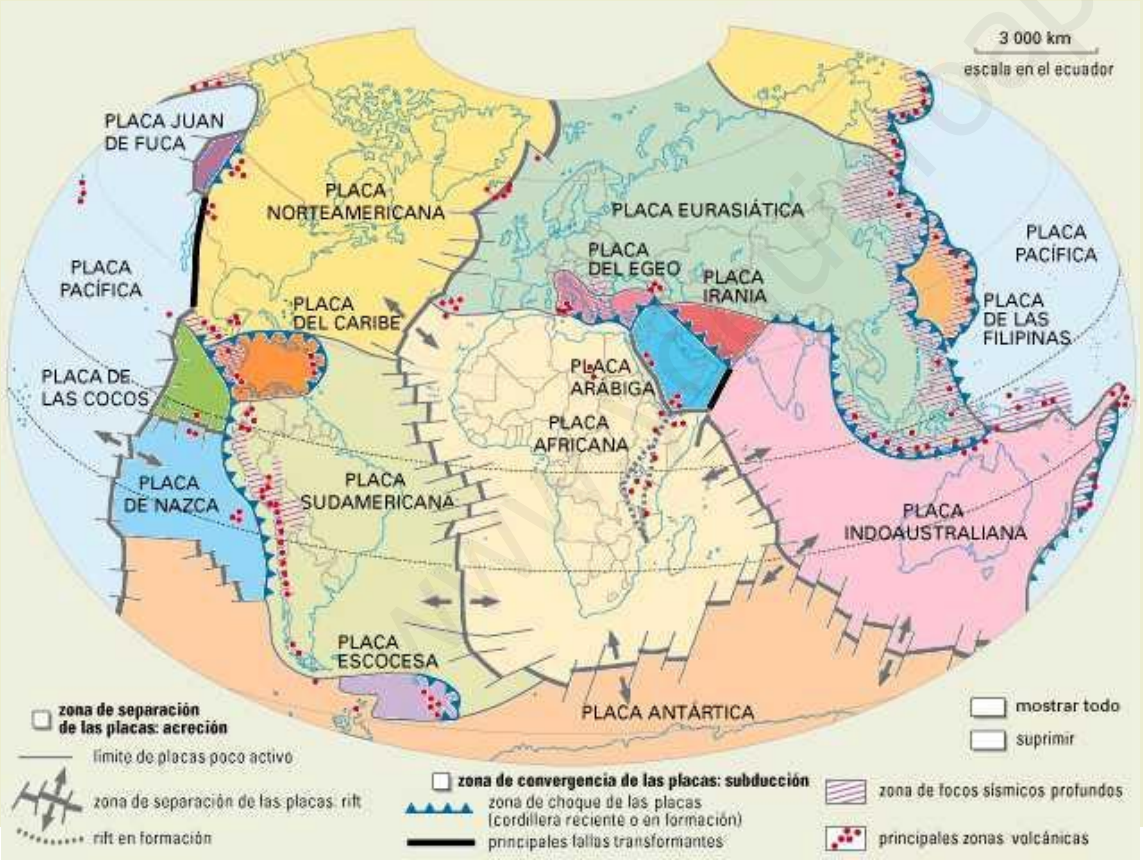
They do it on the asthenosphere

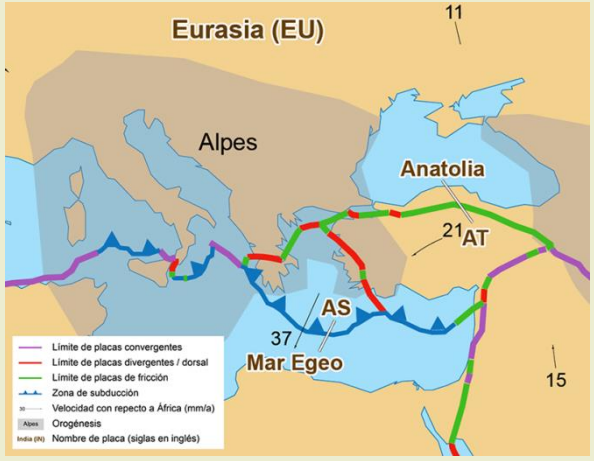
On the edges between plates are regions of great geological activity

Over the years he is responsible for orogeny, ocean formation, continental movements ...

5.1. TYPES OF PLATES

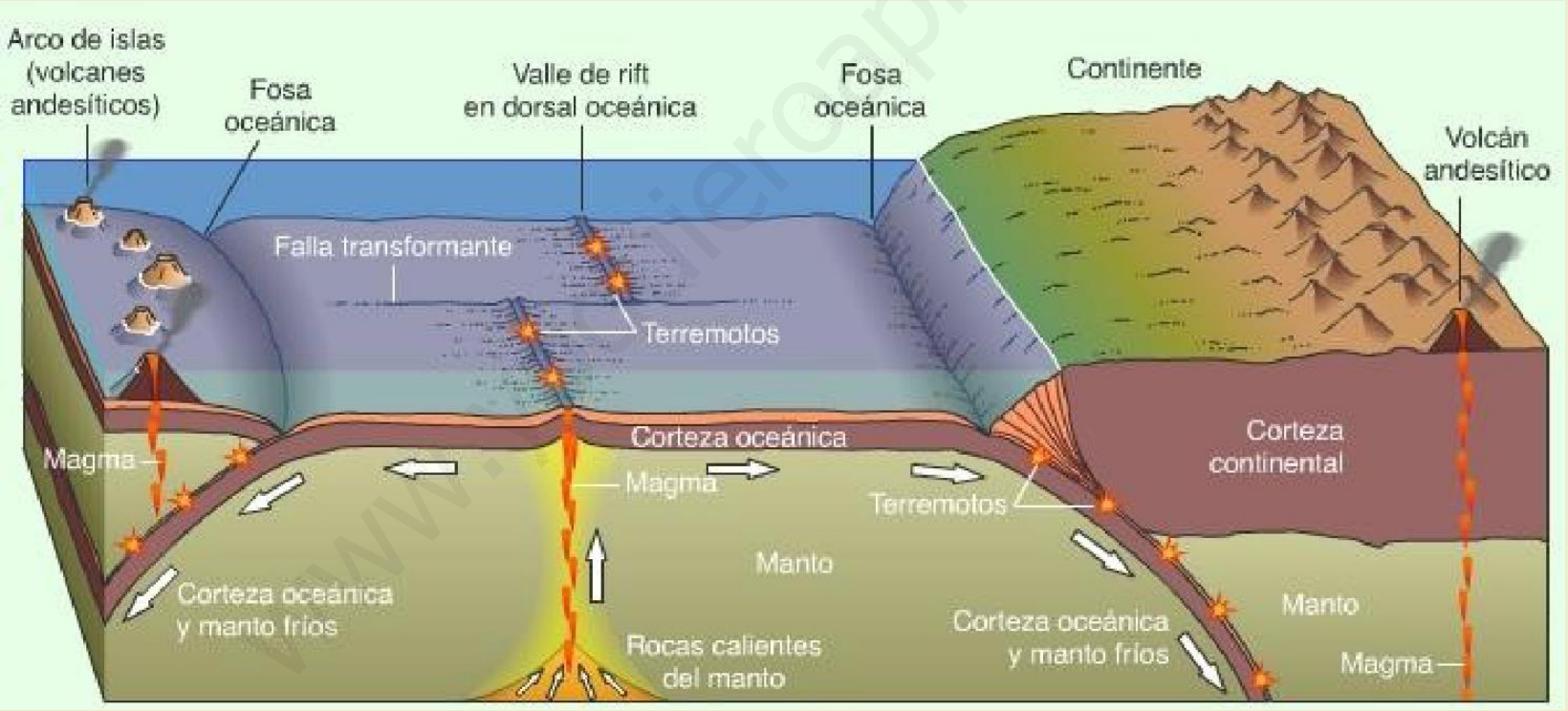
- The plates are formed by oceanic or continental lithosphere
- On the boundaries between plates are the ocean ridges, ocean trenches and transforming faults.
- They have a slow but continuous movement
- We can classify them by:
  - its proportion of oceanic / continental lithosphere. oceanic, continental or mixed
  - its size: larger (15) and smaller (43) such as Anatolian, Aegean





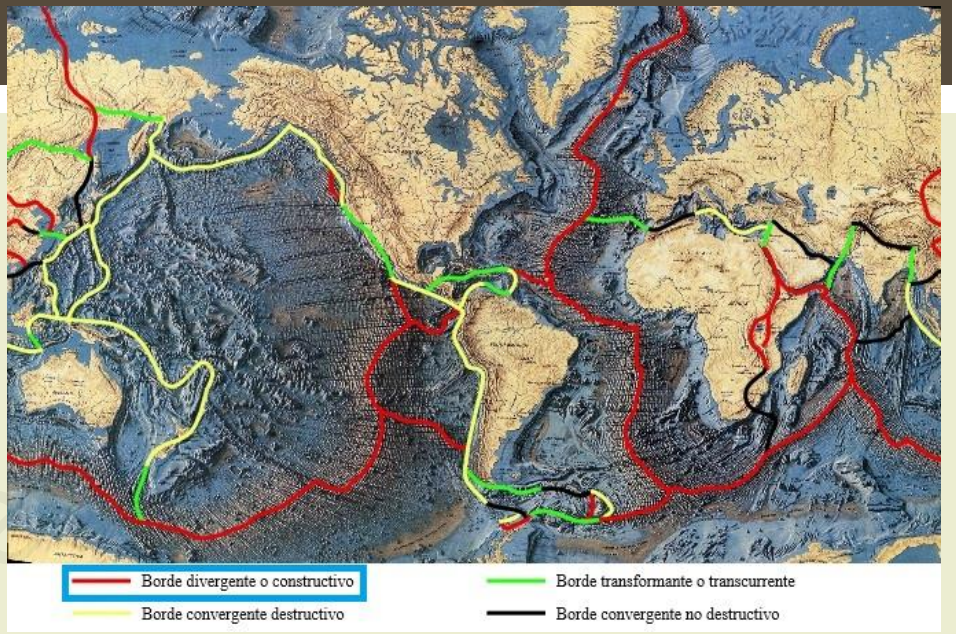
RELATIONS BETWEEN THE PLATES

- The plates interact at their edges along their boundaries.
- There are three types of contacts or edges:
  - Divergent / constructive
  - Transformants / liabilities
  - Convergent / destructive



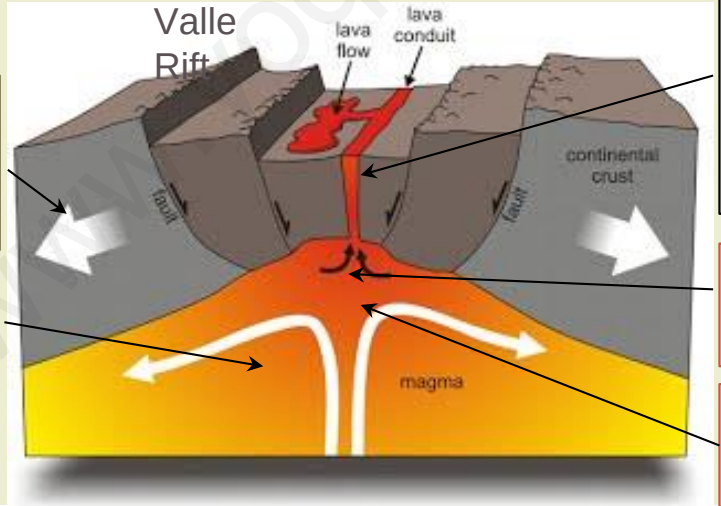
5.2.DIVERGENT / CONSTRUCTIVE EDGES

- The plates are separated
- They consist of a number:
  - Underwater mountain range
  - With valley / central pit, rift, with great volcanic activity
  - In them originates ocean floor



1. Upon separation of the two plates

2. A pressure drop occurs

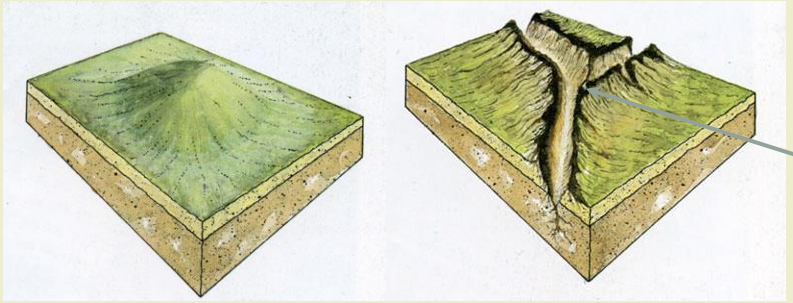


5. The magma that rises to fill the cracks resulting from the divergence, forming an ocean floor

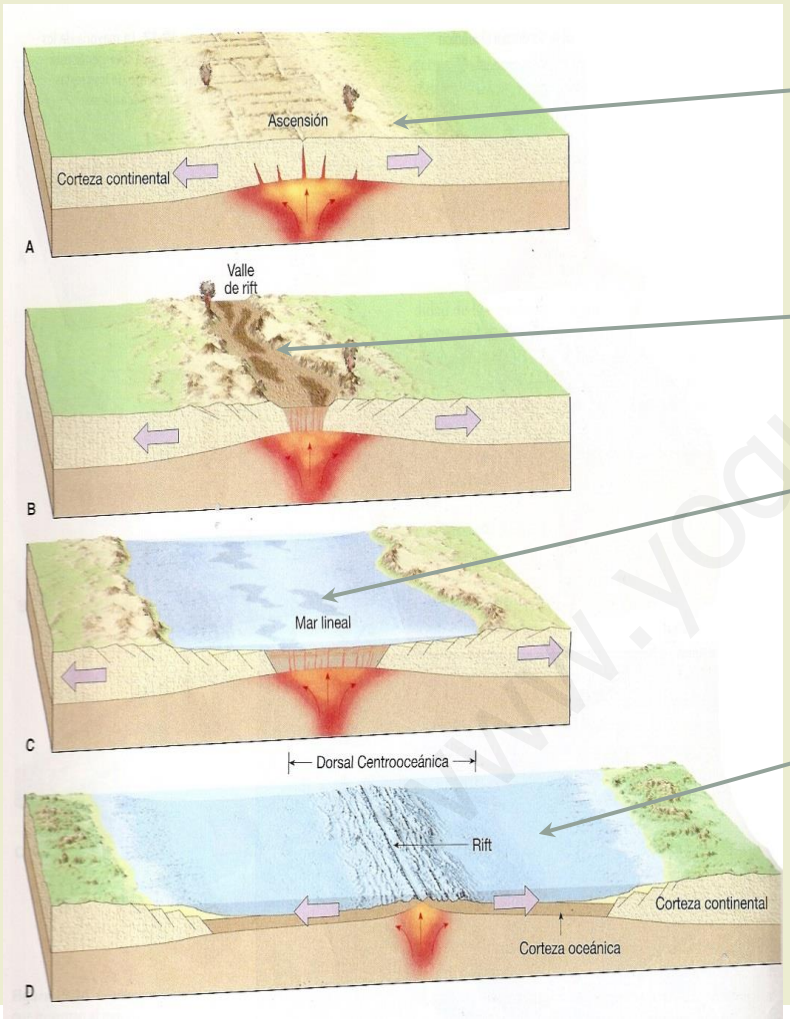
4. The mantle materials melt

3. Decrease melting temperature

3. Decrease melting temperature



Under a continent a hot spot develops that causes the bulge of the lithosphere and a dome is formed. This stretch results in a triple point



Rift-Valley stage

A series of domes are joined in a chain and connected to form a single large opening that laterally will form two differentiated plates. Magma emerges from the lower mantle widening the crack.
The blocks slide in favor of normal faults forming a central valley, called rift valley,

Red sea stage

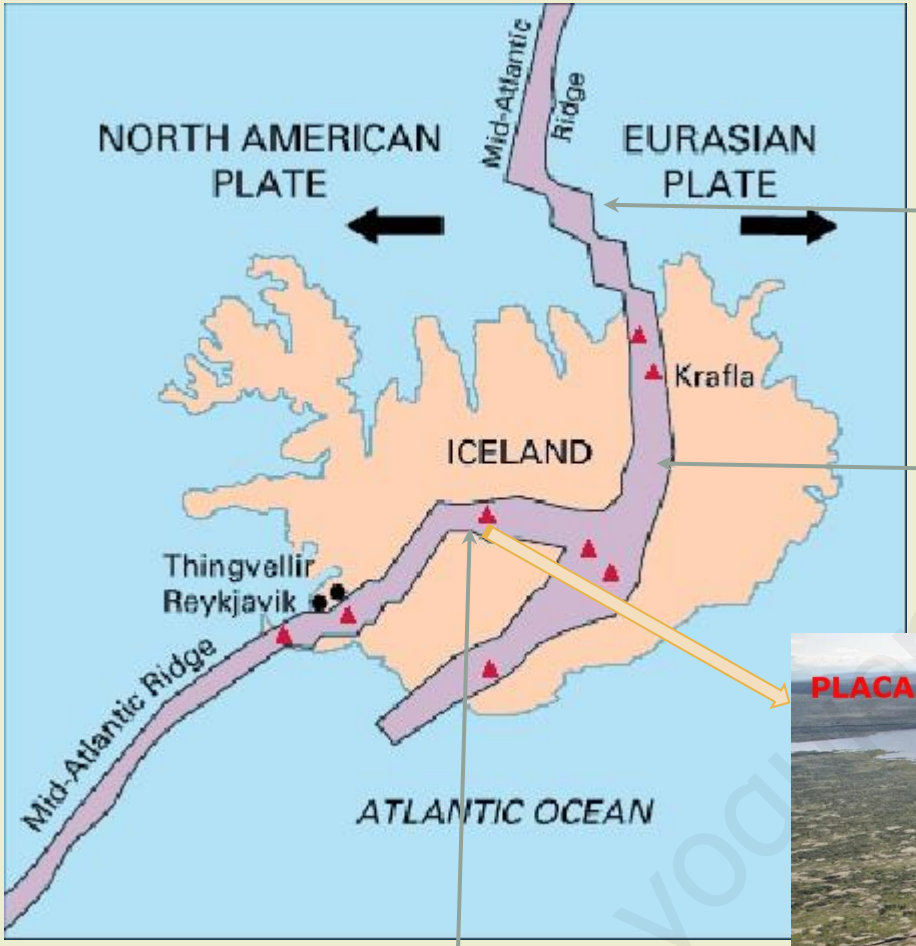
When the separation of the plates has deepened enough the rift valley, the waters of the nearest ocean invade it originating a young and narrow sea.

Atlantic stage

As the plates separate and move away from the dorsal, a continental shelf is installed, close to the continent, which through a slope gives way to the abyssal plains.
An ocean basin has been developed whose most characteristic example is the Atlantic Ocean.

Ver archivo: formación rift continental

❖ THE CASE OF ICELAND

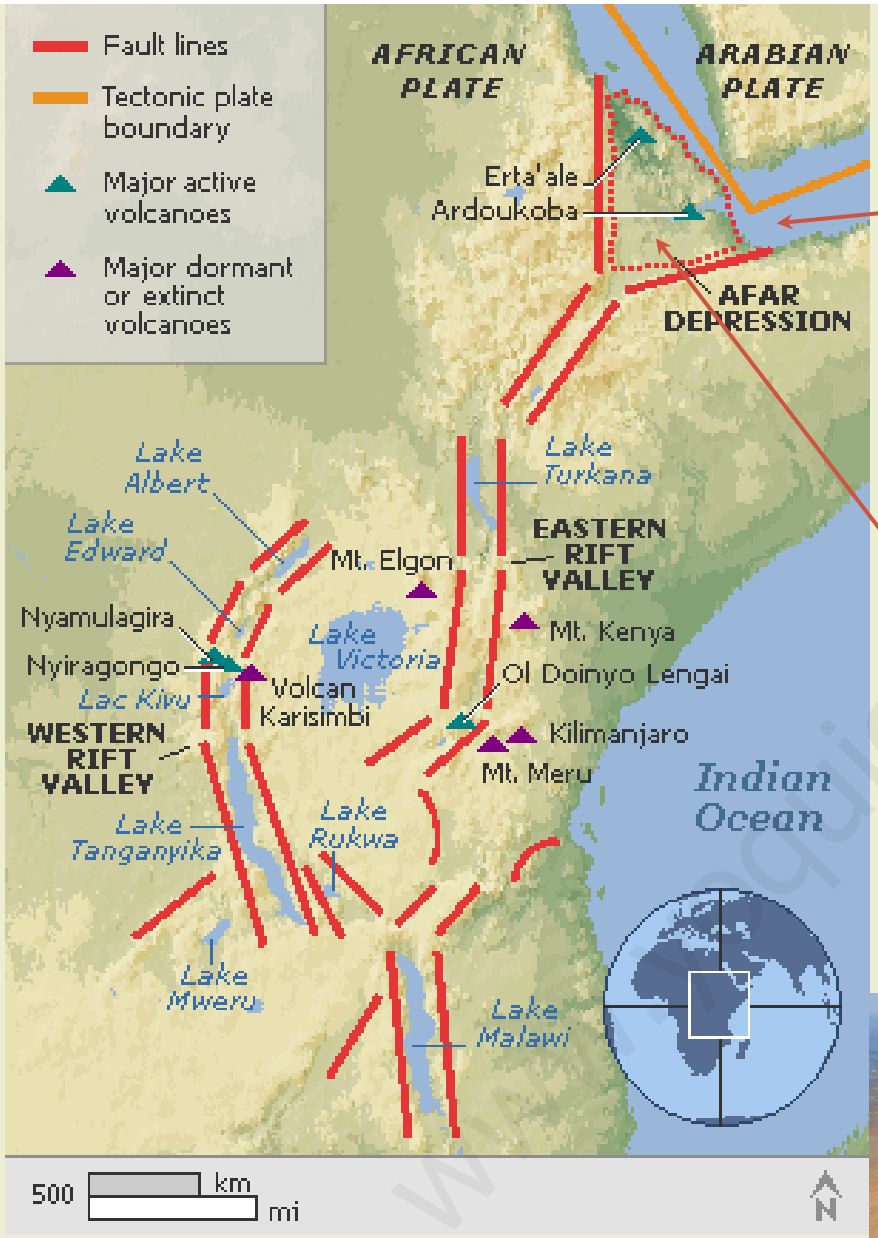


DORSAL

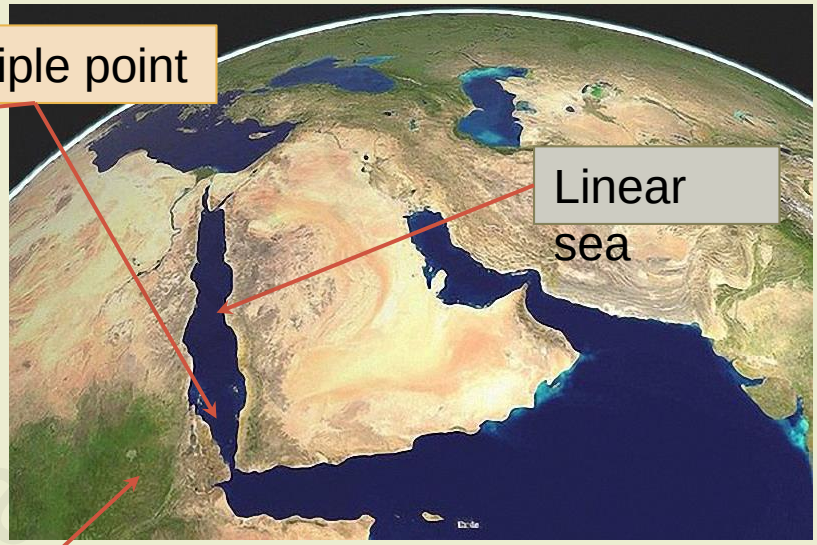
Triple point

Rift Valley

❖ EL CASO DEL RIFT ADFRICANO



Triple point

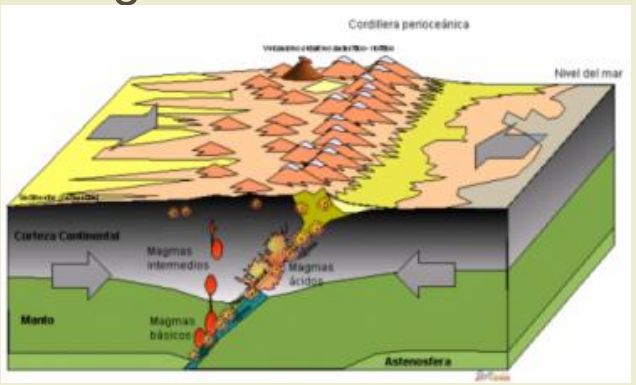


Linear sea

Rift Valley

5.3. CONVERGENT / DESTUCTIVE EDGES

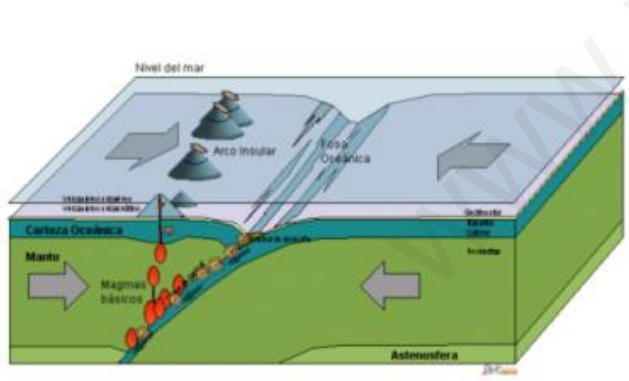
- They are those in which the plates approach each other.
- In them soil is destroyed, so they are destructive edges.
- There are three possibilities:

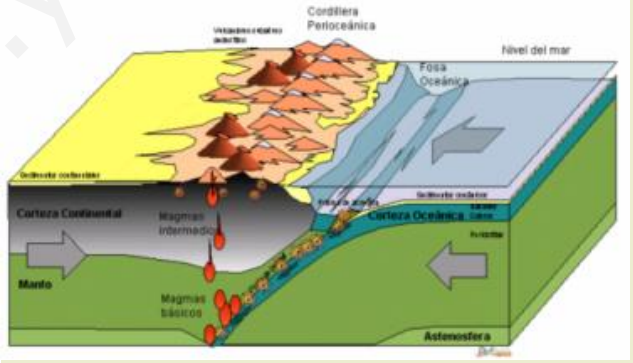


Convergent boundary between two oceanic plates

Convergent boundary between oceanic and continental plates

Convergent boundary between two continental plates





A. LIMIT BETWEEN TWO OCEAN PLATES

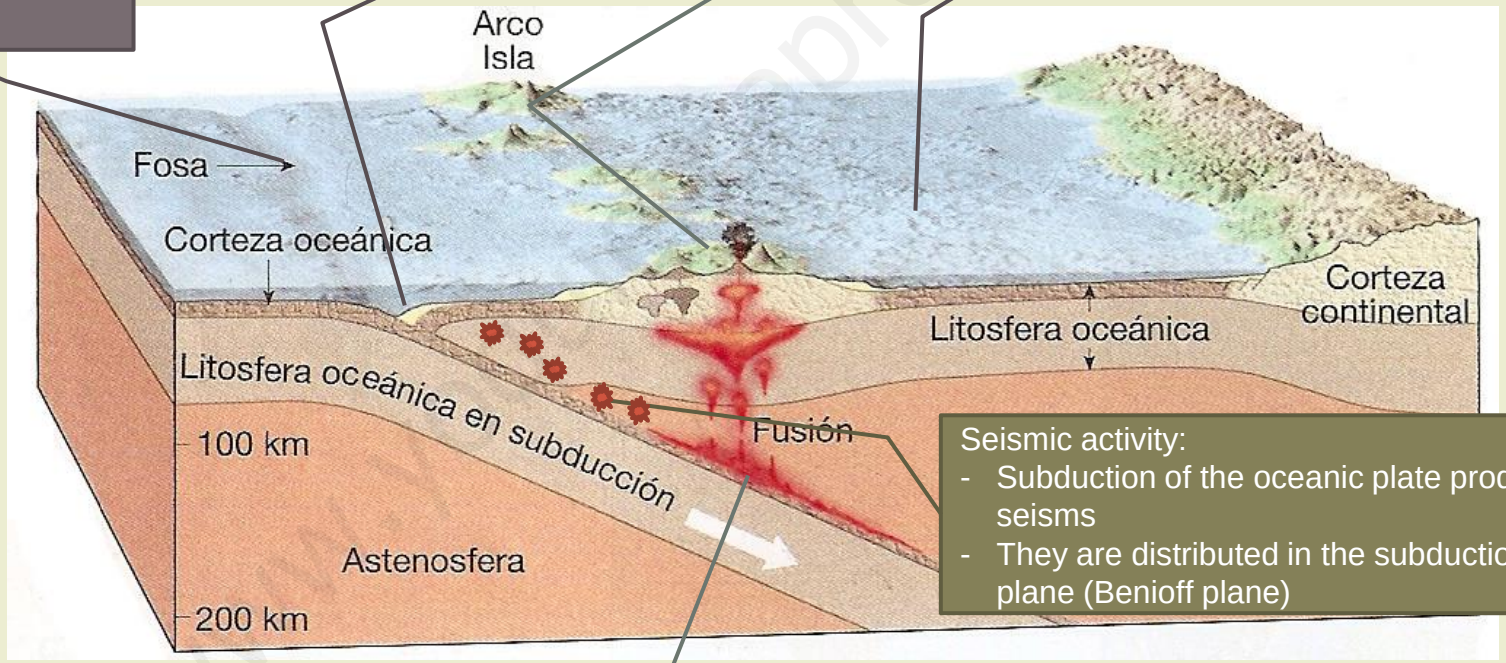
- The oldest oceanic plate (the coldest), being denser, sinks beneath the other and subducts. Ocean floor is destroyed.
- They originate:

Oceanic trench:
- Parallel to the coast
- By subduction of the oceanic plate
- Great depth

Accretion Prism:
- Accumulation of marine sediments
- Very underdeveloped

Volcanic island arch

Transarco Basin:
- Small sea between the continent and the volcanic archipelago

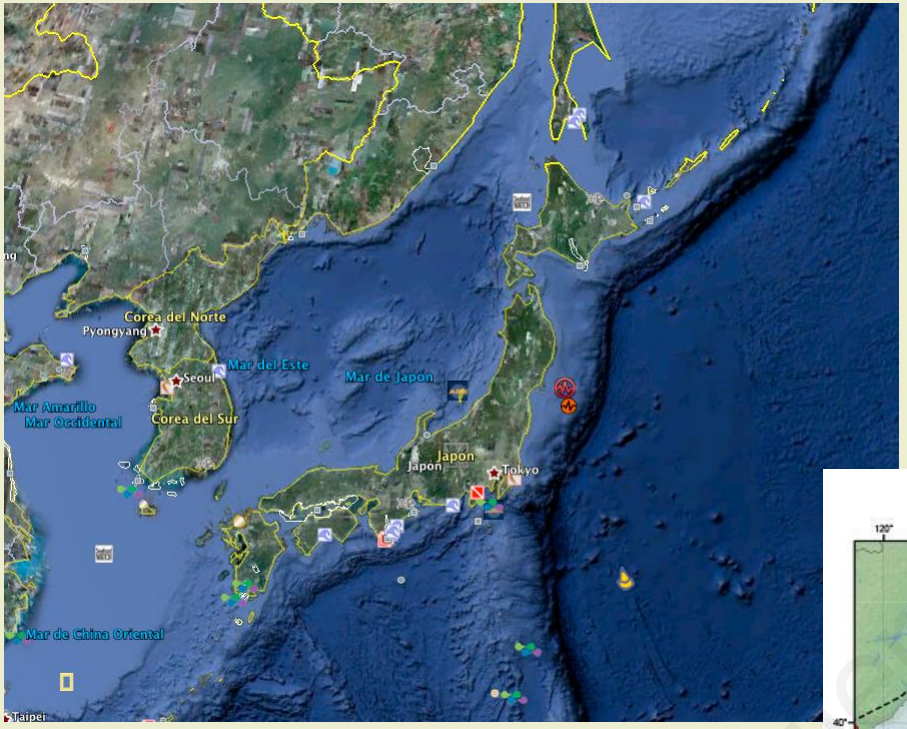


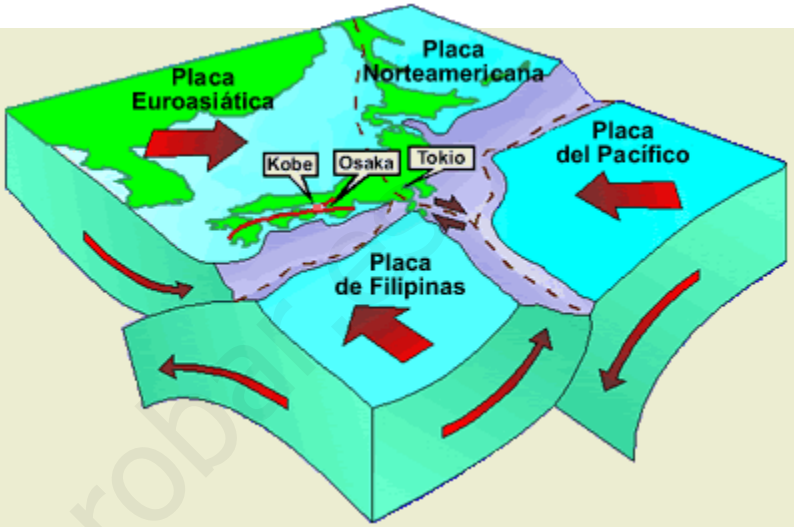
Seismic activity:
- Subduction of the oceanic plate produces seisms
- They are distributed in the subduction plane (Benioff plane)

Basaltic Magmatism:
- Subducting materials carry water that causes the melting point to lower, causing magma to rise to the surface

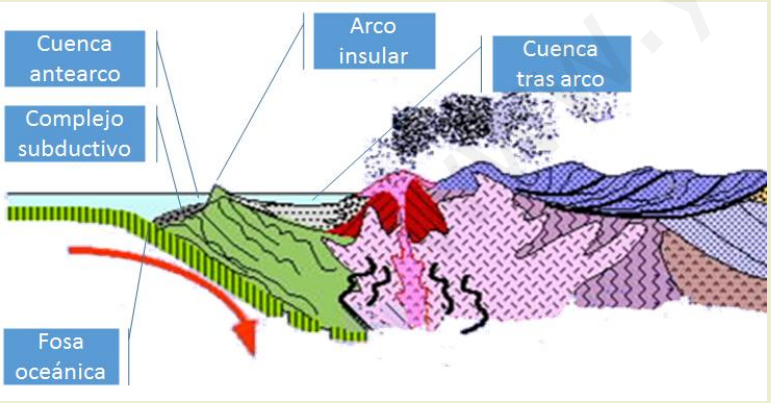
Link to blog “Geobiontes”

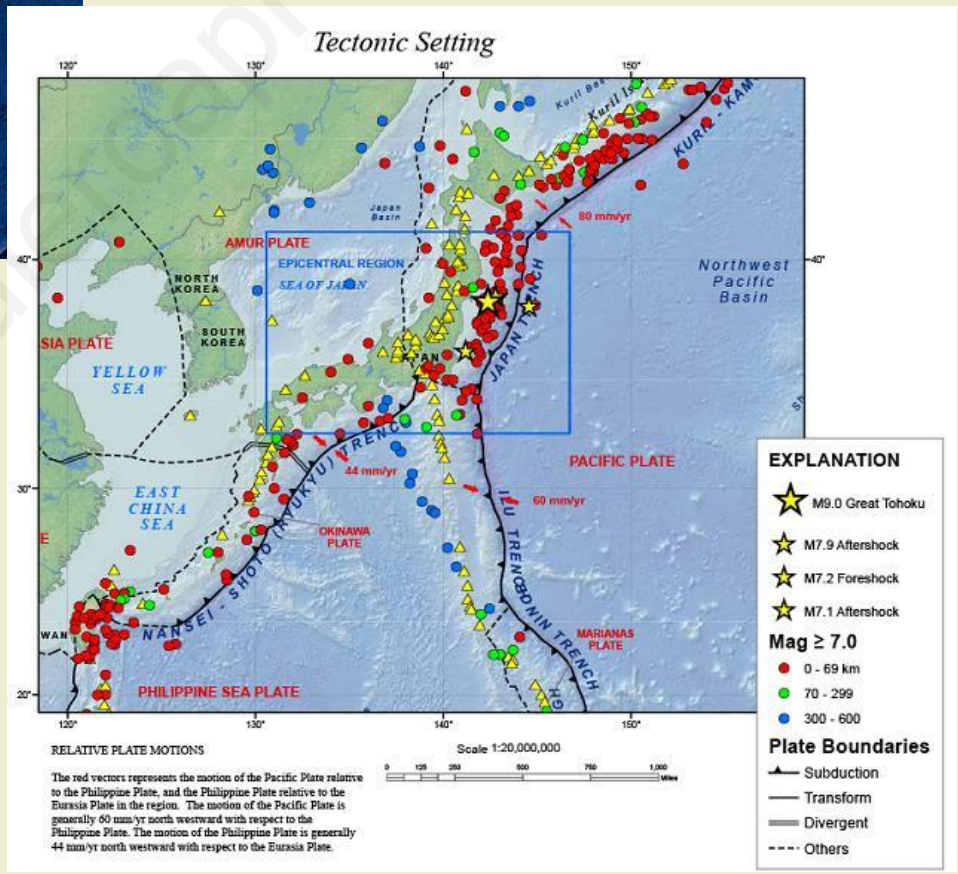
Ver archivos:
Tipos de límites entre placas





❖ THE CASE OF JAPAN





B. LIMIT BETWEEN OCEANIC AND CONTINENTAL PLATES

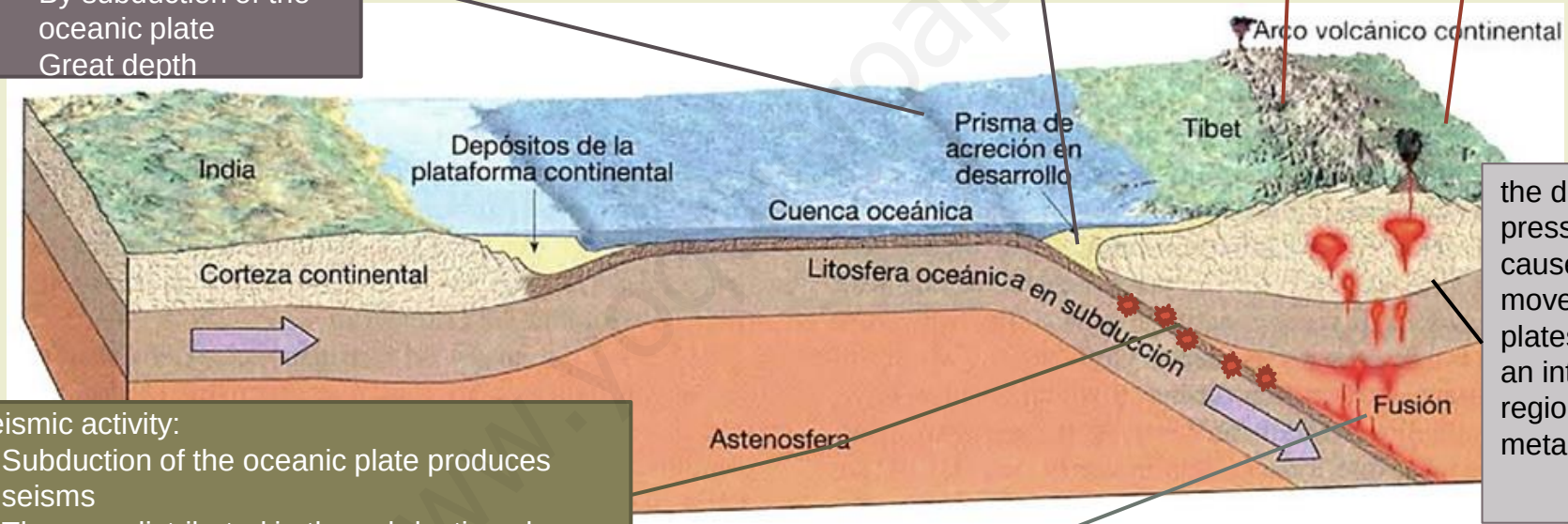
- The oceanic plate being denser sinks below the continental and subducts. Ocean floor is destroyed.
- They originate:

Accretion Prism:
- Accumulation of marine sediments
- Additives to the continental coast
- Very deformed

Andean halogen:
- Cordillera parallel to the coast
- Great volcanic activity

Plateau

Oceanic trench:
- Parallel to the coast
- By subduction of the oceanic plate
- Great depth



the directed pressures caused by the movement of the plates produce an intense regional metamorphism

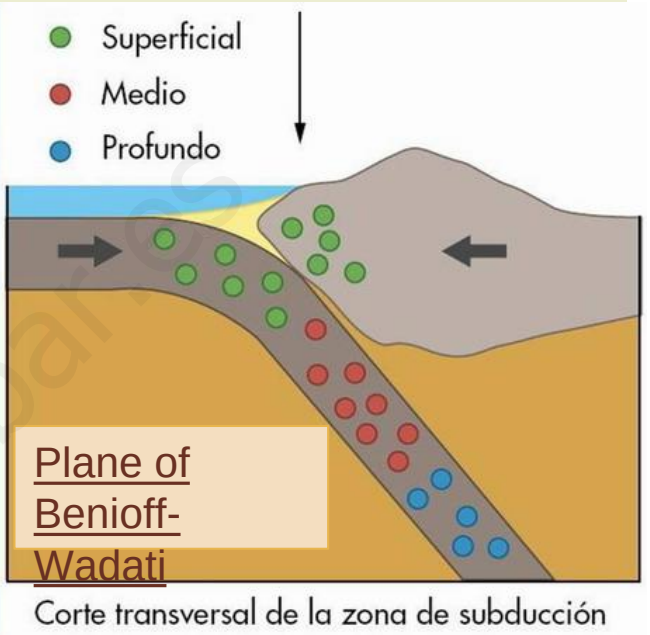
Seismic activity:
- Subduction of the oceanic plate produces seisms
- They are distributed in the subduction plane (Benioff plane)

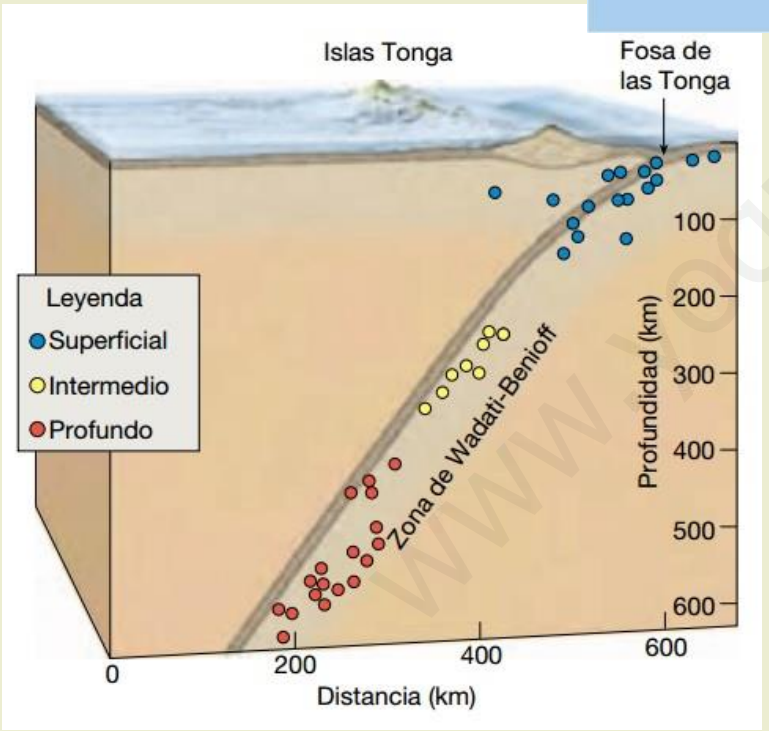
Andesitic or granitic magmatism:
- Subducting materials carry water that causes the melting point to lower, causing magma to rise to the surface

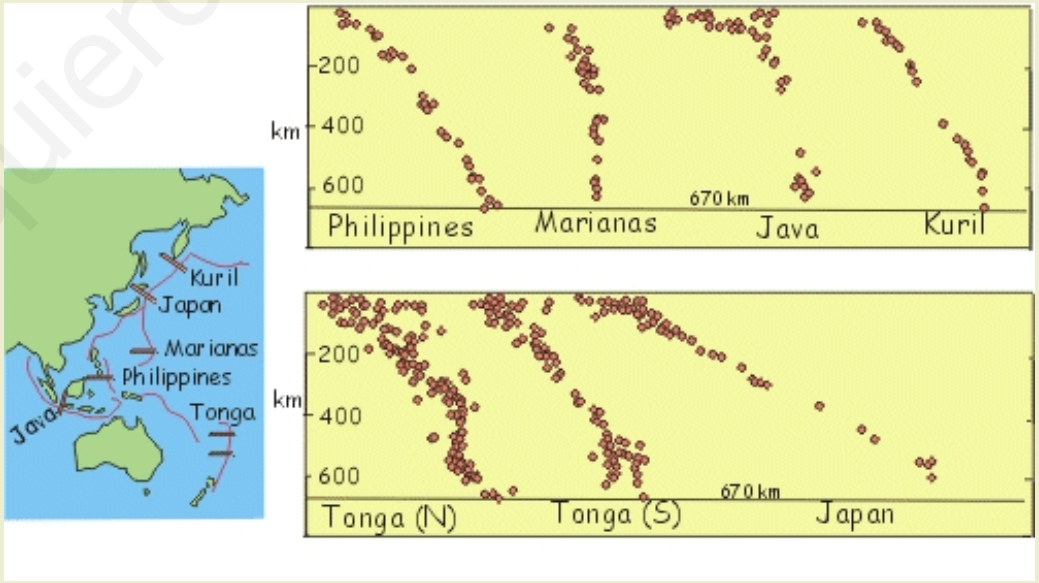
Enlace para blog “Geobiontes”

Ver archivos:
Tipos de límites entre placas
Convergencia O-C

❖ THE CASE OF SOUTH AMERICA







❖ THE CASE OF INDONESIA AND THE PHILIPPINES

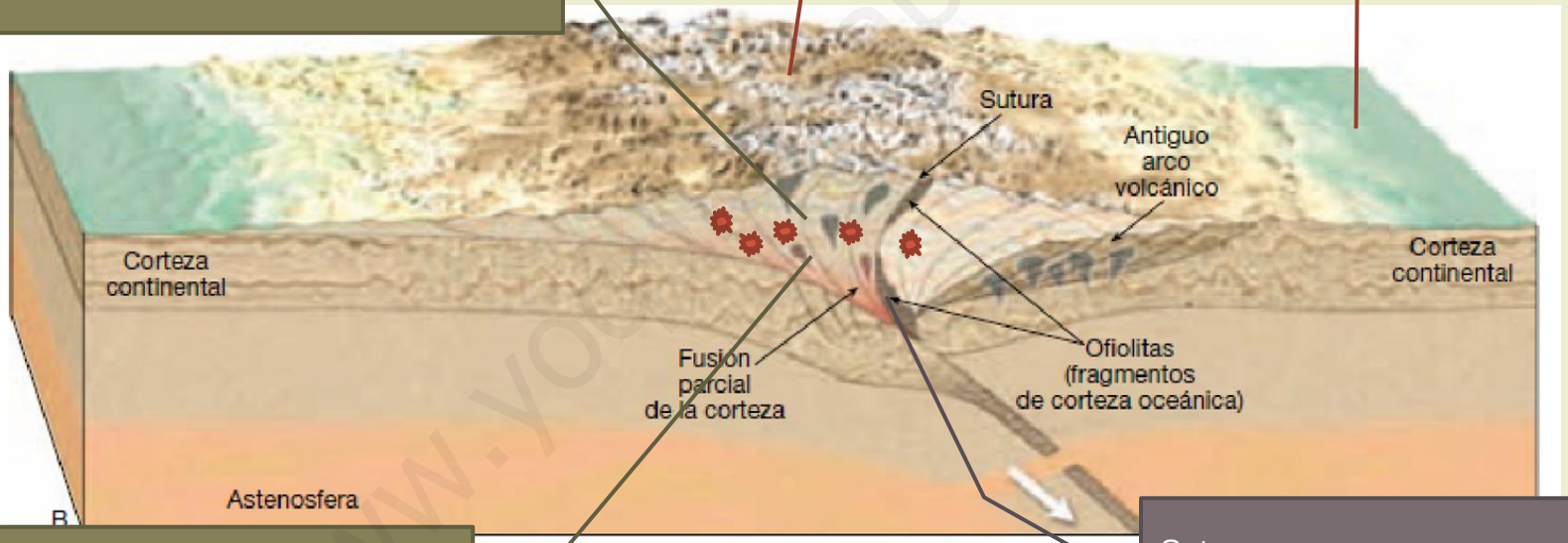
C. LIMIT BETWEEN PLATES TWO CONTINENTAL PLATES

- Continental plates do not produce subduction, but obduction
- They fold and ride, which thickens the continental crust and destroys soil.
- It originates:

Intracontinental Orogen:
- No volcanic activity
- High seismic activity

Plateau:
- High altitude plateau after the orogen

Intense Metamorphism:
- Materials suffer high pressures and transform

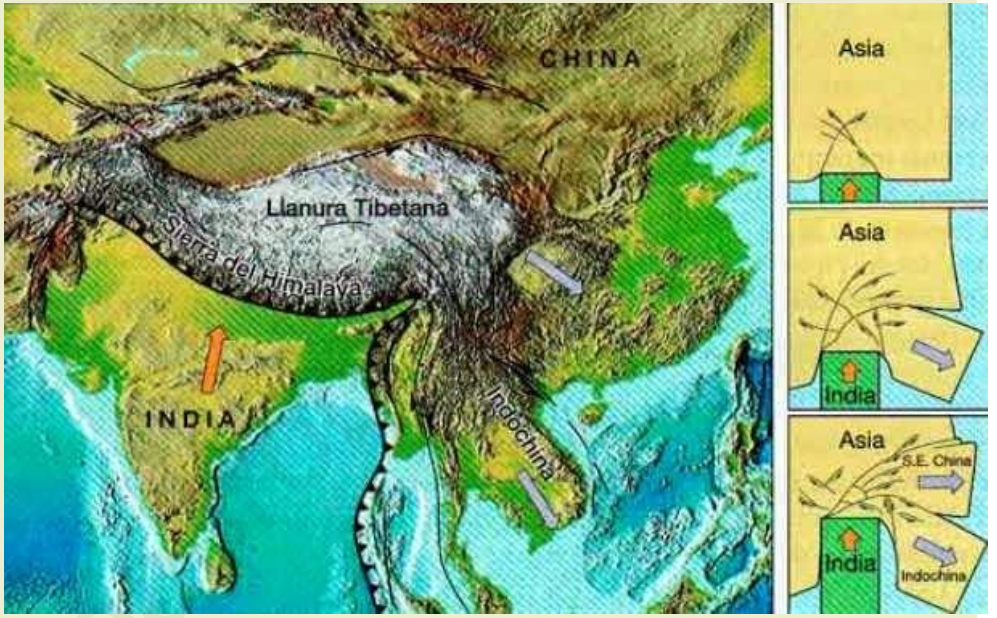


Seismic activity:
- Horse riding produces earthquakes
- They are distributed inside the orogen

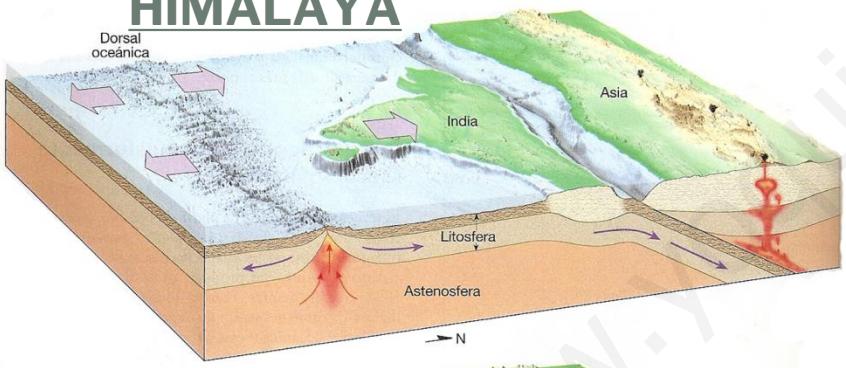
Suture:
- Area with ocean floor fragments that do not subduct, ophthalites

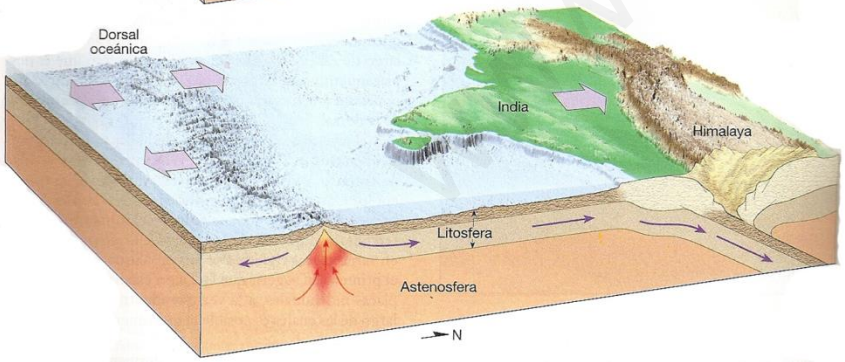
Enlace para blog “Geobiontes”

Ver archivos:
Colisión continentes
Colisión India Asia

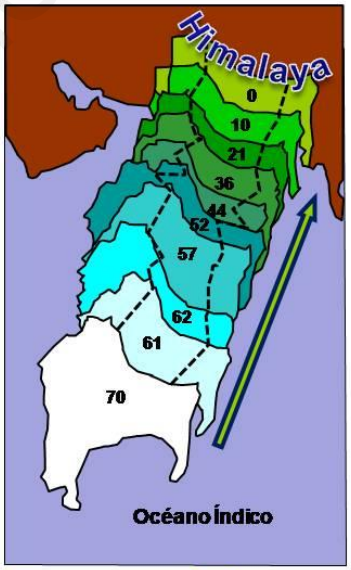


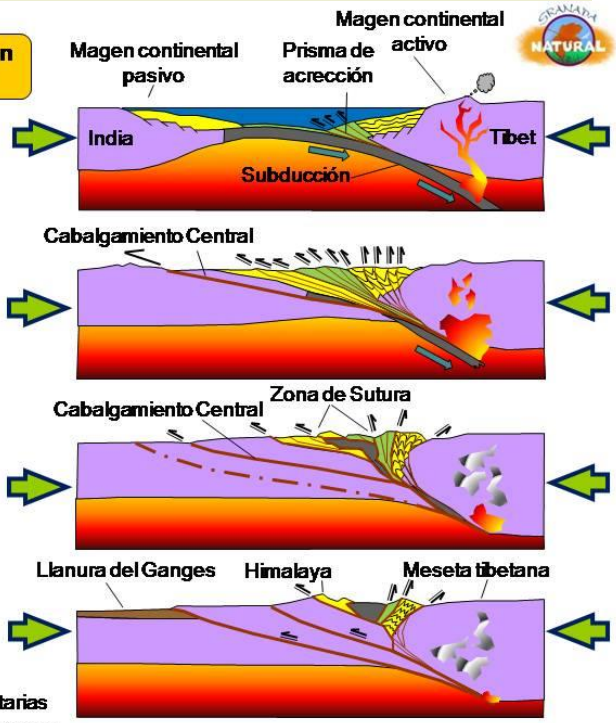
❖ THE CASE OF HIMALAYA





Orogénesis de Colisión o formación de Cordilleras de tipo Himalayo



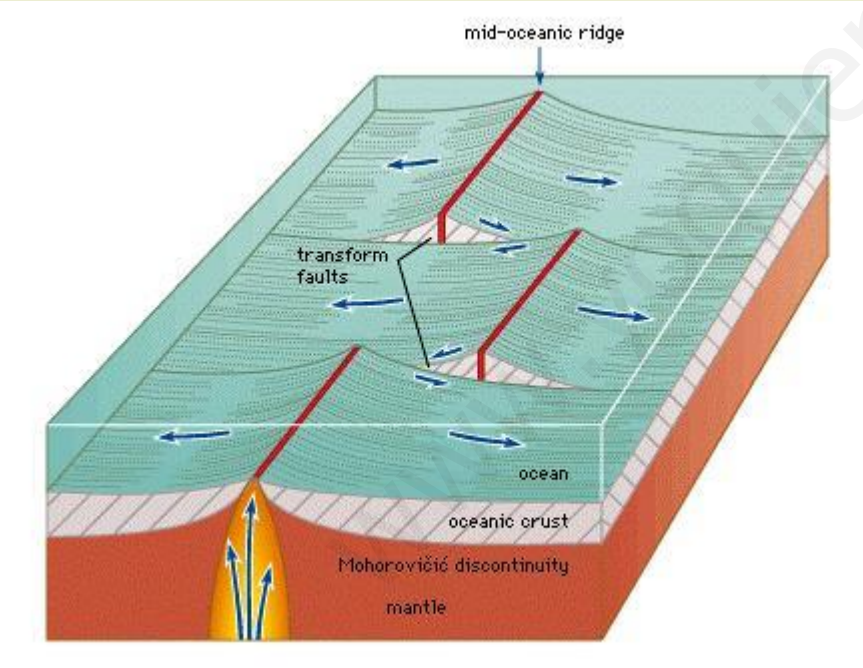


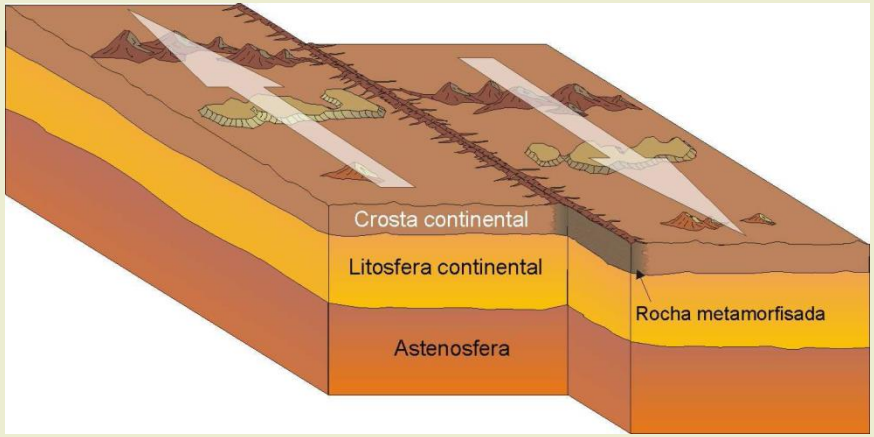
Corteza continental
Corteza oceánica
Rocas sedimentarias
Sedimentos oceánicos
Manto litosférico

Modificado de Molnar, 1986

5.4 TRANSFORMING / PASSIVE / CONSERVATIVE EDGES

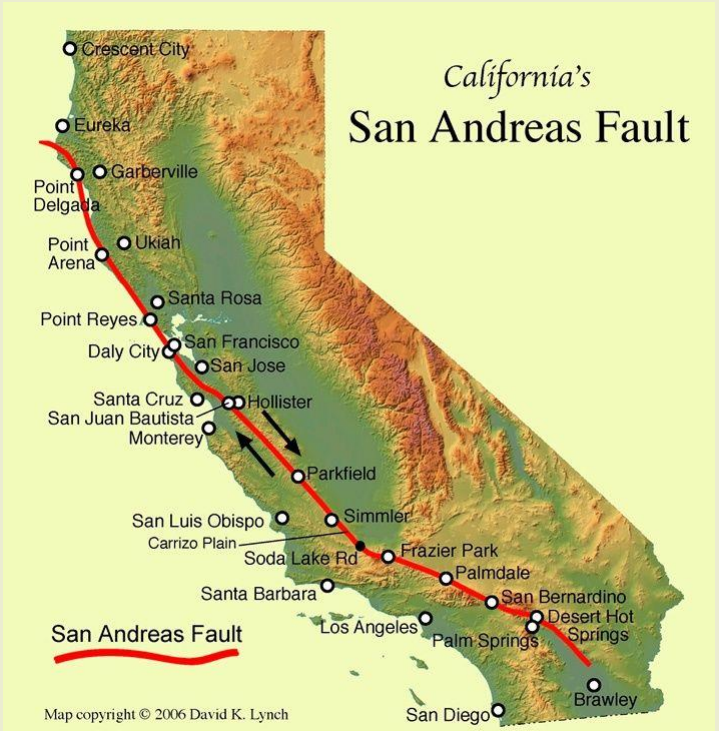
- Edges where the plates have a parallel displacement direction
- Lithosphere is not created or destroyed
- The lateral displacement produces **transforming failures**
- They are areas of great seismic activity
- Most are located under the sea in the dorsals



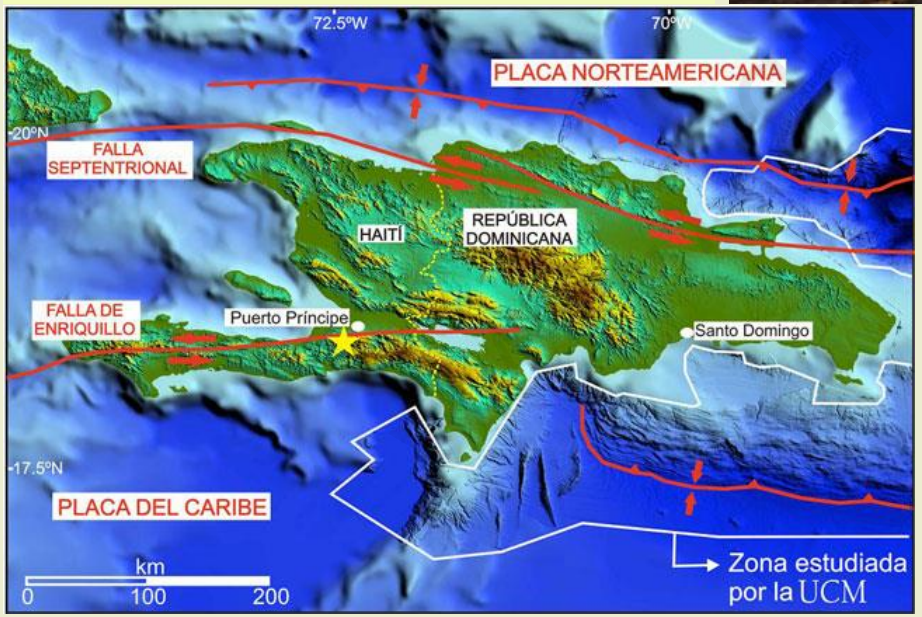


Enlace para blog "Geobiontes"

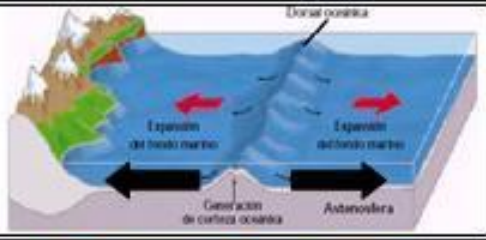
Ver archivo: Tipos de límites entre placas



❖ San Andreas Fault

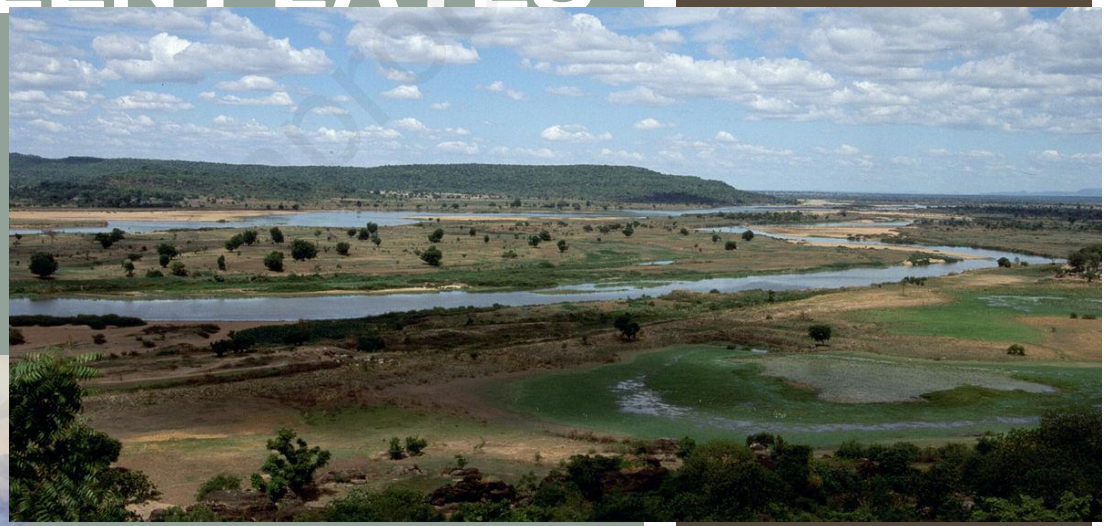


❖ Haiti earthquake, January 12, 2010

BORDES DE PLACAS	ESQUEMA	ELEMENTO ASOCIADO	FENOMENOS ASOCIADOS	EJEMPLOS
BORDES CONSTRUCTIVOS O DIVERGENTES Las placas se separan y se crea litosfera (fondo oceánico)		**DORSALES OCEANICAS** Gran grieta volcánica submarina	- vulcanismo submarino - terremotos submarinos - expansión de los océanos - deriva continental	**DORSAL MEDIOATLANTICA**
BORDES DESTRUCTIVOS O CONVERGENTES Las placas se acercan y se destruye litosfera, que se recicla al pasar de nuevo al manto		**ZONAS DE SUBDUCCION** La placa oceánica se mete por debajo de la continental	- terremotos - volcanes - ***OROGENESIS***: cordilleras perioceánicas	**LOS ANDES** (la placa de Nazca subduce bajo la placa Sudamericana)
		**ZONAS DE SUBDUCCION** Una de las placas oceánicas se mete por debajo de la otra	- arcos insulares volcánicos - fosas marinas	**ARCHIPIELAGO DEL JAPON**
		**LEVANTAMIENTO DE AMBAS PLACAS** Chocan dos placas continentales	- terremotos - ***OROGENESIS***: cordilleras intercontinentales	**CORDILLERA DEL HIMALAYA** (La India choca con el continente asiático)
BORDES PASIVOS O NEUTROS Placas rozándose lateralmente. Ni se crea ni se destruye litosfera		**FALLAS DE TRANSFORMACION**	- terremotos	**FALLA DE SAN ANDRES** (la península de California roza con Norteamérica)

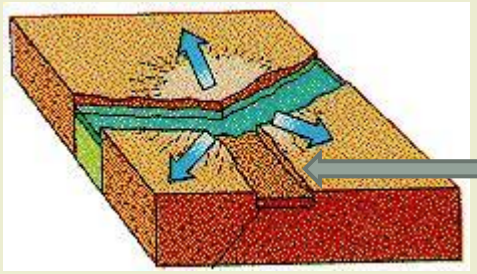
6. OTHER PROCESSES INSIDE OR AT THE LIMIT BETWEEN PLATES

AULACOGENS



TRAPLACY MAGMATISM: THE HOT POINTS

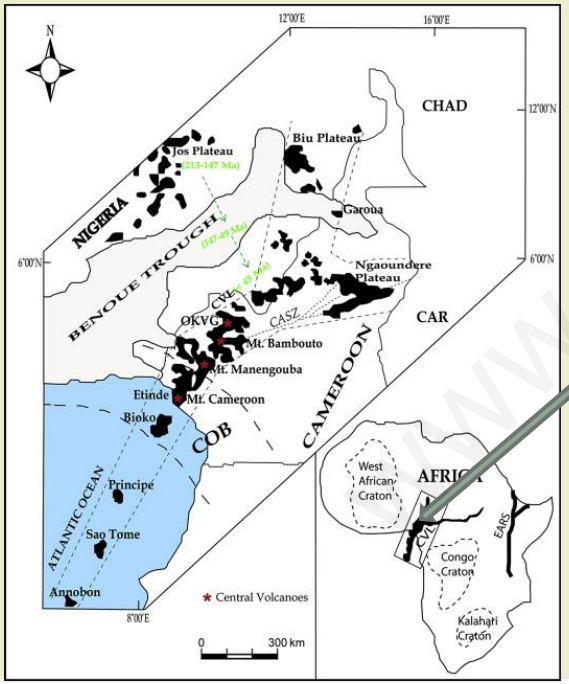
6.1. AULACOGENS

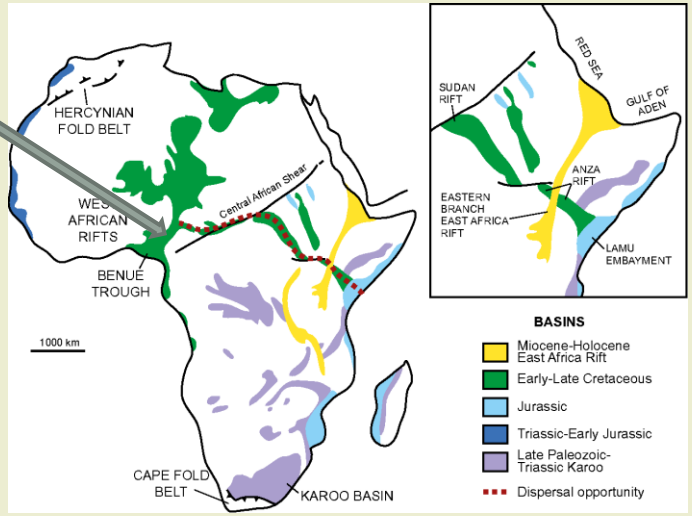


When a thermal dome is established under a continent, the formation processes of a rift originate a triple point.

The branch of the same that is not going to join to form the dorsal degenerates, stops its progression and remains as a depressed area and delimited by major failures, the aulacogen.

Sometimes these graves are invaded by large rivers, as in the Amazon or Benué basin.

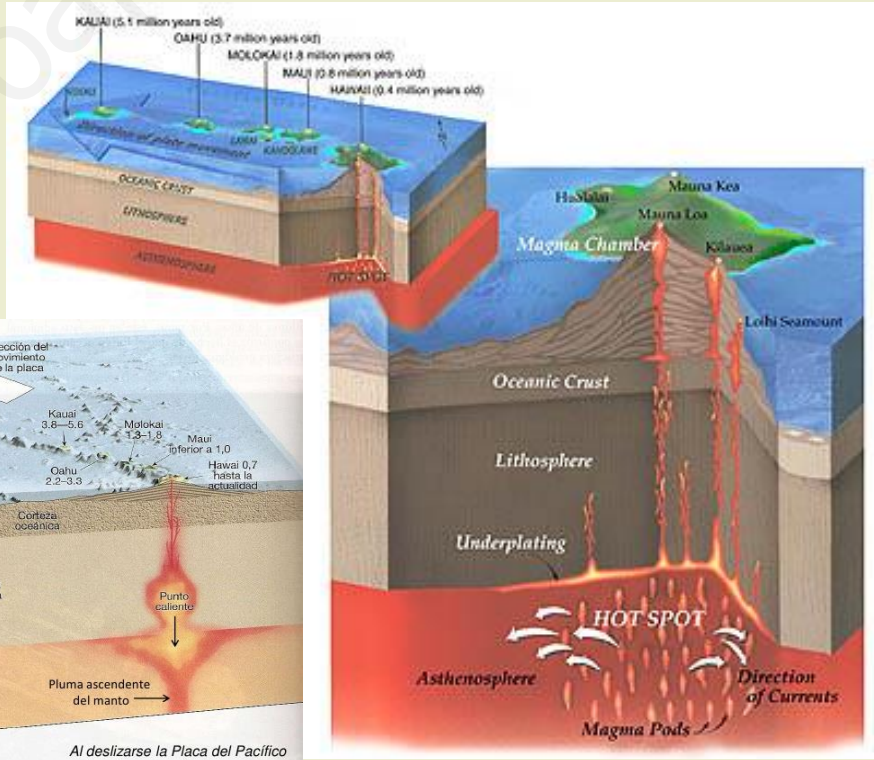


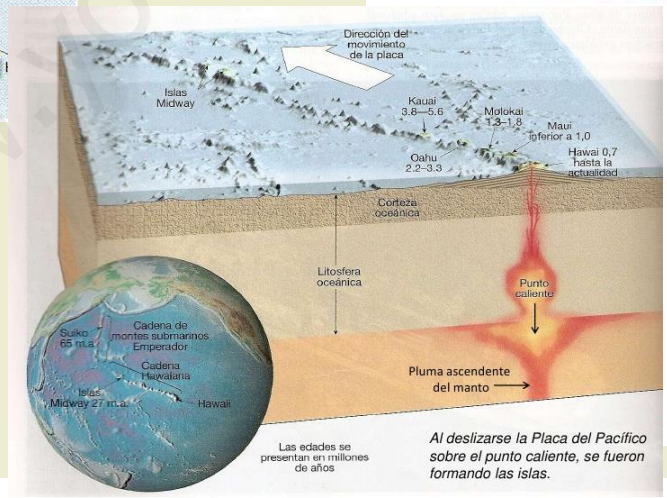


6.2.INTRAPLACY MAGMATISM: THE HOT POINTS

Proposed by Tuzo Wilson, hot spots or hot spots, are regions of the earth's surface where there is a rise of magma in the form of feathers or plumes from very deep areas of the mantle.

Probably, this material comes from the mantle-core interface, layer D ".





It is the case of the Hawaii Islands

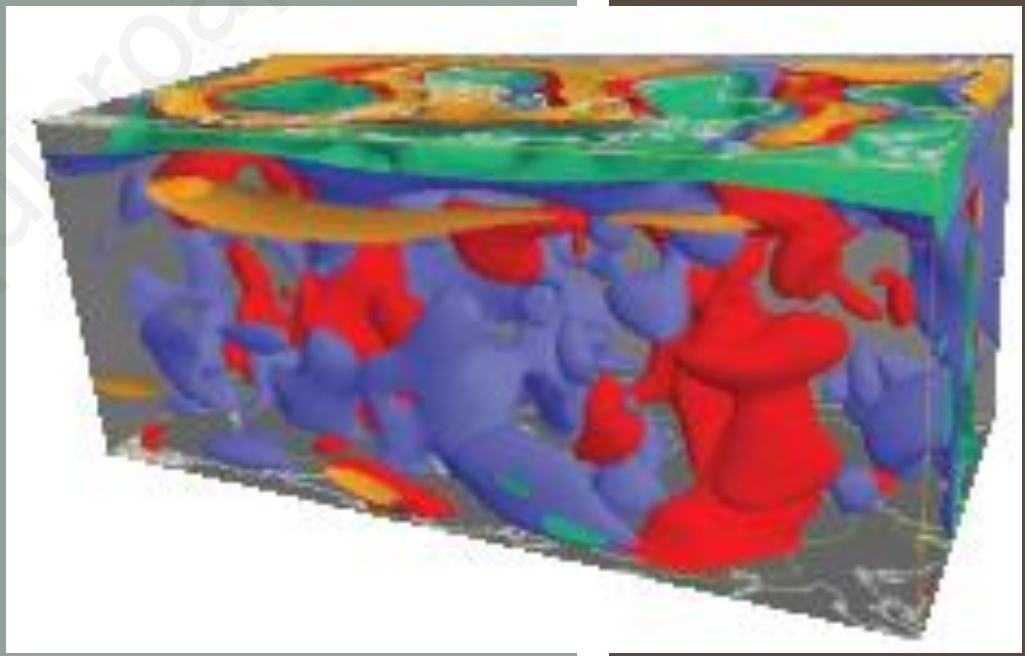
7. CAUSES OF PLATE MOVEMENT

The plates move a few cm / year.

Not all do it at the same speed

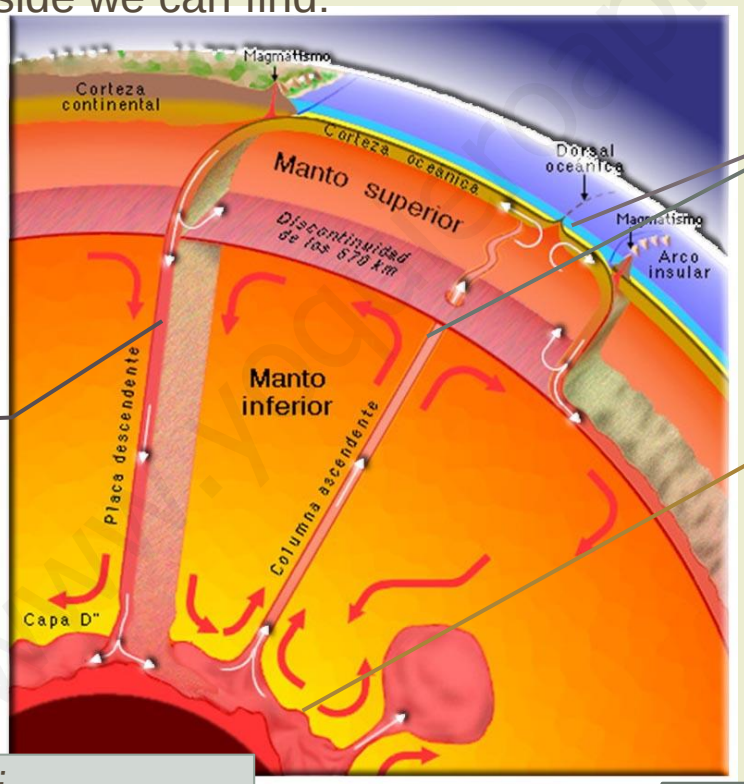
It has been measured with GPS

The cause of movement is gravity and internal terrestrial heat



7.1. THE CONVECTION CURRENTS

- The heat inside the Earth is dissipated by:
- radiation, conduction and convection.
- The latter form causes convection currents in the mantle
- Therefore, inside we can find:



The hottest areas rise and emerge in the dorsals

Cold lithospheric plates subduct and penetrate the mantle

Layer D "is a hot zone that causes ascending hot material

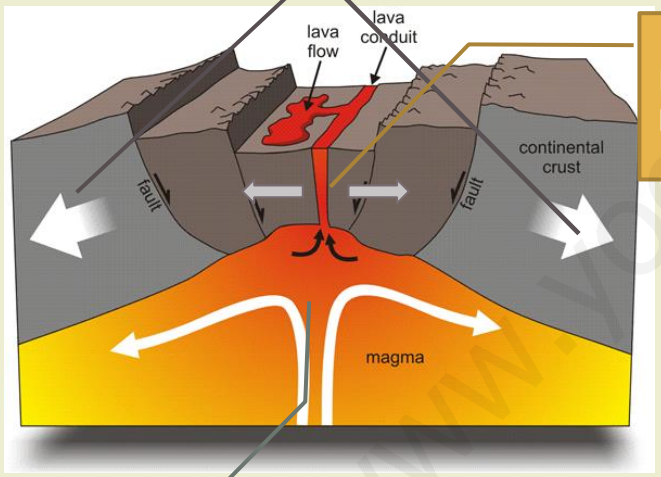
Ver archivo:
Corrientes convectivas manto

Enlace para blog "Geobiontes"

7.2.GRAVITY AS THE MOTOR OF TECTONIC PLATES

- In the dorsals (wedge effect))

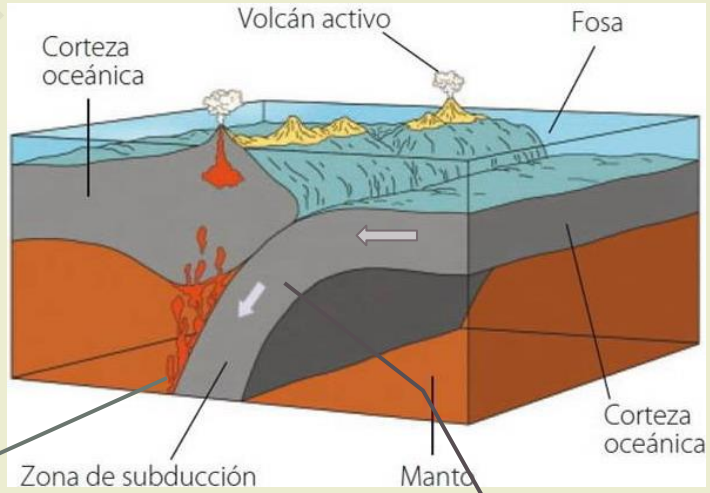
Gravity causes the flanks of the dorsal "to fall" away higher point



Built-in materials also push sideways

As magma ascends from the mantle, it raises the oceanic lithosphere, raising the edges of the dorsal

- In subduction zones (“towel” effect)



Mineralogical changes occur in the subducted lithosphere that increase its density

The subducted plate drags the oceanic lithosphere

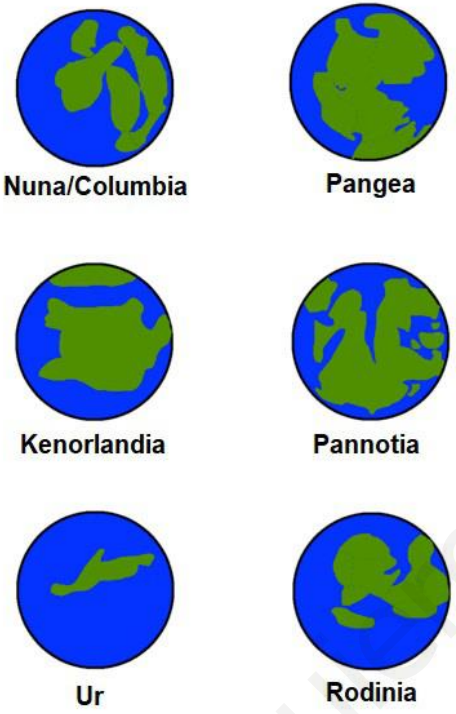
8. WILSON CYCLE

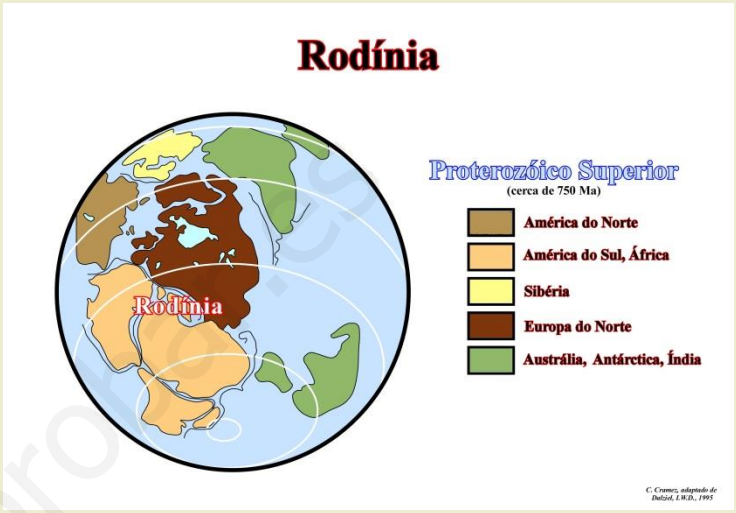
- Proposed by Tuzo Wilson.
- This cycle presupposes that all continents come together in a single land mass, the supercontinent, approximately every 500 million years.

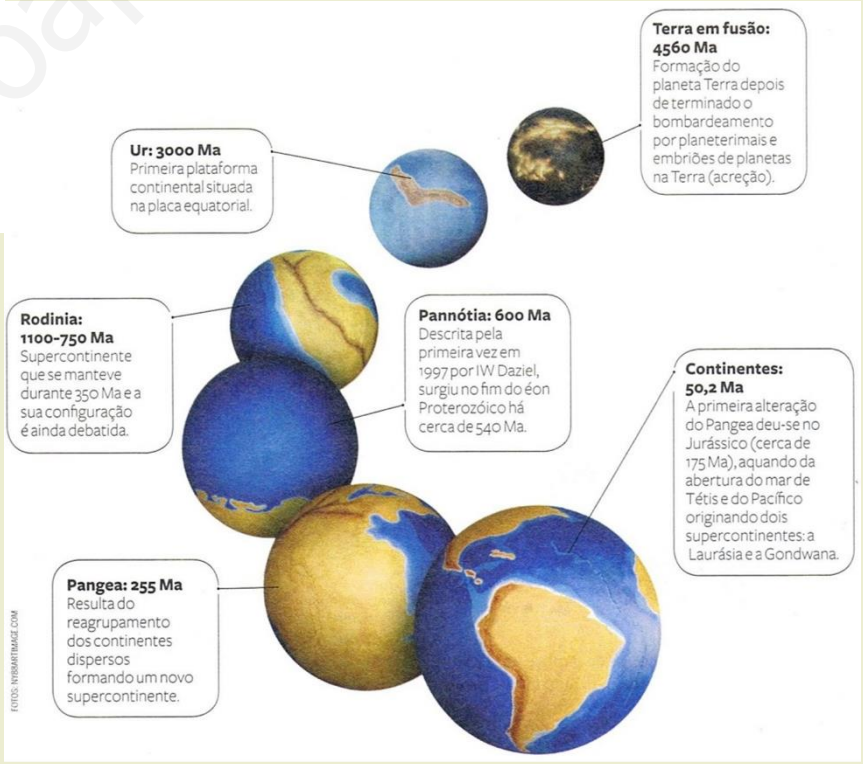
paleomap

Evento	Millones de años antes del presente	Reconstrucción paleogeográfica simplificada
Separación de Pangea	~200	
Formación de Pangea	~300–250	
Separación de Pannotia	~550	
Formación de Pannotia	~600	
Separación de Rodinia	~760	
Formación de Rodinia	~1100	
Formación de Nuna/Columbia	~1800	
Formación de Kenorlandia	~2500	
Formación de Ur	~3000	

Cronología de los supercontinentes

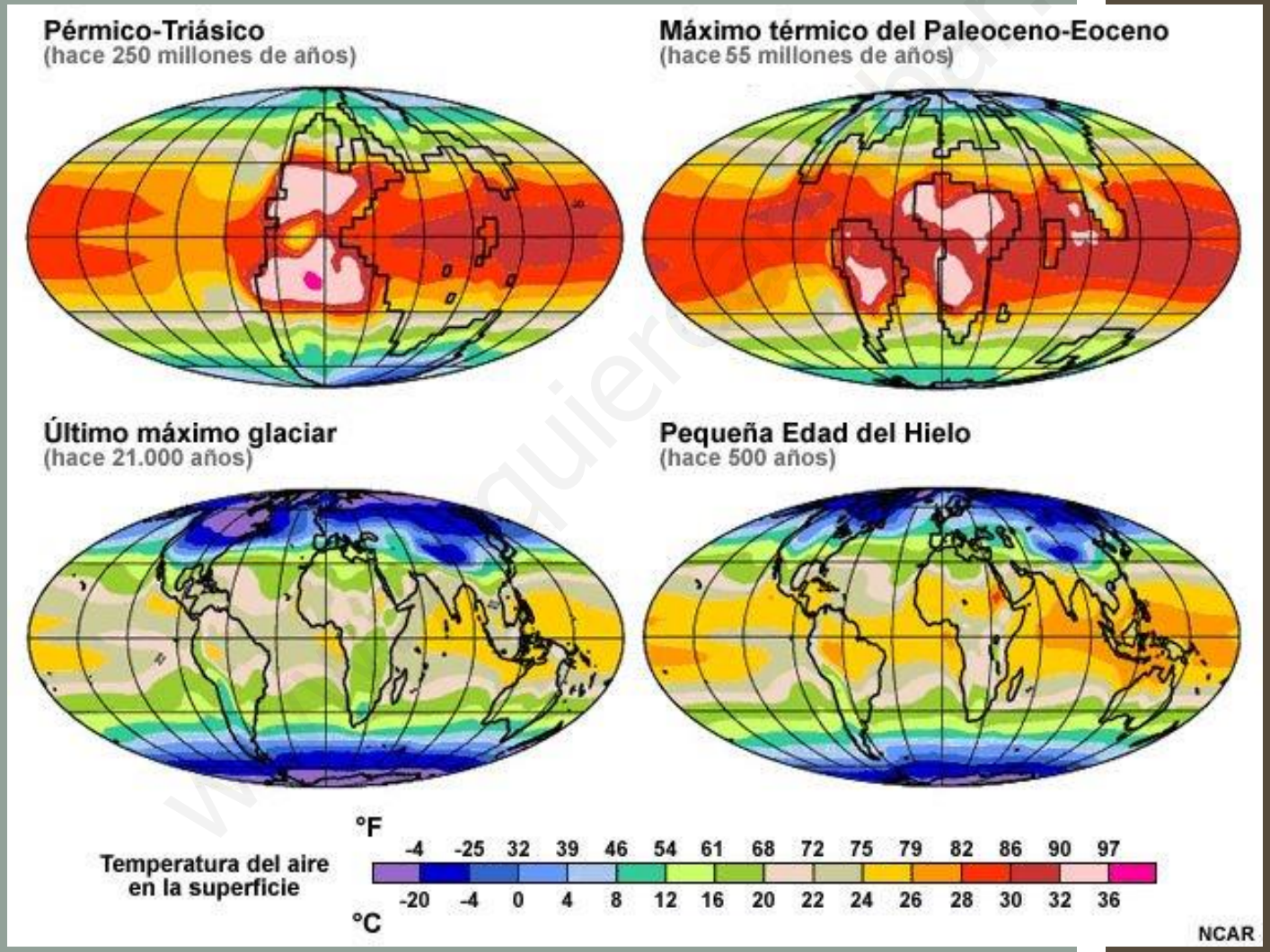


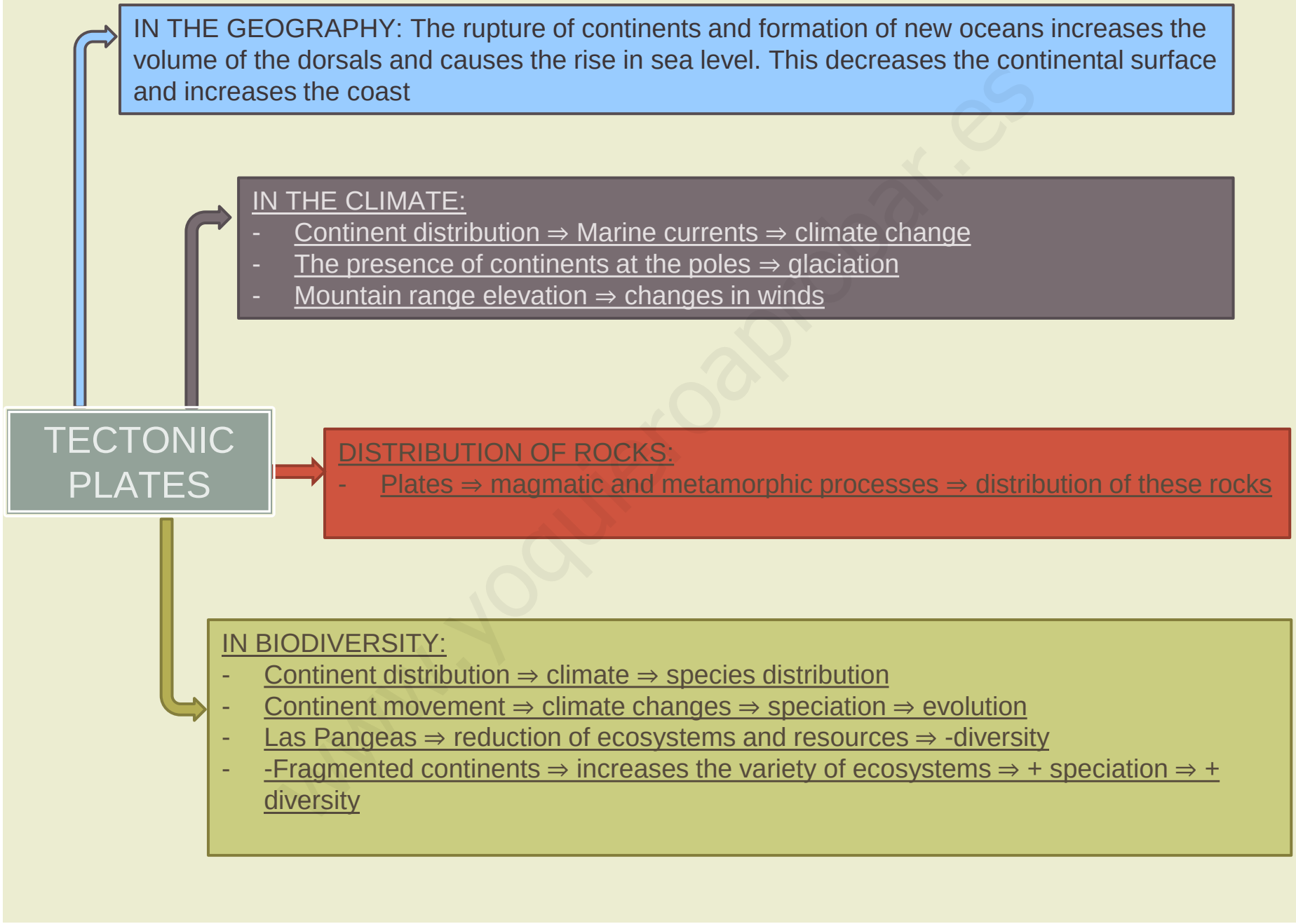


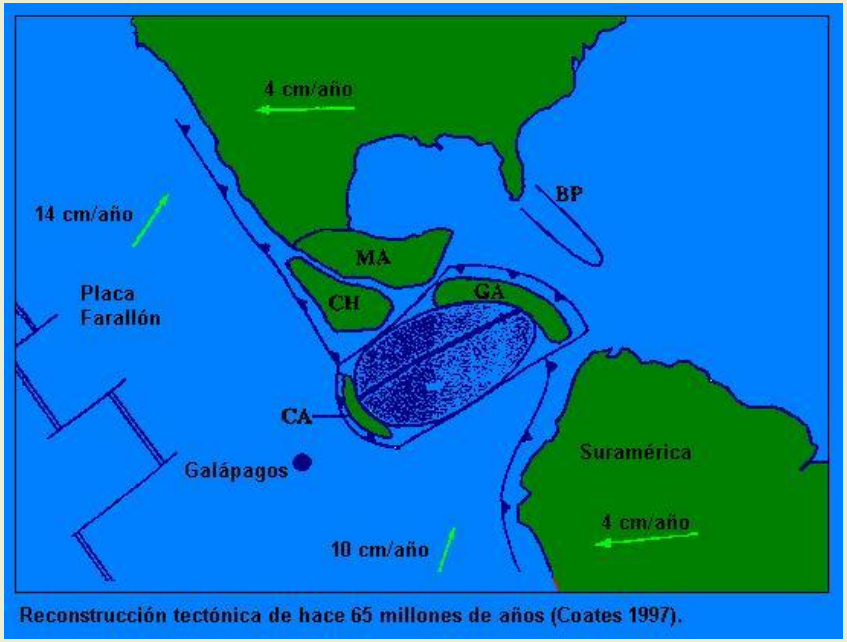


Ancient-earth

8. OTHER CONSEQUENCES OF PLATE TECTONICS




IN THE GEOGRAPHY: The rupture of continents and formation of new oceans increases the volume of the dorsals and causes the rise in sea level. This decreases the continental surface and increases the coast
IN THE CLIMATE:
- Continent distribution ⇒ Marine currents ⇒ climate change
- The presence of continents at the poles ⇒ glaciation
- Mountain range elevation ⇒ changes in winds
TECTONIC PLATES
DISTRIBUTION OF ROCKS:
- Plates ⇒ magmatic and metamorphic processes ⇒ distribution of these rocks
IN BIODIVERSITY:
- Continent distribution ⇒ climate ⇒ species distribution
- Continent movement ⇒ climate changes ⇒ speciation ⇒ evolution
- Las Pangeas ⇒ reduction of ecosystems and resources ⇒ -diversity
- -Fragmented continents ⇒ increases the variety of ecosystems ⇒ + speciation ⇒ + diversity



Reconstrucción tectónica de hace 65 millones de años (Coates 1997).