

# **AMBIENTES TECTÓNICOS**

**(documento complementar de  
Descobrir a Crosta terrestre)**

# MAIN MENU

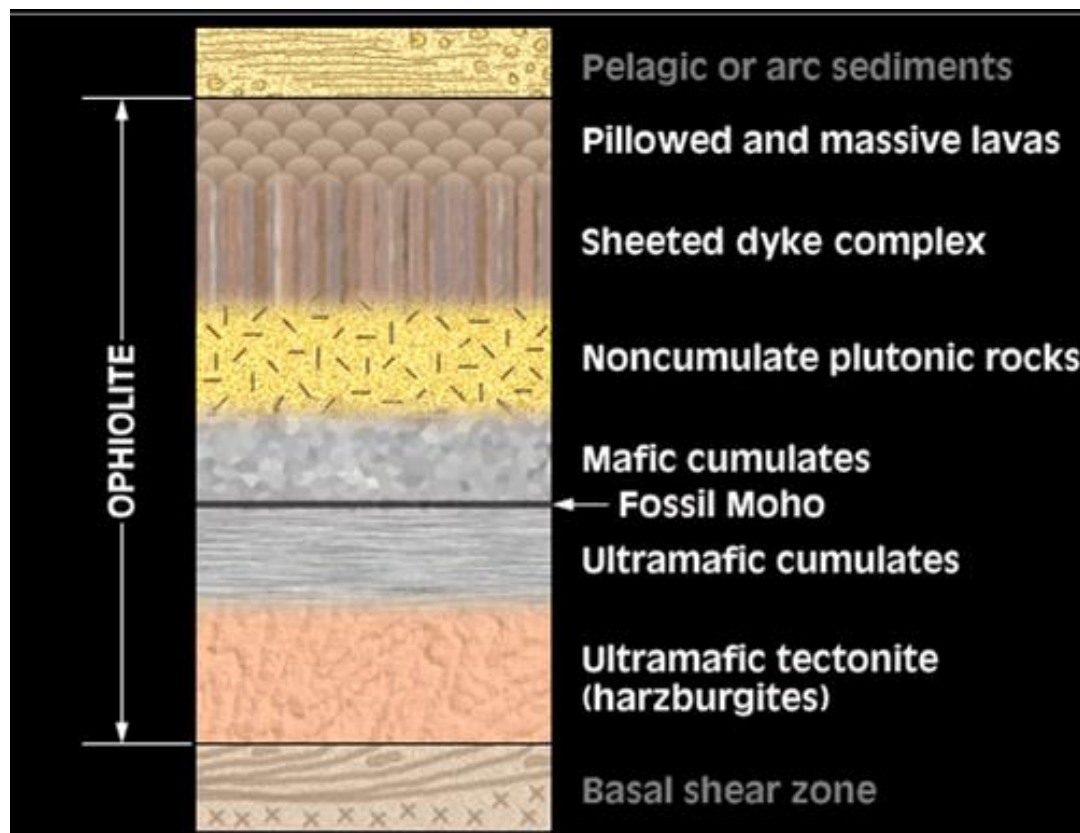
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- Mantle-Plume-Related Tectonic Settings
- Cratons and Passive Margins
- Continental Rifts
- Convergent Margins
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# OFIOLITOS – TERRENOS MÁFICOS OU ULTRAMÁFICOS

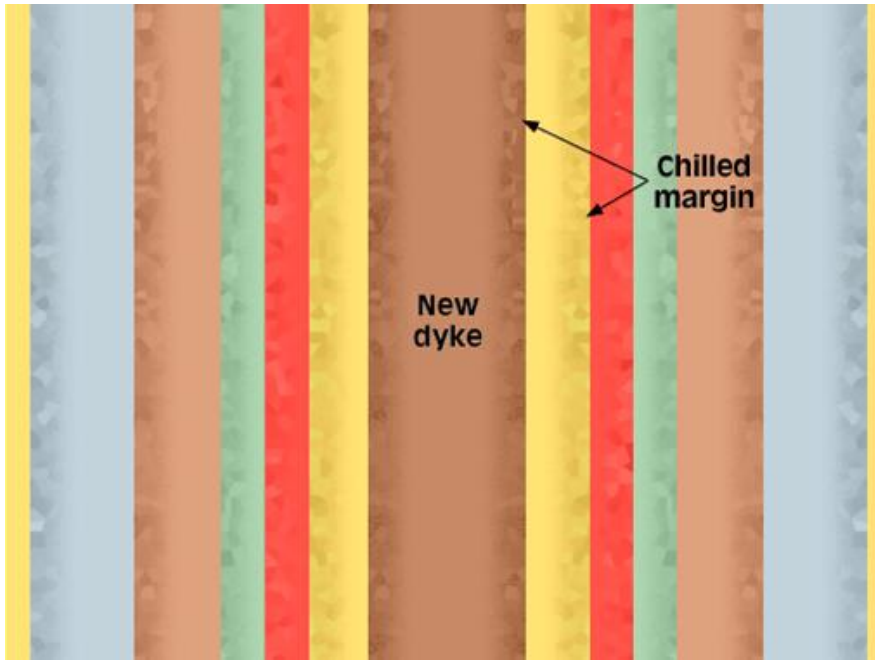
(Fragmentos de crosta oceânica ou de bacias backarc)

Ophiolites are tectonically emplaced terranes of mafic and ultramafic rocks that are considered to represent fragments of oceanic or back arc basin crust. An ideal ophiolite includes from bottom to top the following units:



Sedimentos pelágicos

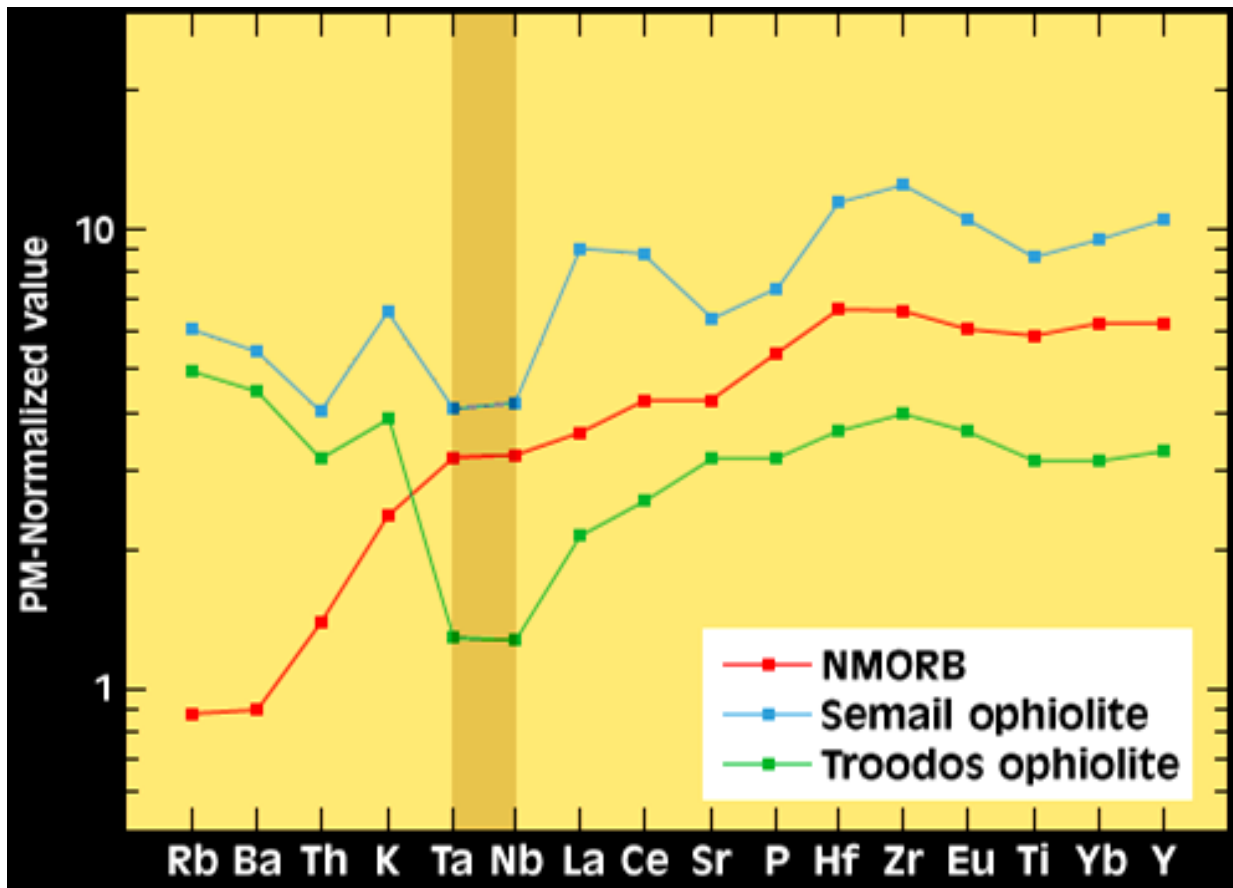
Zona de cisalhamento



Perhaps the most distinctive feature of ophiolites is their sheeted mafic dykes. Many of these dykes, which typically range from 1-3 m thick, have one-way chilled margins, a feature generally interpreted to reflect vertical intrusion in an oceanic axial rift zone, where one dyke is intruded in the center of another as the lithosphere spreads.

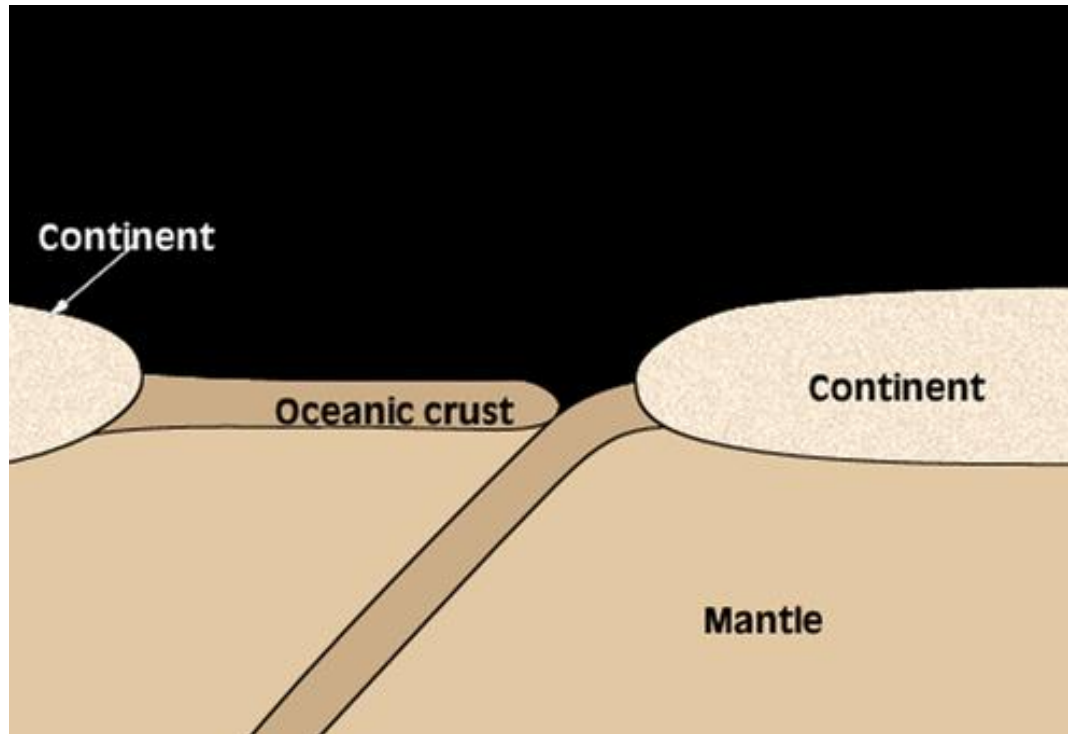
Sheeted diabase dykes from the 2-Ga Jormua ophiolite in northern Finland. Light-colored chilled dyke margins all show a uniform cooling direction (to the lower left).

Filões diabásicos - família do gabro, textura microgranular



Primitive-mantle normalized incompatible element distributions in most ophiolitic basalts, as for example the Semail ophiolite in Oman and the Troodos Complex in Cyprus, show a subduction geochemical component (relative depletion in Ta and Nb) suggesting they are fragments of back arc oceanic crust. Few ophiolites show the depleted element patterns of normal ocean ridge basalts (NMORB).

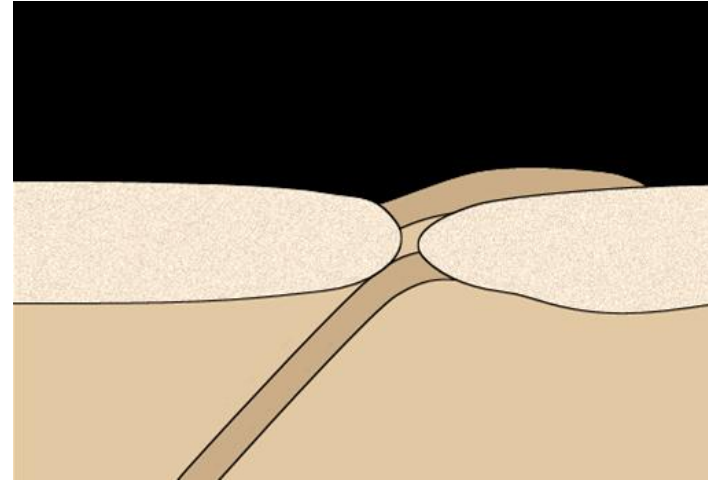
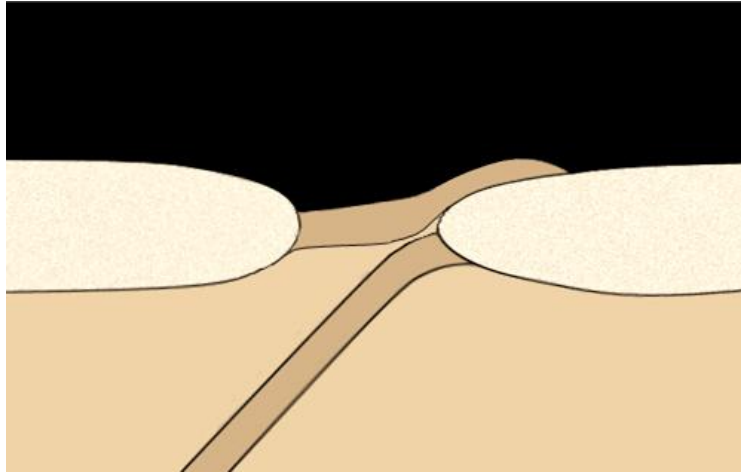
Evidência da existência de subducção – diminuição relativa de Nb e Ta



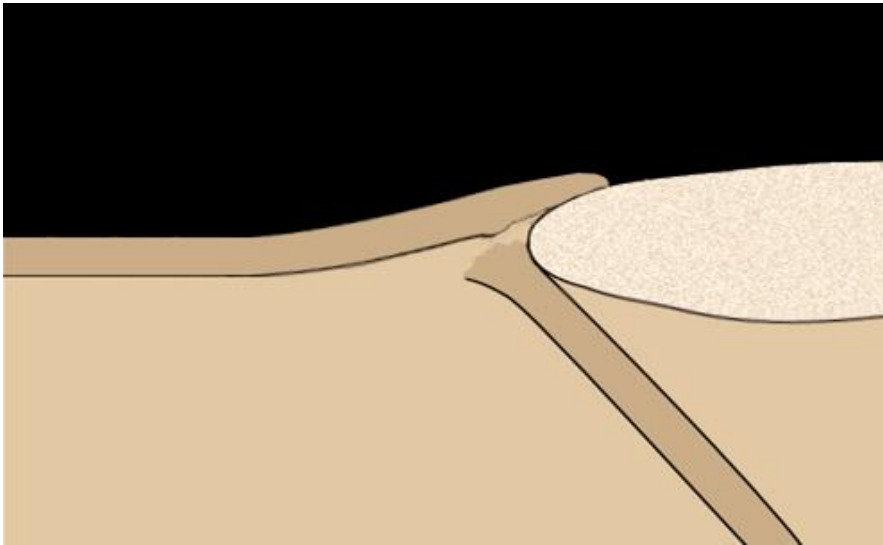
Ophiolites are emplaced in arcs or collisional orogens by three major mechanisms:

## MECANISMOS PROPOSTOS PARA A IMPLANTAÇÃO DOS OFIOLITOS

# Obdução

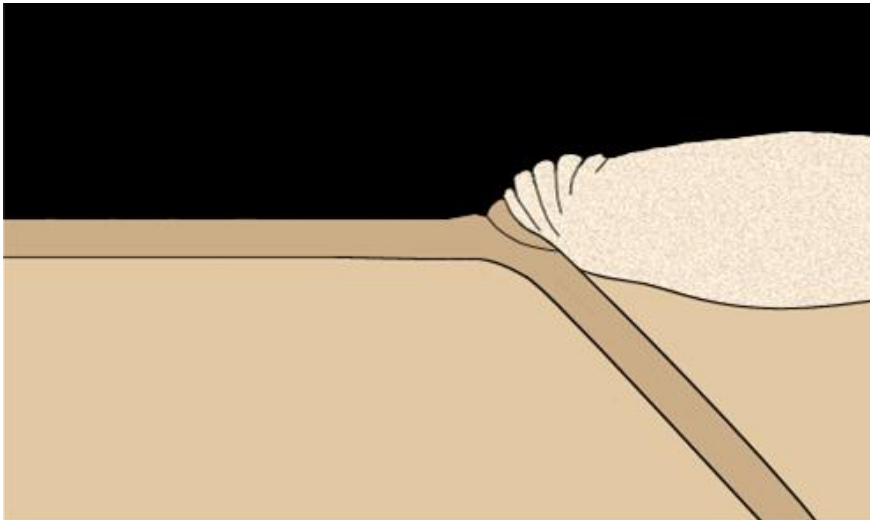


1) Obduction or thrusting of oceanic lithosphere onto a passive continental margin during a continental collision; ...



**FRAGMENTAÇÃO  
COM OBDUÇÃO  
E CAVALGAMENTO**

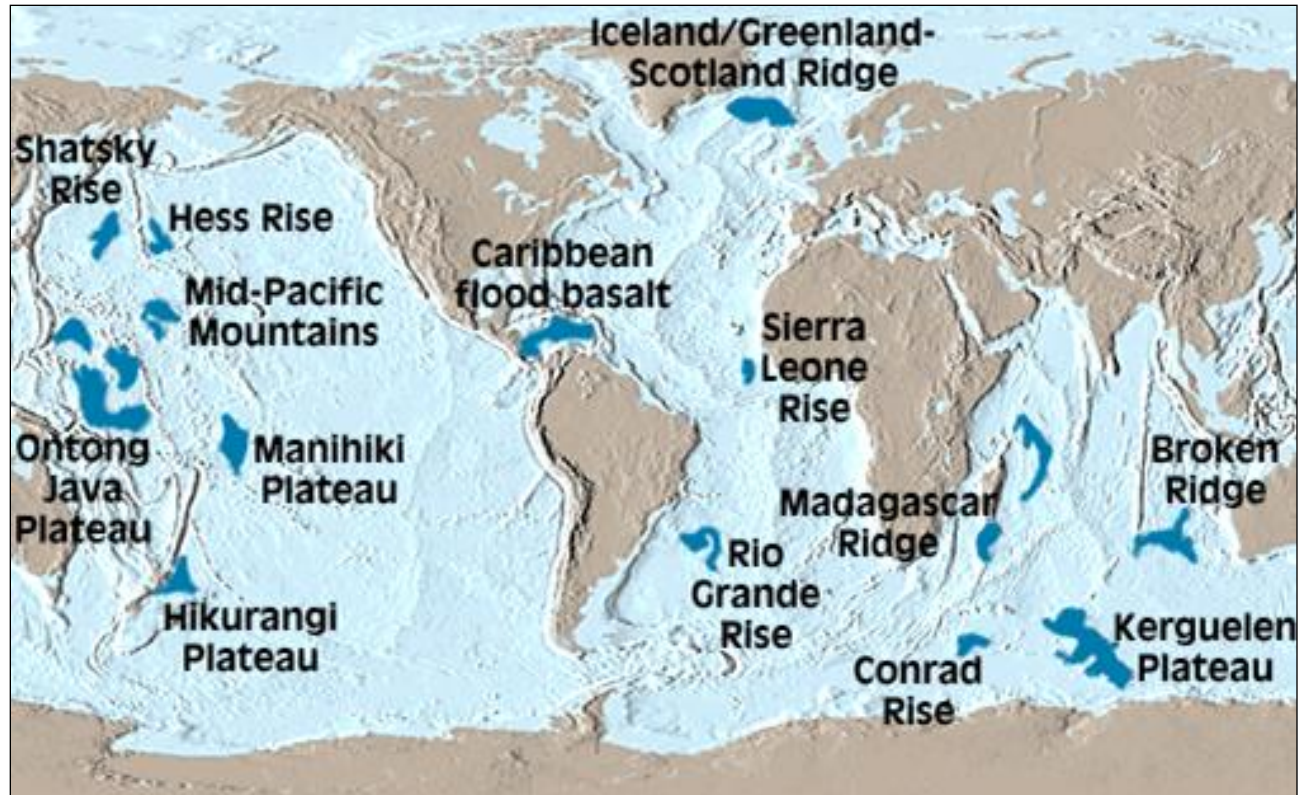
... 2) splitting of the upper part of a descending slab and obduction of a thrust sheet onto a former arc; ...



**ADIÇÃO DE UMA FATIA DE  
CROSTA OCEÂNICA  
A UM PRISMA DE ACREÇÃO**

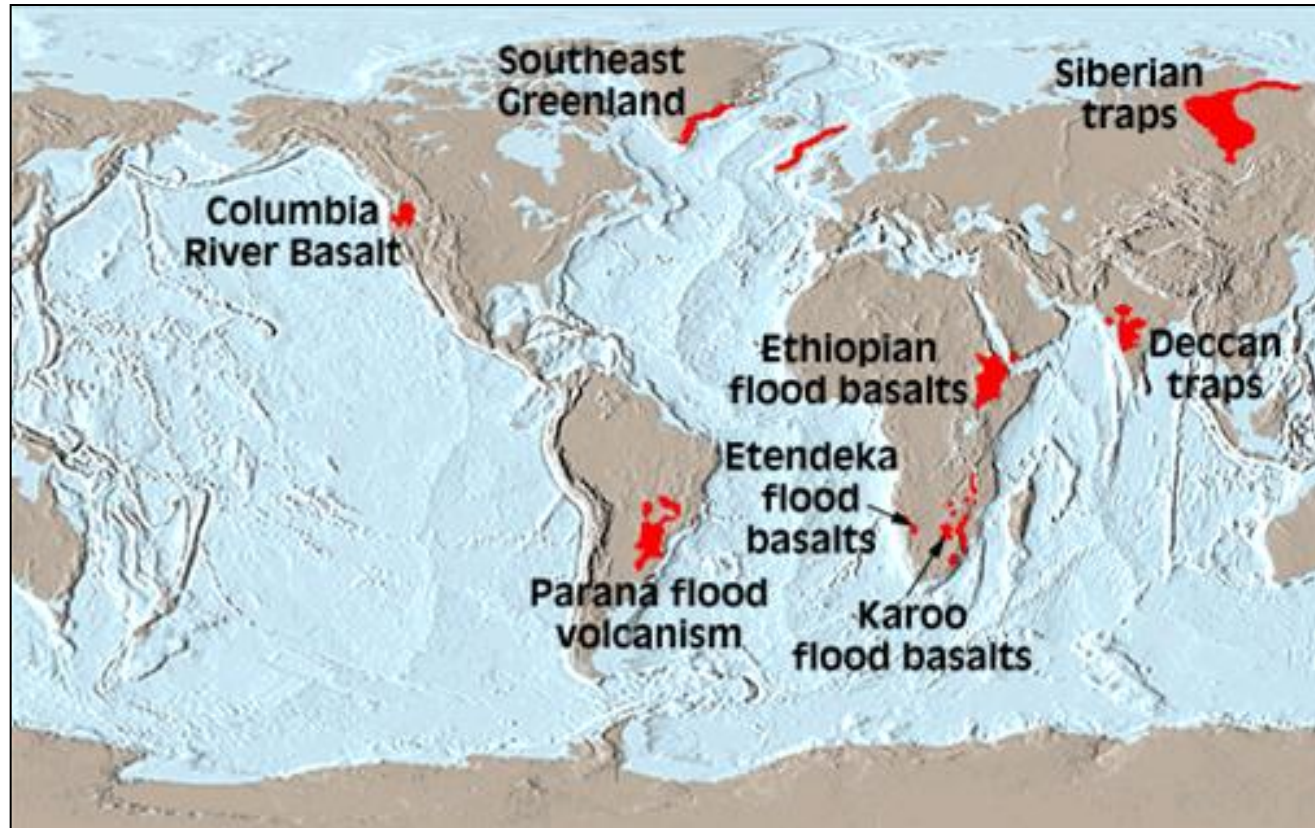
... 3) and addition of a slab of oceanic crust to an accretionary prism in an arc system.

# Planaltos lávicos oceânicos



Oceanic plateaus, which are composed chiefly of basalt flows erupted beneath the oceans, are the largest topographic features on the seafloor.

# Planaltos lávicos continentais



Hotspot tracks are chains of oceanic islands showing plate motions over mantle plumes. Flood basalts are thick successions of basalt erupted on the continents over short periods of time.

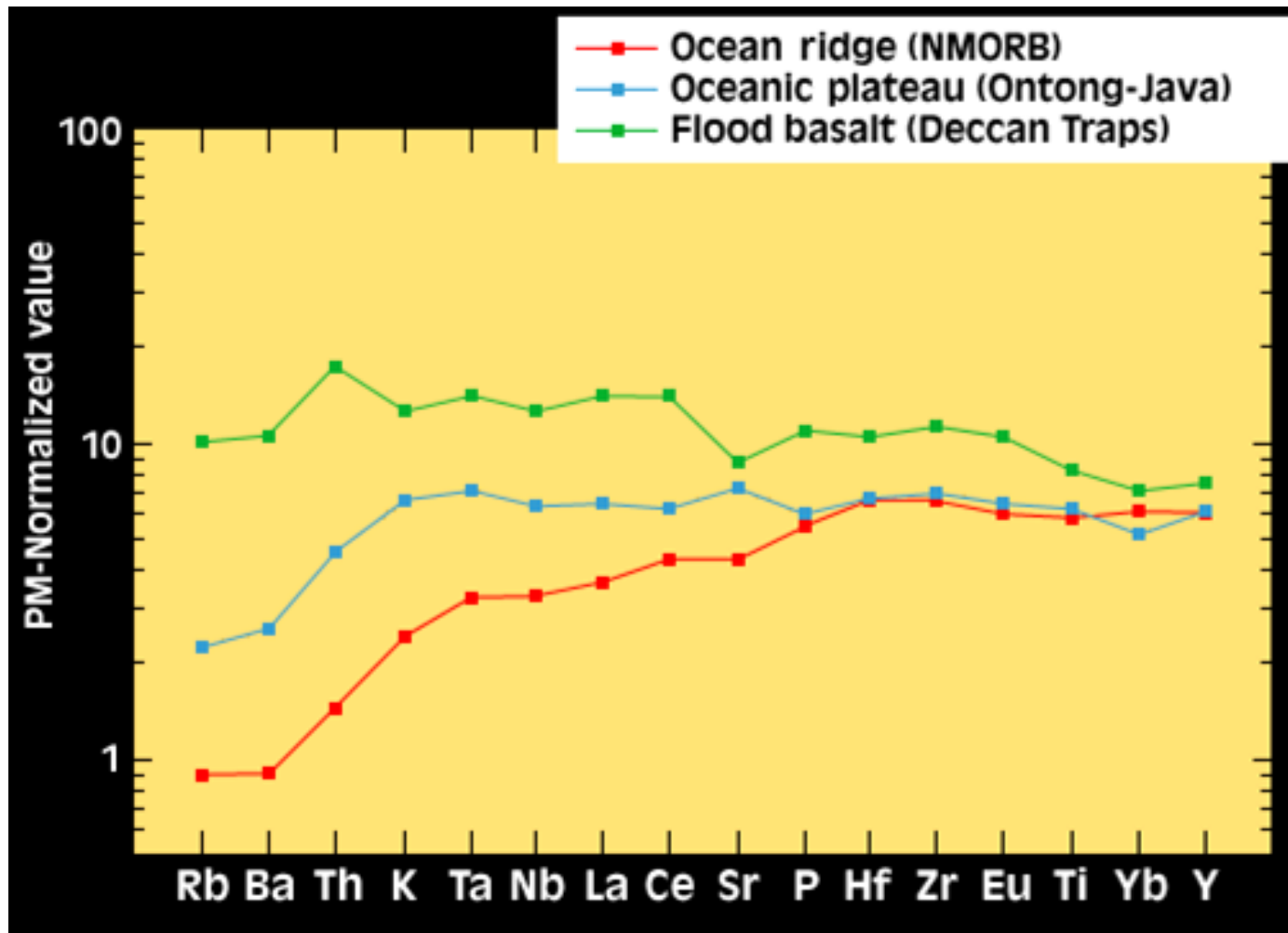
The Columbia River basalts in the NW United States are an example of flood basalts erupted at 17.5 - 6 Ma. Many of the individual flows exceed 50 meters in thickness and show huge columnar joints as shown here.



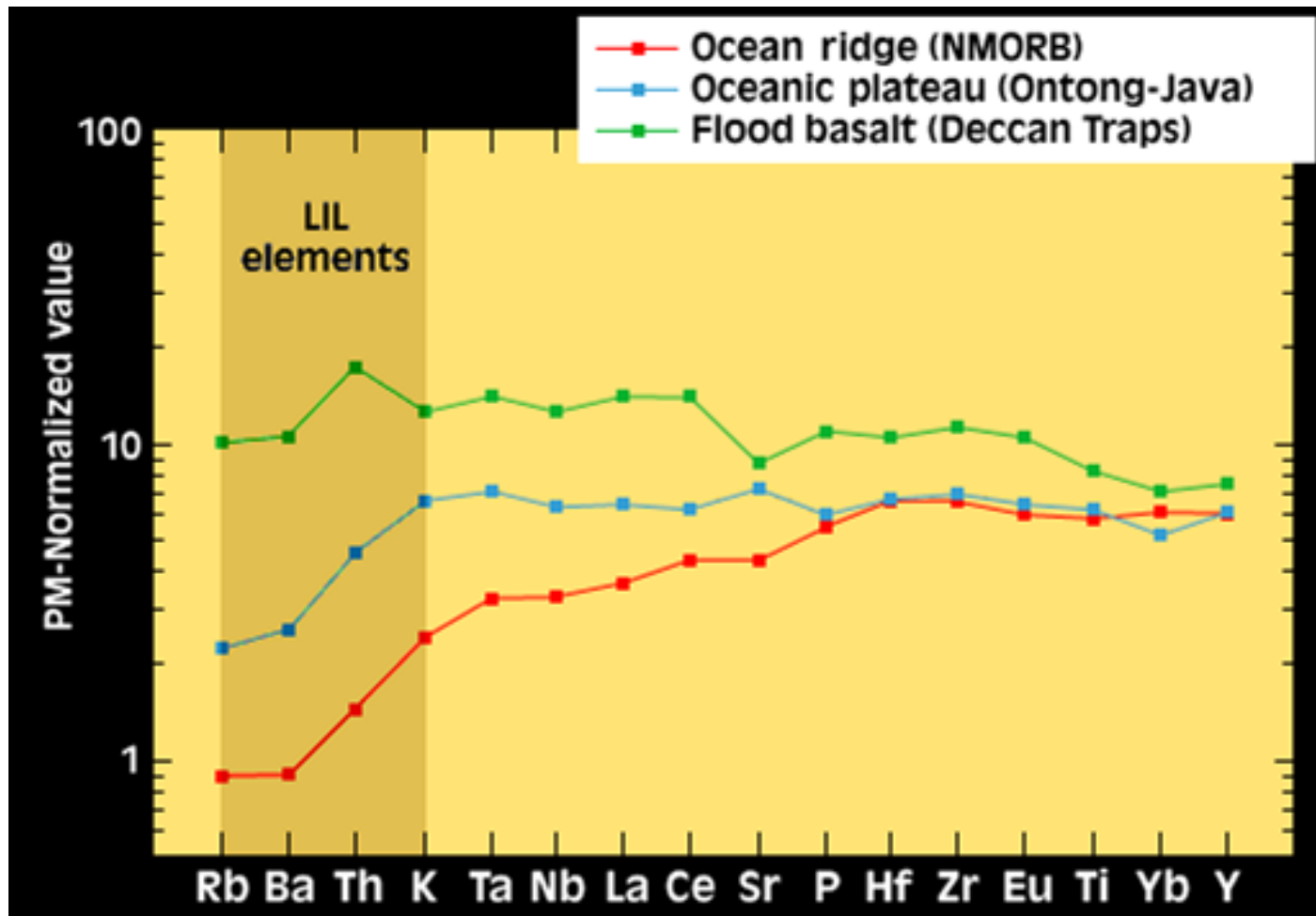
## Planaltos lávicos continentais



Victoria Falls in Zimbabwe pours into the canyon of the Zambezi River, which cuts through the Karoo flood basalts erupted about 200 Ma.



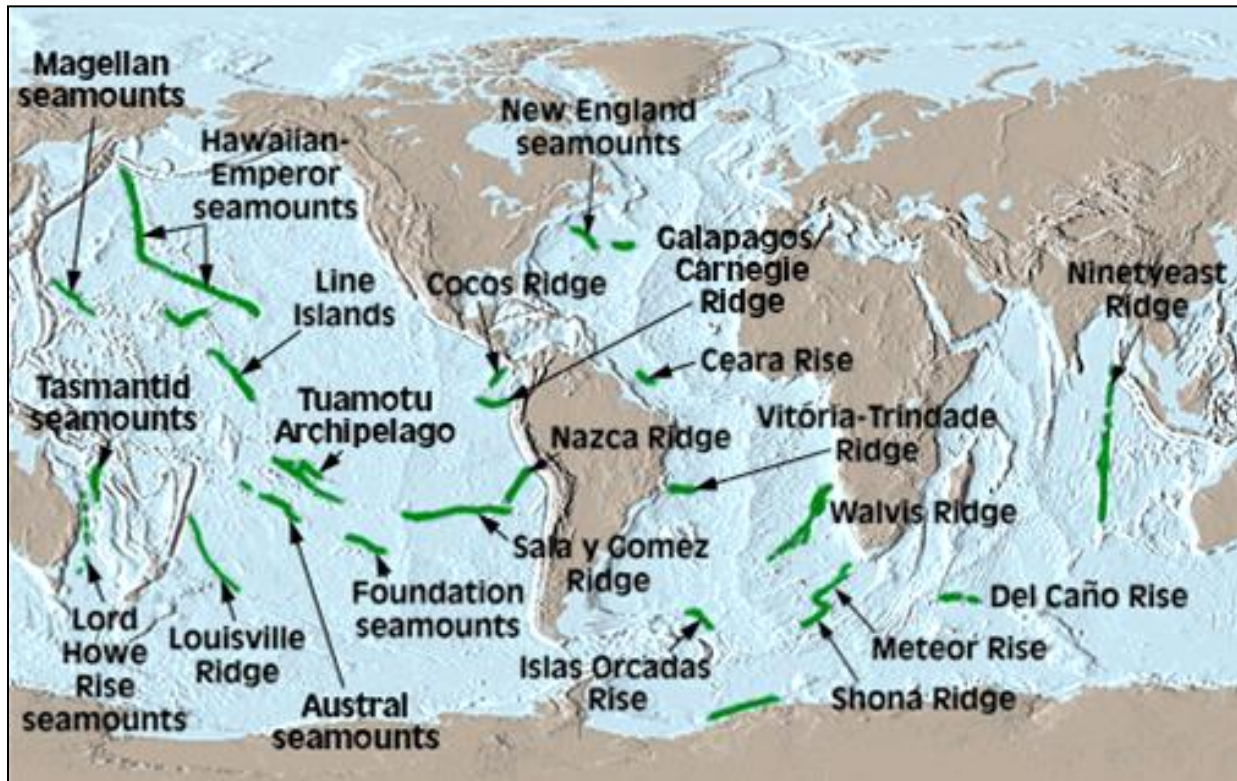
Oceanic plateau basalts are largely tholeiites and most show incompatible elements only slightly enriched compared to NMORB. Incompatible element distributions vary widely in flood basalts, often within the same volcanic field.



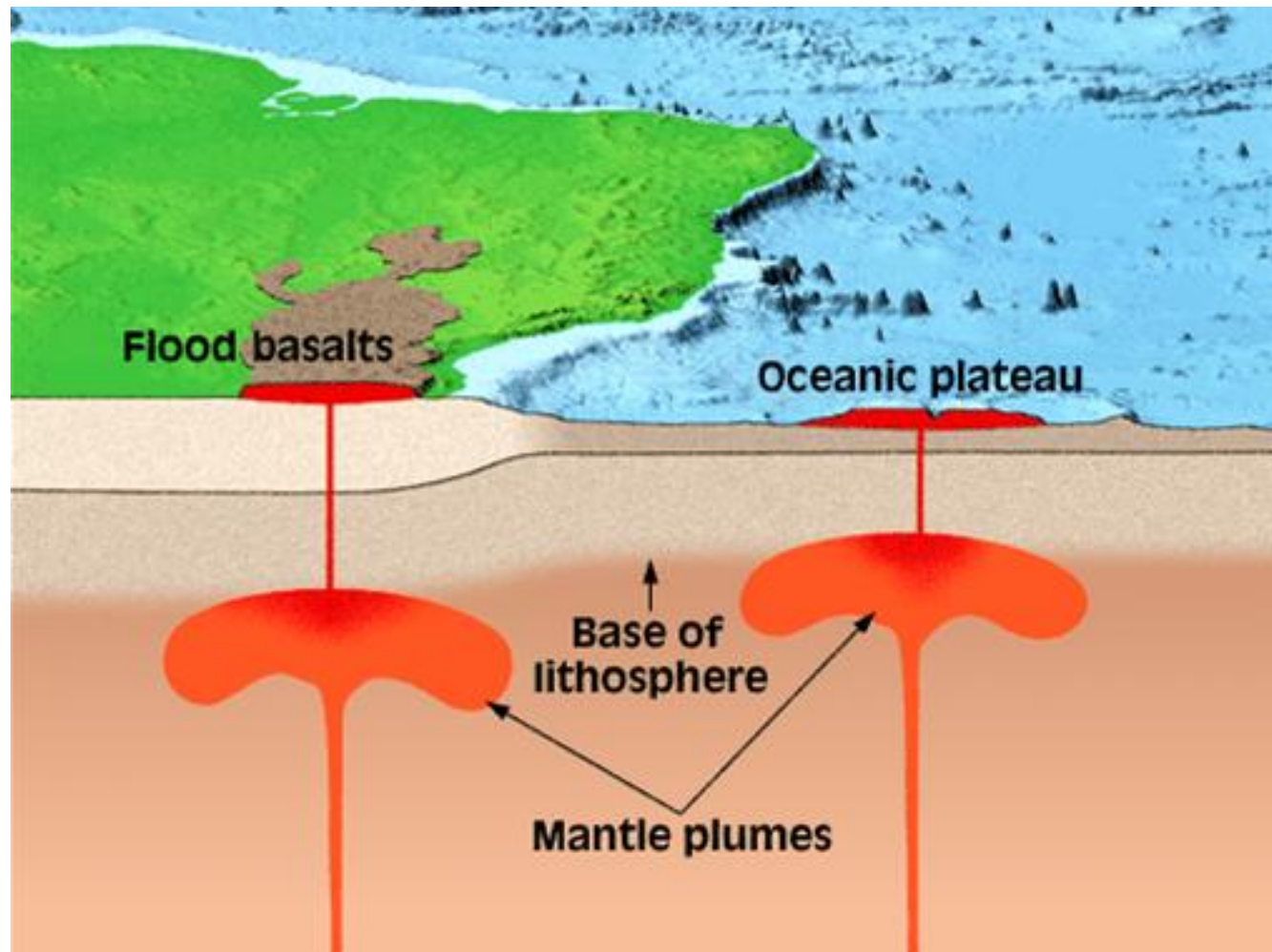
Those with relatively high contents of LIL elements, like the Deccan traps, are either contaminated by continental crust, or come from enriched sources in the subcontinental lithosphere.

**ENRIQUECIMENTO RELATIVO EM ELEMENTOS LITÓFILOS**

# Hot spots – Pontos Quentes

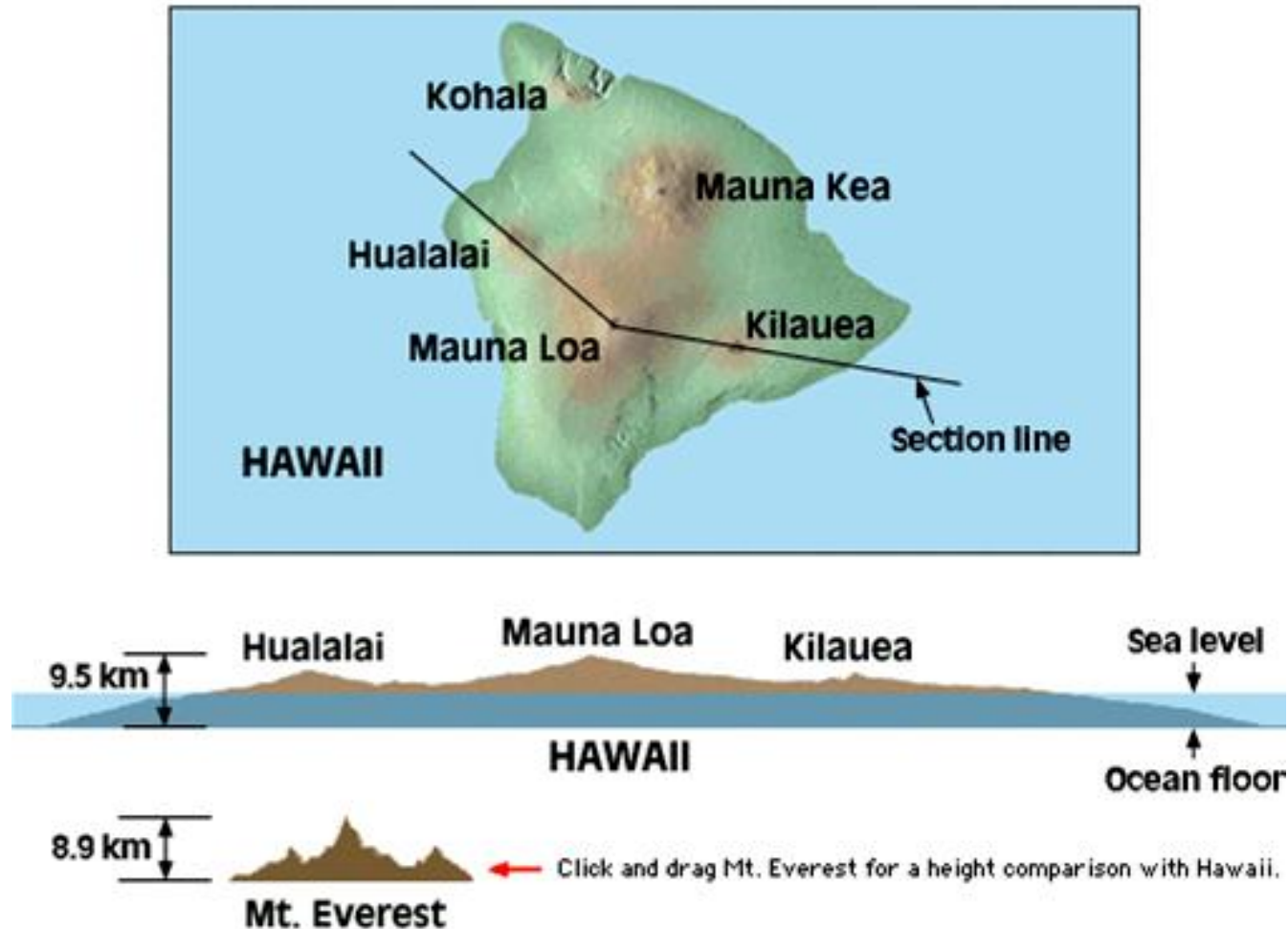


Oceanic plateaus, which are composed chiefly of basalt flows erupted beneath the oceans, are the largest topographic features on the seafloor. Hotspot tracks are chains of oceanic islands showing plate motions over mantle plumes. Flood basalts are thick successions of basalt erupted on the continents over short periods of time.



Flood basalts and oceanic plateaus are thought to be the products of magmas erupted from mantle plumes.

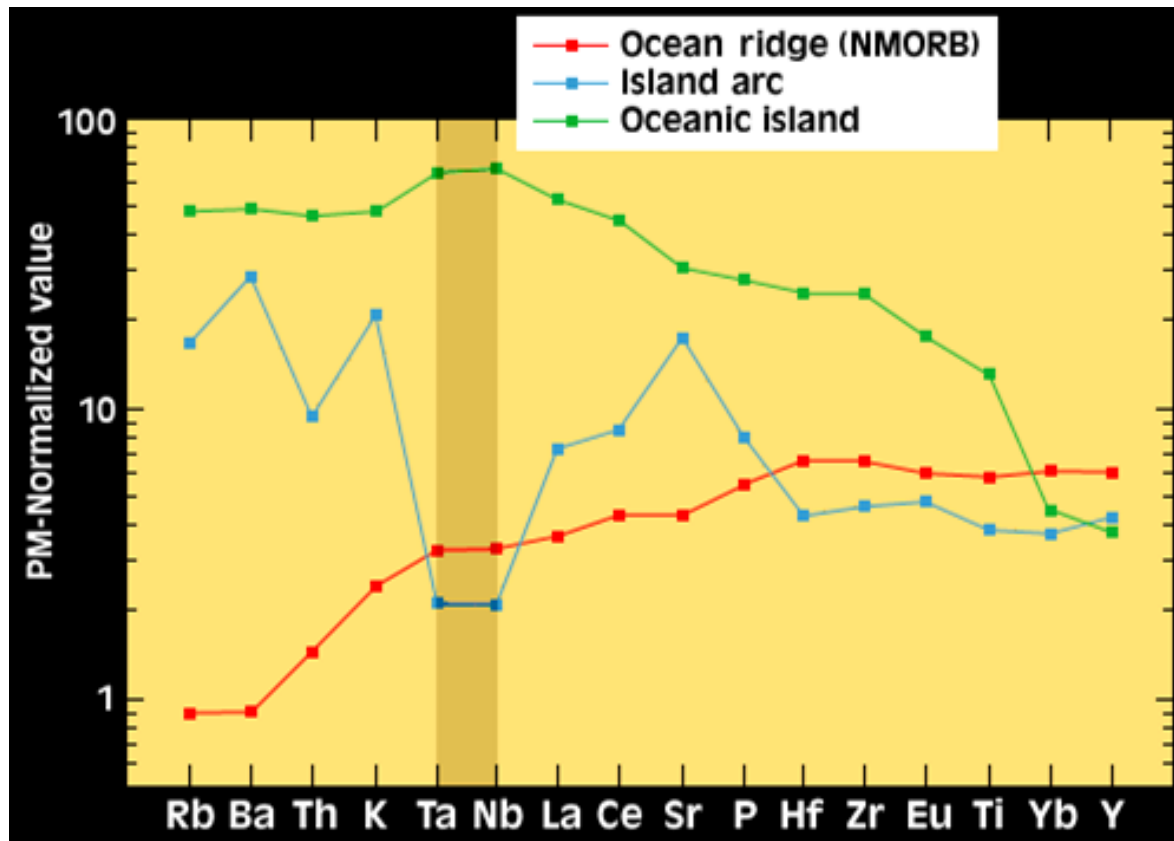
# Arcos vulcânicos oceânicos



As exemplified by Hawaii, oceanic volcanic islands are some of the largest mountains on Earth, often rising many kilometers above the seafloor. Mauna Loa, for instance rises more than 9.5 km above the ocean floor.



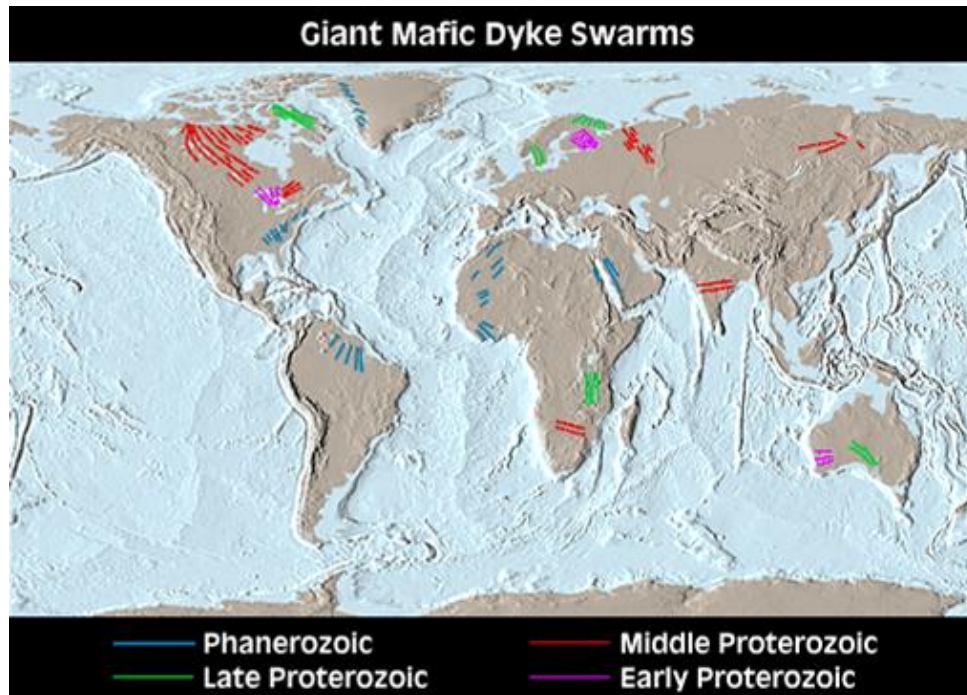
Volcanic islands are composed chiefly of tholeiitic basalt, with only minor amounts of alkali basalt and its derivatives erupted during terminal volcanism. Shown here are basalt flows erupted from Kilauea in 1971.



In striking contrast to subduction-related basalts, most island basalts show relative enrichment in Nb and Ta, reflecting a mantle plume source enriched in these elements.

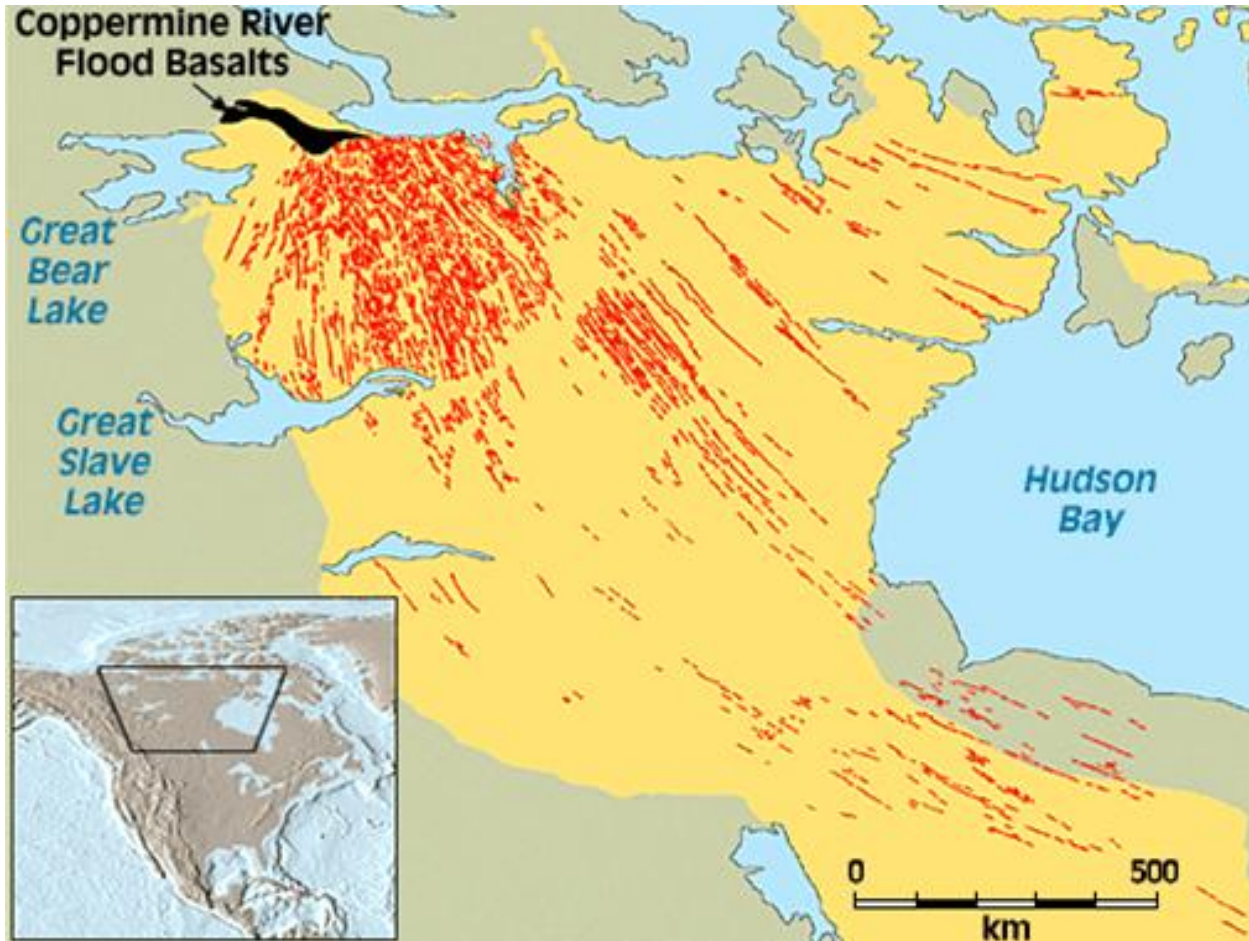
# Diques máficos gigantes

Vast swarms of mafic dykes that range up to 500 km wide and over 3000 km long, occur on Precambrian shields and include many thousands of dykes. Shown here are the largest dyke swarms on Earth. Individual dykes range from 10 to 50 m in width, with some up to 200 m and some single dykes can be traced for up to 1000 km.



Dykes of the Mackenzie dyke swarm in Northern Canada. These dykes, which were intruded about 1267 Ma, are more resistant than surrounding rocks and weather into ridges.

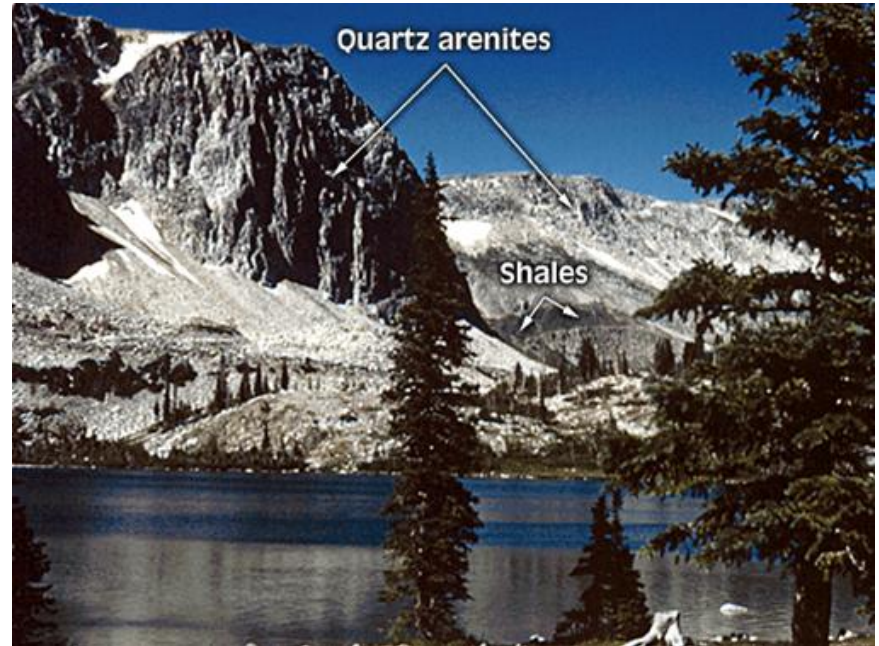
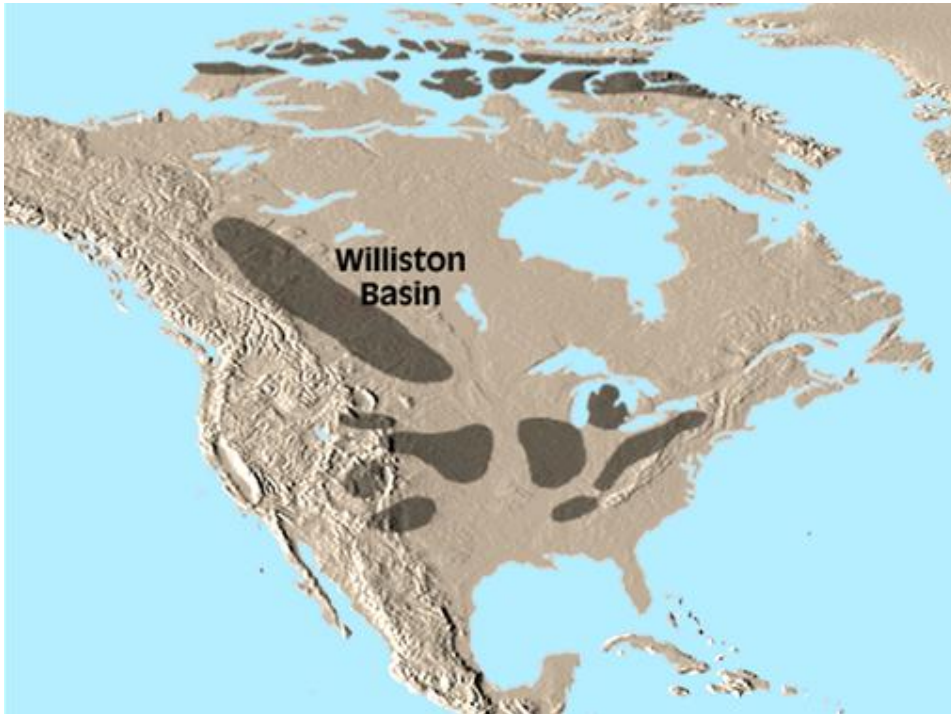
# Diques máficos gigantes



Some swarms, such as the giant Mackenzie swarm in Canada, appear to radiate from a point, commonly interpreted as a plume source for the magmas. The Coppermine River flood basalts were erupted at the same time near the plume head.

# Bacias intracratónicas

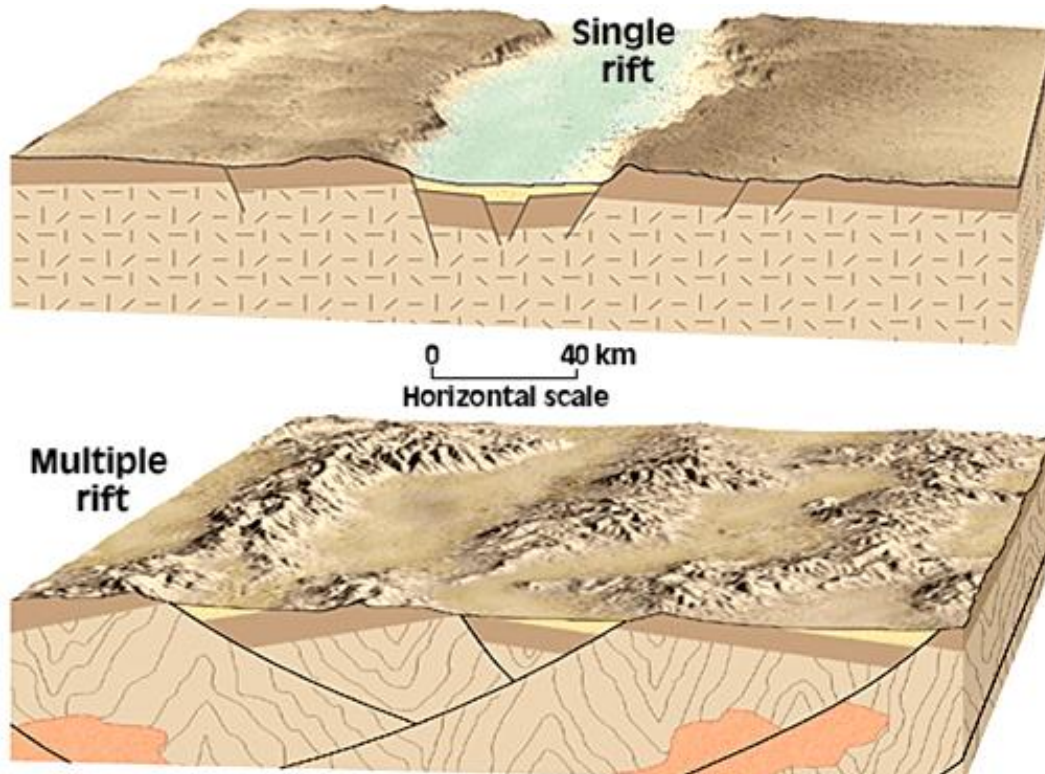
Intracratonic basins were widespread in North America during the Phanerozoic. Many of these basins, such as the Williston Basin in Canada, have major reserves of oil and gas.



Rock assemblages deposited on cratons and passive margins are mature clastic sediments, chiefly quartz arenites and shales, and shallow marine carbonates. Shown here are Early Proterozoic quartz arenites and shales in the Snowy Range in southern Wyoming.

# Riftes Continentais

Continental rifts are fault-bounded basins produced by extension of continental crust. They may be single, like the rifts in East Africa, ...



... or multiple, as in the case of the Basin and Range Province in the western United States.

# Riftes Continentais

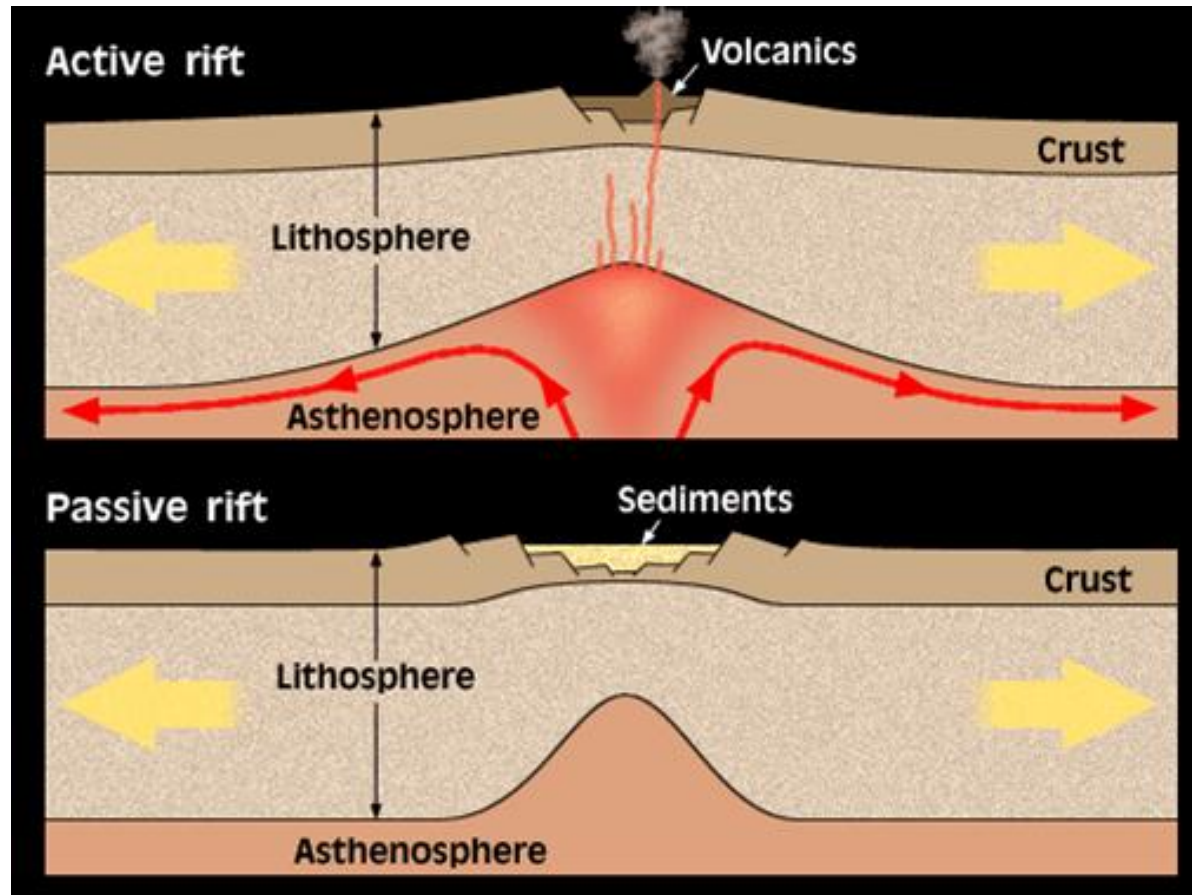
The East African Rift System is the largest modern rift system. Here we see Longonot, a recently active volcano in the East African Rift NW of Nairobi, Kenya.



View from the summit of Mt. Whitney in the Sierra Nevada (E California), looking east into the Basin and Range Province, comprising multiple horsts and grabens.

# Riftes Continentais

Active rifts are produced by doming and cracking of the lithosphere that results from upwelling asthenosphere or rising mantle plumes.



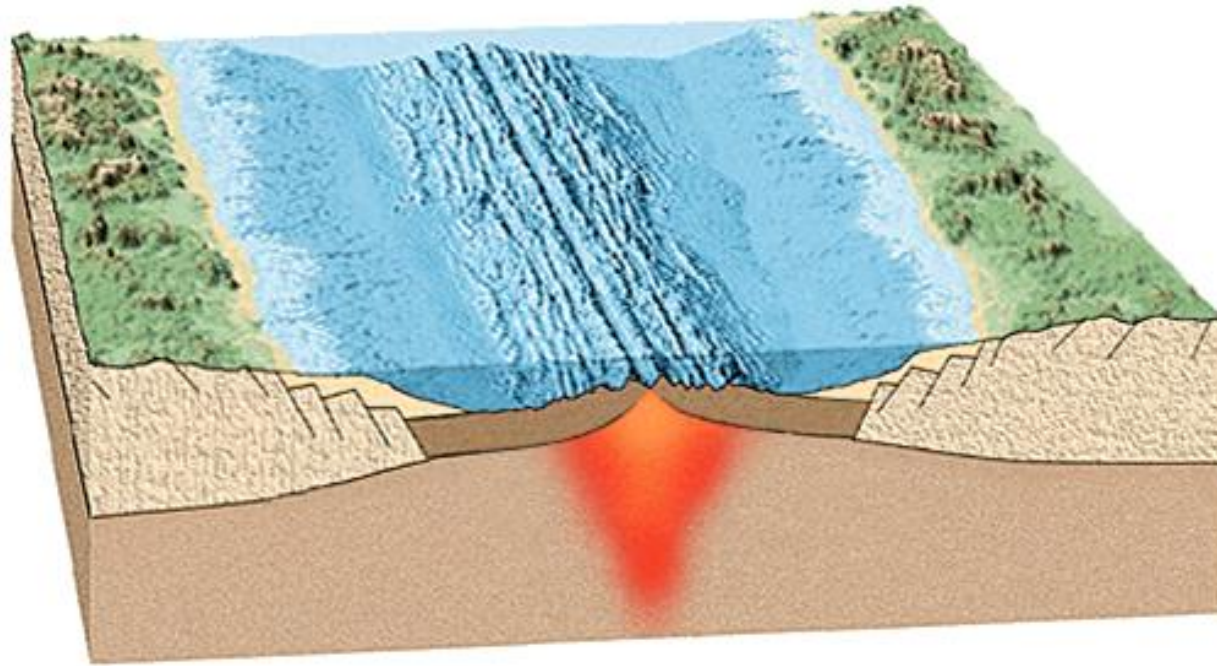
Passive rifts, on the other hand, are produced by stresses in moving lithospheric plates or drag at the base of the lithosphere.

# Riftes Continentais

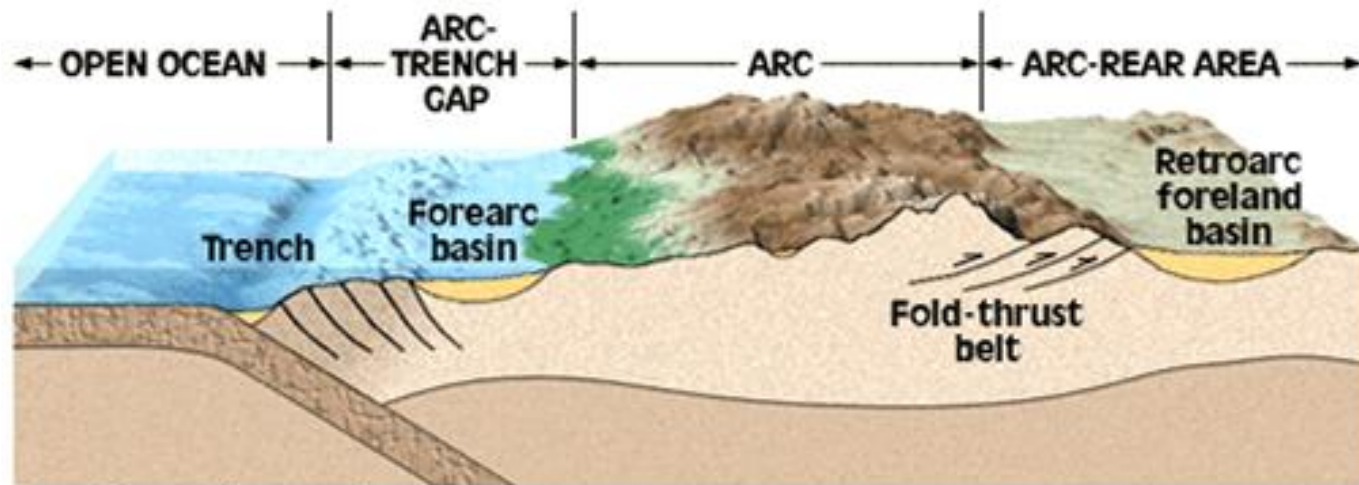
As illustrated here for the Rio Grande Rift in New Mexico, active rifts contain relatively large volumes of volcanic rock. Shown are massive felsic ash flow tuffs near Los Alamos, New Mexico.



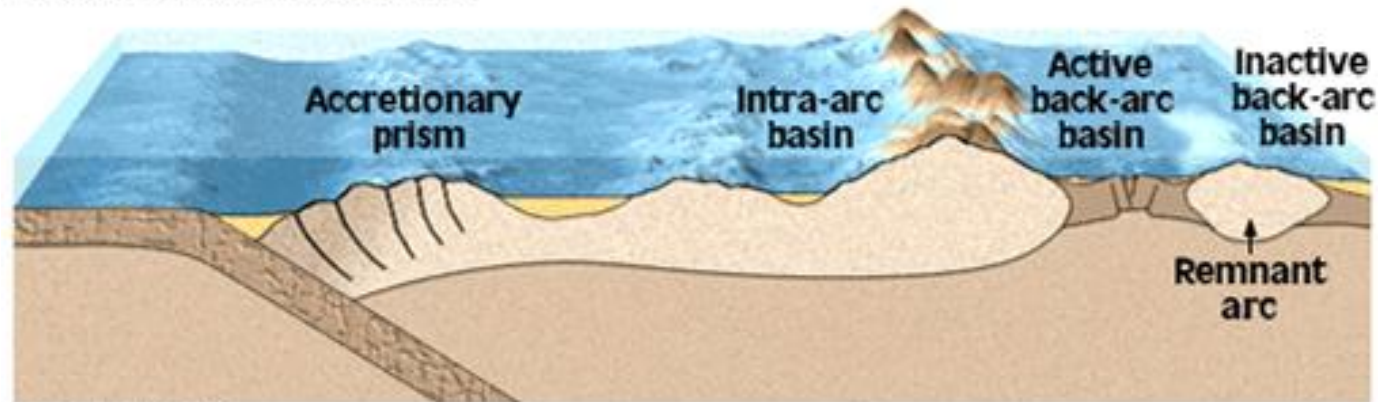
Passive rifts, on the other hand, are characterized by immature clastic sediments, such as these arkoses with channel cross bedding from the 1-Ga Keweenaw Rift in Minnesota.



As continental rifts continue to open, they can evolve into ocean ridges as occurred with the opening of the Red Sea in the last 30 My.



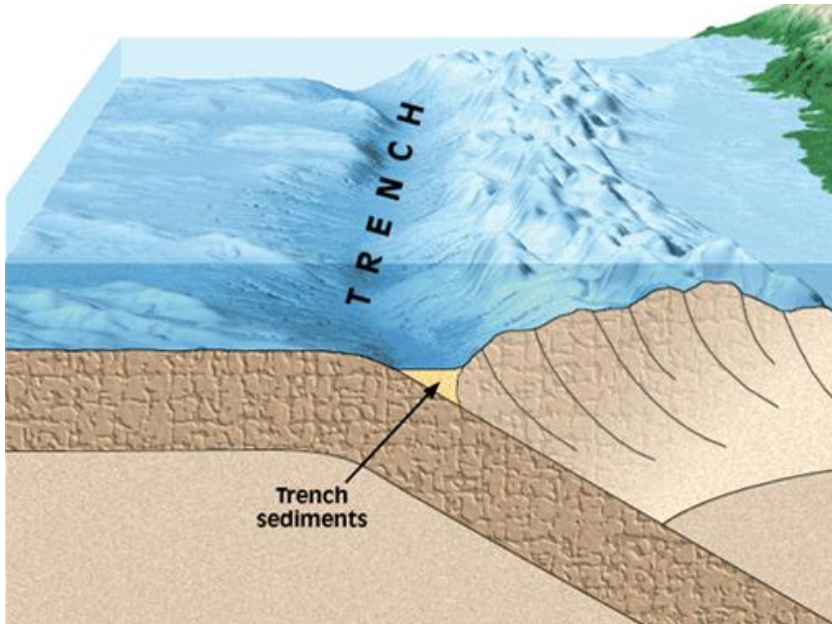
Continental-margin arc



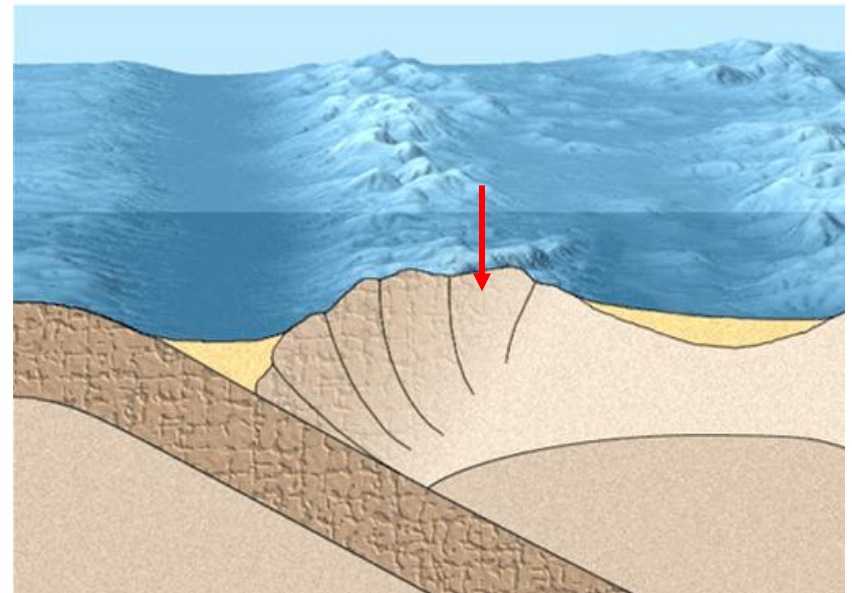
Oceanic arc

An oceanic arc differs from a continental-margin arc primarily in the arc-rear area where it includes some combination of active and inactive back-arc basins, and in some instances, remnant arcs.

Trenches are formed where lithospheric slabs begin to descend into the mantle. Trench sediments are dominantly fine grained graywacke turbidites with minor pelagic components.

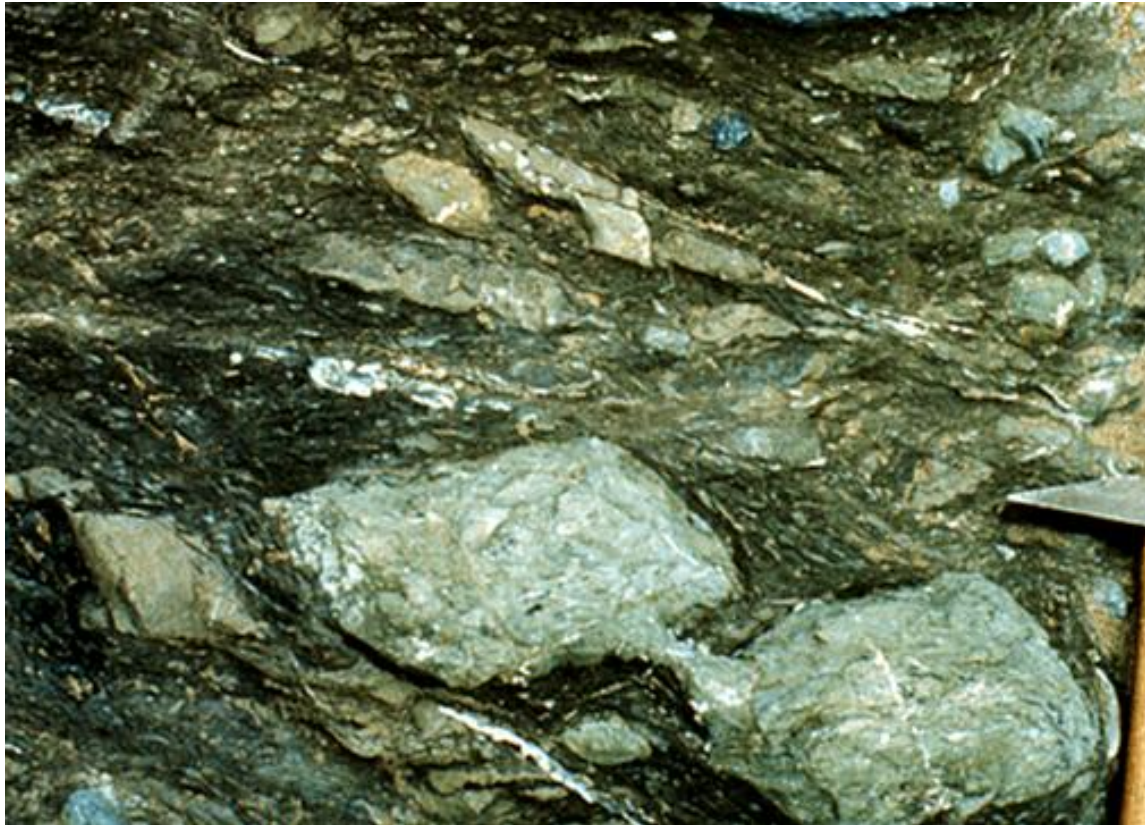


## FOSSAS



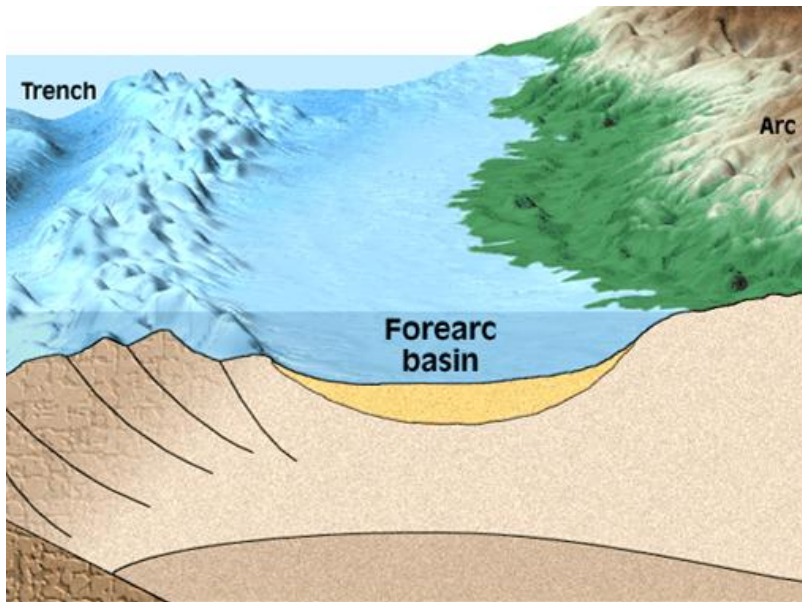
## PRISMAS DE ACREÇÃO

The accretionary prism consists of a series of steeply inclined, fault-bounded wedges of sediments and volcanic rocks that have been accreted to the front of an arc above a descending slab.



Melange is produced in accretionary prisms by intense shearing. As shown here for the Franciscan melange in California, it lacks bedding and contains broken rock fragments in a fine grained, deformed matrix.

Forearc basins are marine depositional basins on the trench side of arcs.



## BACIAS ANTE-ARCO FOREARC BASIN



Sediments in forearc basins are chiefly ash beds and graywacke turbidites with volcanic sources in the adjacent arc system. Shown here is a graded turbidite fining from bottom to top from a Miocene forearc basin of Japan.

Both tholeiitic and calc-alkaline magmas characterize arcs, with basalts and basaltic andesites dominating in oceanic arcs, and andesites and dacites often dominating in continental margin arcs. As shown here for submarine basalts from the Kermadec Arc, pillows are common features in oceanic arc volcanics.



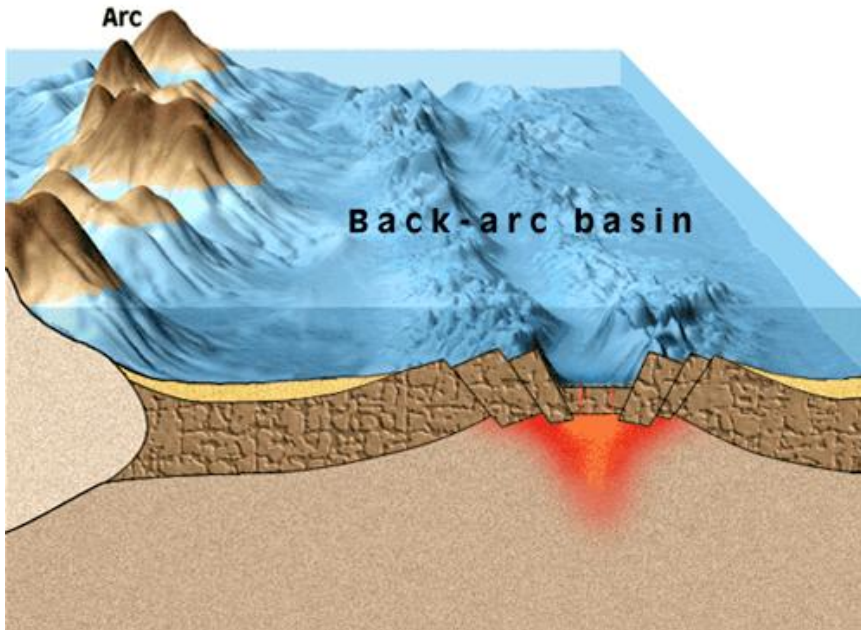
← Arcos vulcânicos oceânicos



Arcos vulcânicos de margem continental →

Mt. Jefferson in the Cascades of western Oregon is a typical continental-margin stratovolcano composed chiefly of andesites and dacites.

Back-arc basins occur over descending slabs behind oceanic arcs and commonly have high heat flow, relatively thin lithosphere, and in many instances, an active ocean ridge, which is enlarging the size of the basin.

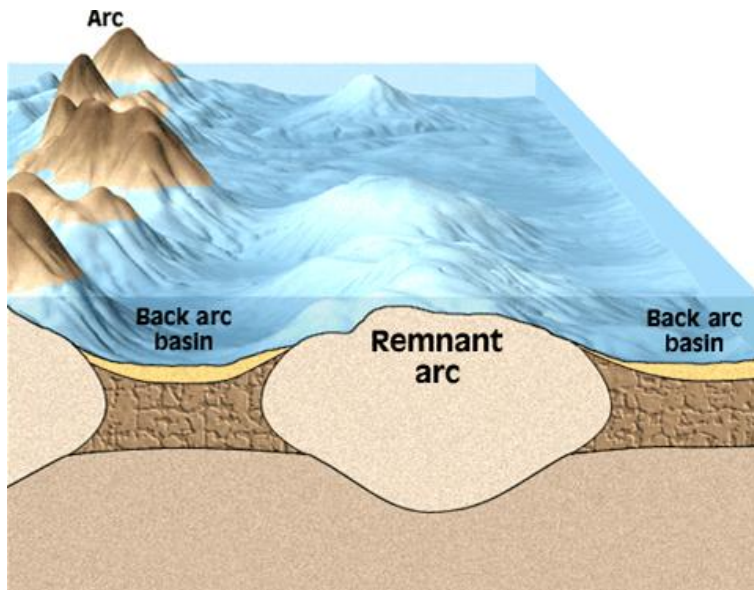


## BACIA PÓS-ARCO BACK-ARC BASIN

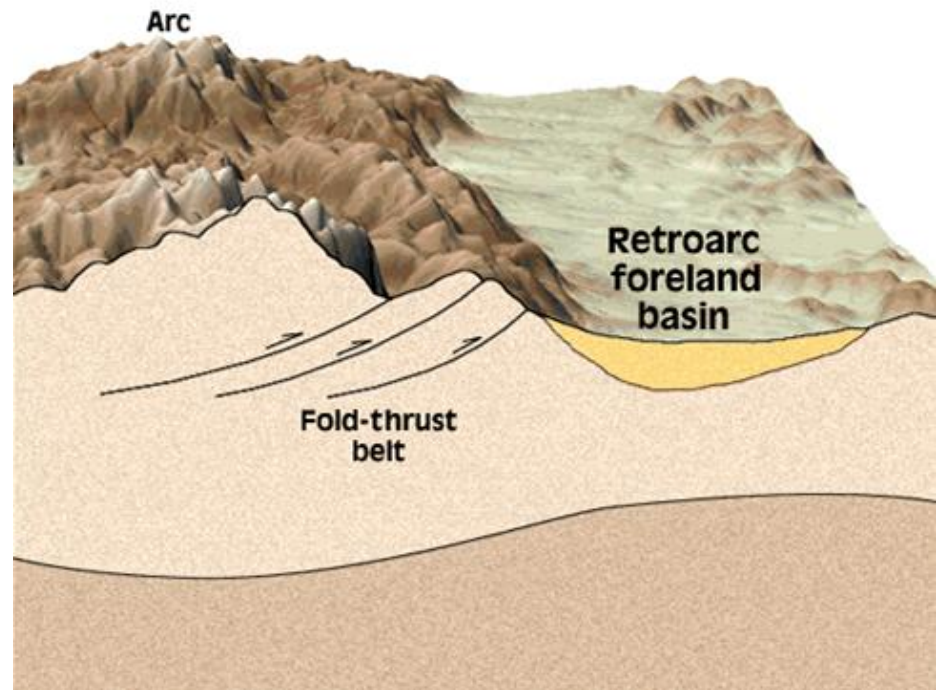


Sediments in back arc basins are varied depending on basin size and nearness to an arc. As shown here, proximal to arcs, volcaniclastic sediments dominate (note the pillow fragment in the center), whereas in more distal regions, pelagic, hemipelagic, and biogenic sediments are more widespread.

Remnant arcs are submarine ridges that are extinct portions of arcs that have been rifted away by the opening of a back-arc basin.



## ARCO REMANESCENTE



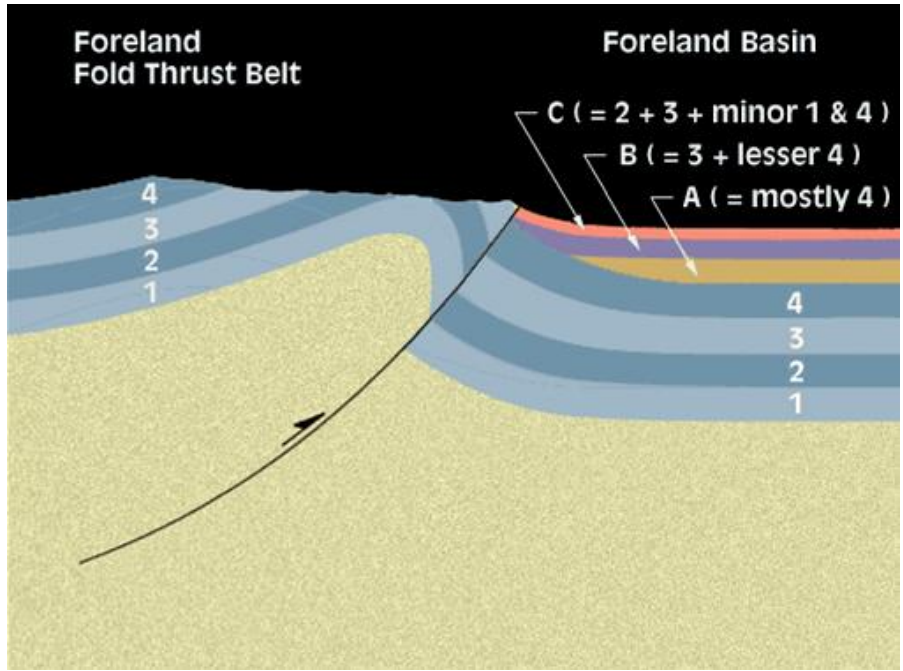
## Bacia pós-arco Continental Foreland Basin

Retroarc foreland basins form behind continental-margin arc systems and they are filled largely with clastic terrigenous sediments derived from a fold-thrust-belt behind the arc.

Sediments shed from a rising fold-thrust belt are eroded and redeposited in foreland basins. As shown here for Miocene sediments in the northern Alps, proximal regions of foreland basins are characterized by coarse, arkosic, alluvial-fan sediments.



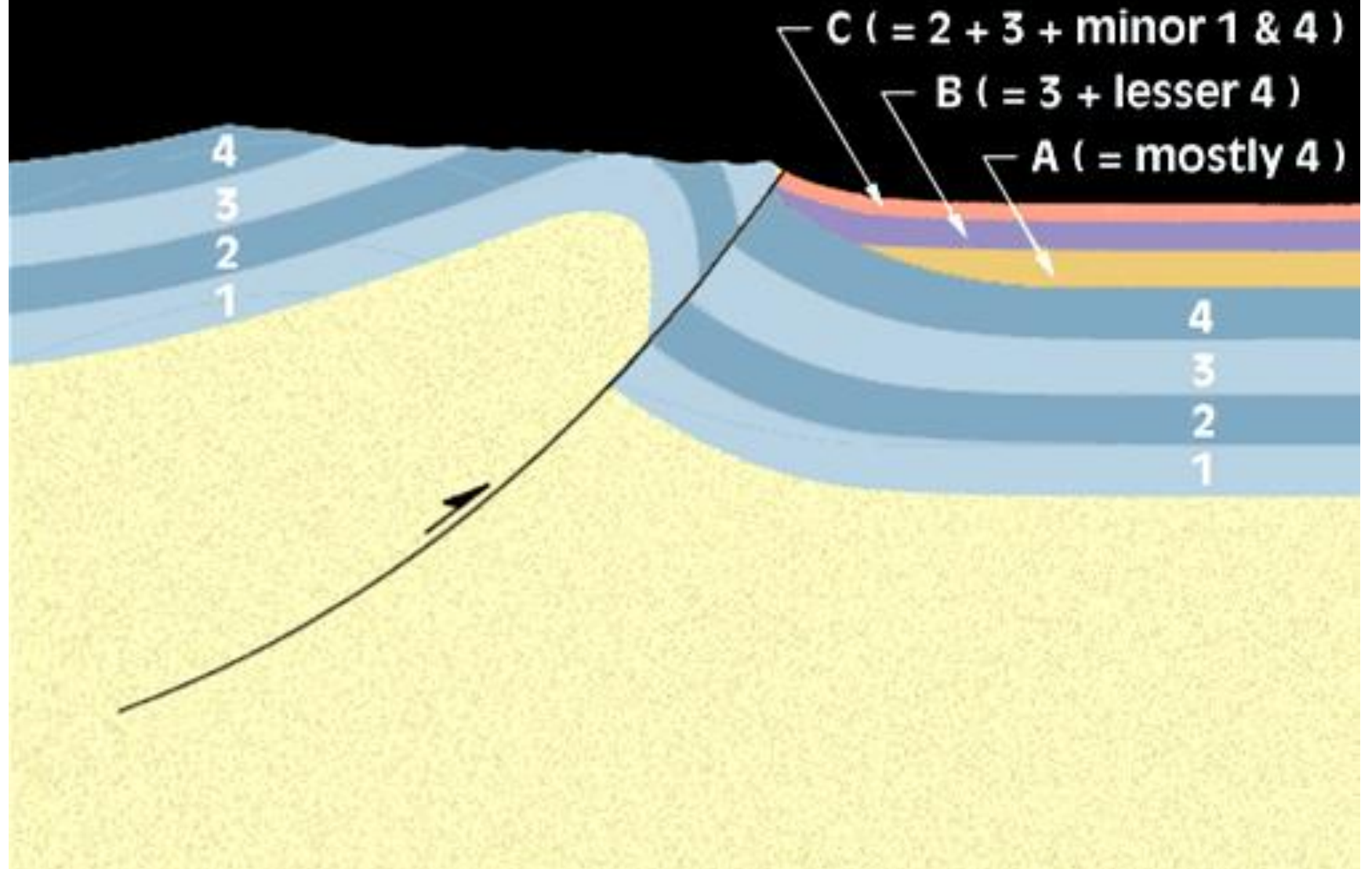
**Sedimentação e estruturas cavalgantes**



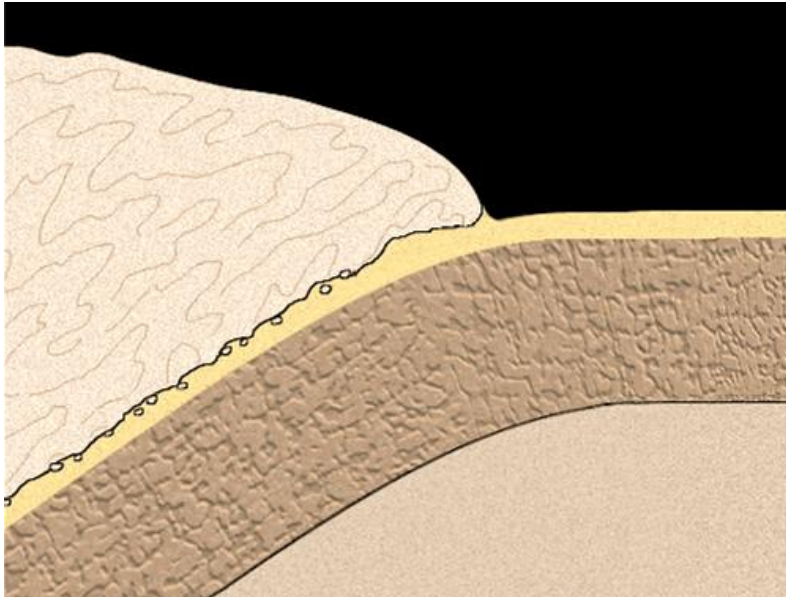
Progressive unroofing in the fold and thrust belt produces an "inverse" stratigraphic sampling of the source in foreland basin sediments.

# Foreland Fold Thrust Belt

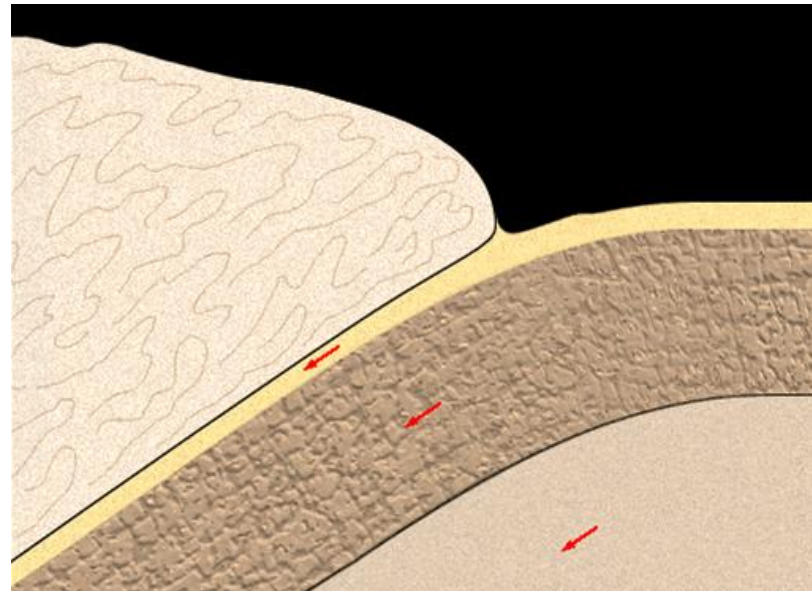
# Foreland Basin



Subduction erosion is mechanical plucking and abrasion along the top of a descending slab, which causes a trench's landward slope to retreat shoreward.



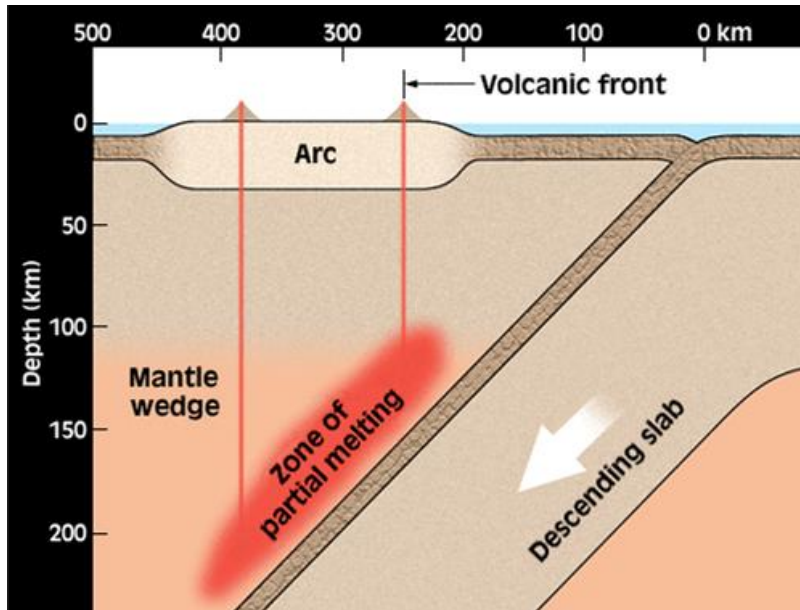
## Subdução erosiva



## Subdução de sedimentos

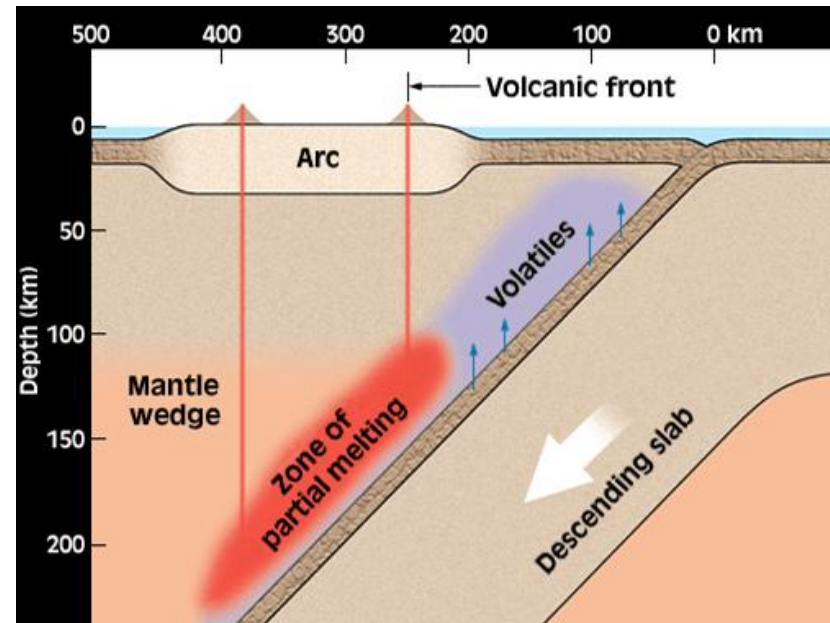
In modern arcs, the combined average rates of subduction erosion ( $0.9 \text{ km}^3/\text{y}$ ) and sediment subduction ( $0.7 \text{ km}^3/\text{y}$ ) suggest that on average,  $1.6 \text{ km}^3$  of sediment are subducted each year.

The onset of arc volcanism at a volcanic front reflects the onset of melting in the mantle wedge above a descending slab.

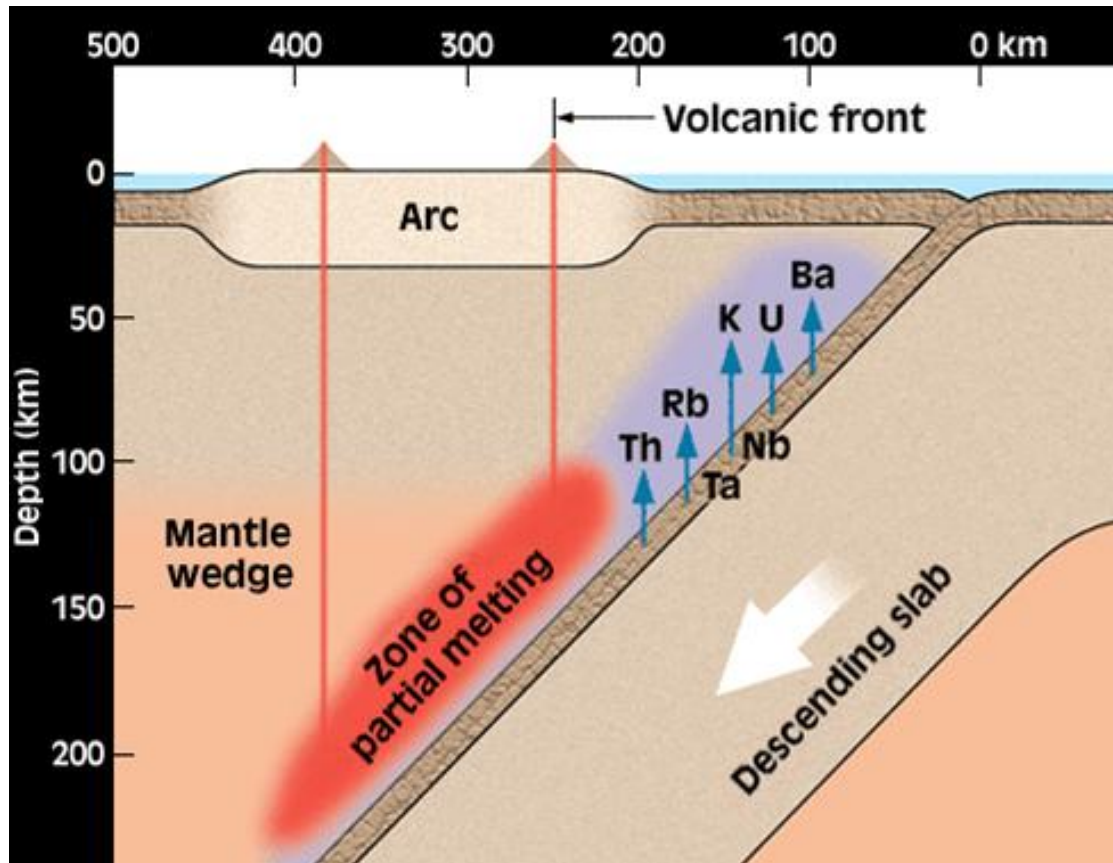


Fusão parcial húmida  
da crosta oceânica

Localização dependente da cunha  
mantélica



Both experimental and geochemical data show that most arc basalts are produced by partial melting of the mantle wedge in response to the introduction of volatiles (principally water) from the breakdown of hydrous minerals in descending slabs.

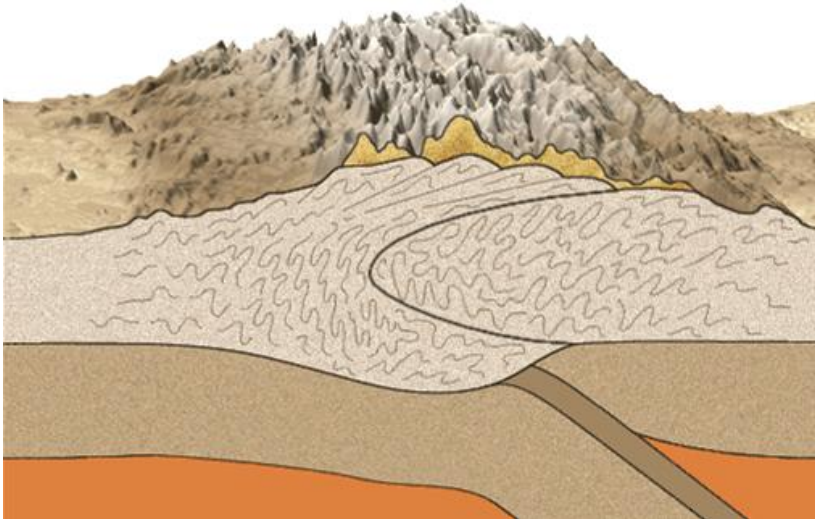


A subduction geochemical component may be produced by extraction of soluble LIL elements from descending oceanic crust by escaping water, leaving Nb and Ta behind.

# ORÓGENOS

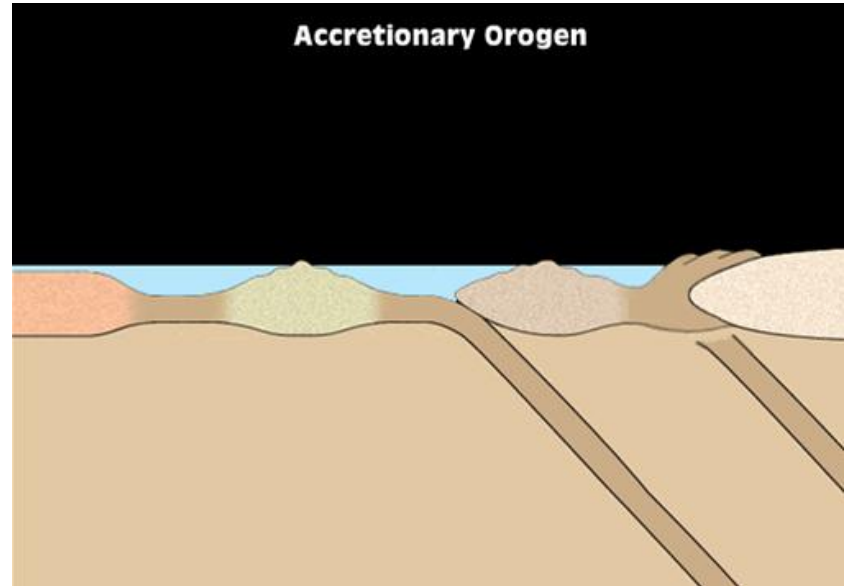
Collisional orogens are produced by the collision of two continents, during which time the crust is greatly thickened and extensively reworked. Very little juvenile crust is produced or tectonically "captured" during collisional orogeny.

Collisional Orogen



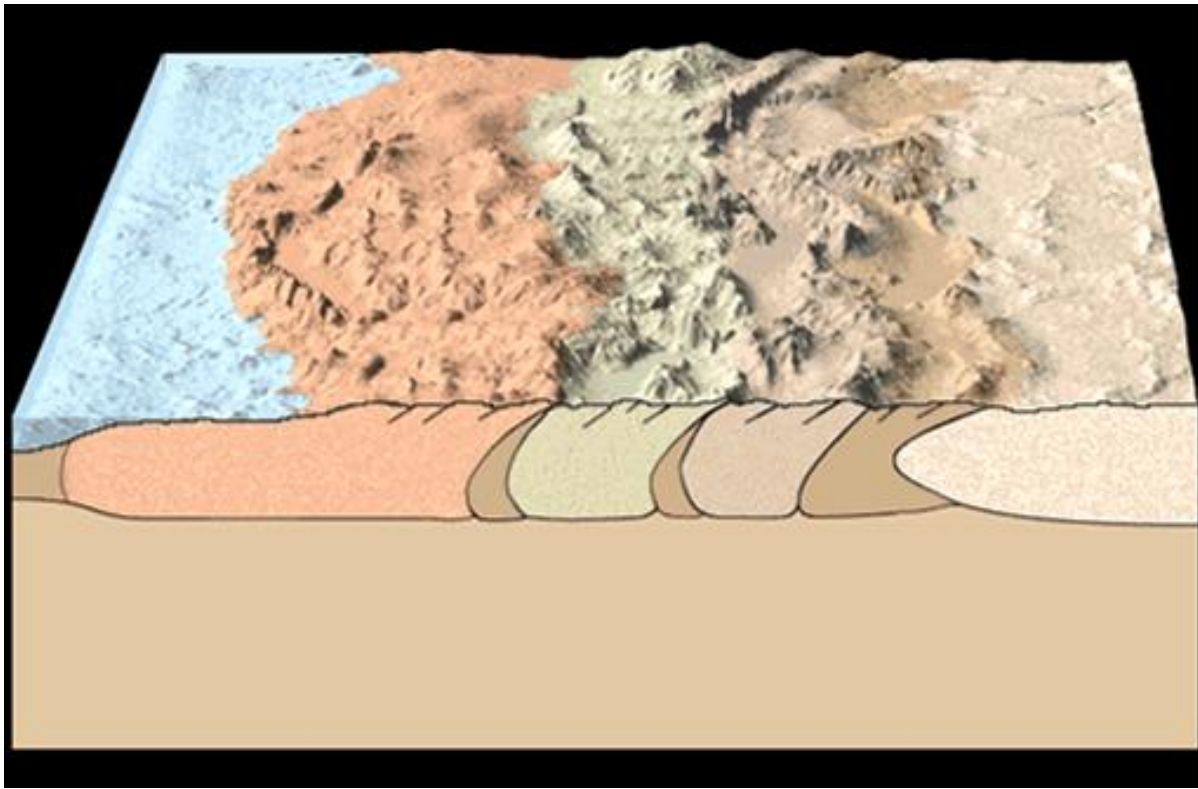
COLISIONAIS

Accretionary Orogen



DE ACREÇÃO

In contrast, accretionary orogens involve collision and suturing of largely juvenile crustal blocks (ophiolites, island arcs, oceanic plateaus, etc.) to continental crust. Accretionary orogens contain very little reworked older crust.



Accretion of oceanic terranes is one of the major mechanisms by which continents grow.



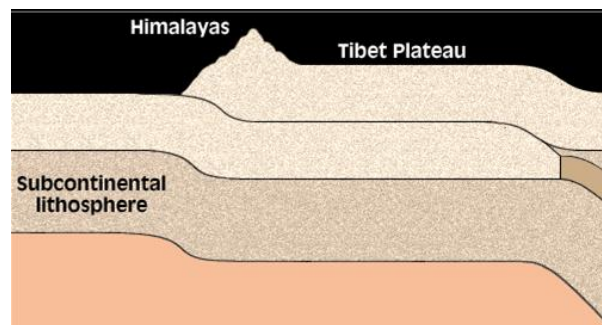
1 At deeper exposure levels (10-20 km) in collisional orogens, granitoids are common as shown here for an S-type granite formed during the India/Tibet collision some 30 Ma.

2 Geochemical data indicate that collisional granites are produced by partial melting of the middle to lower crust during a continental collision. Shown here are migmatites from a Precambrian collisional orogen (the Limpopo belt) in southern Zimbabwe showing numerous felsic veins resulting from partial melting of surrounding rocks.

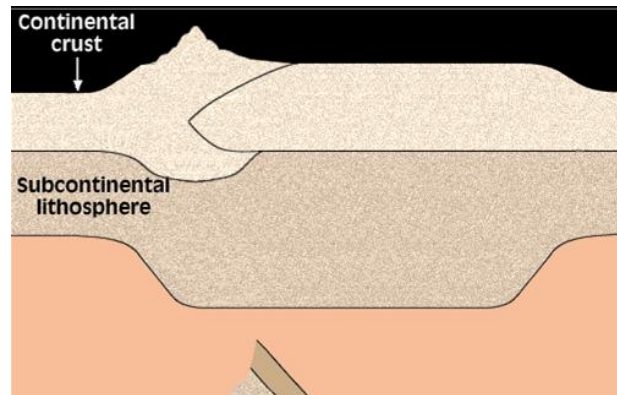
3 During a collision, thickening of continental crust leads to the production of high pressure granulites at depths > 20 km as fluids escape upwards. The brown patches of granulite in this quarry (beneath the hammer) in southern India were produced by the introduction of CO<sub>2</sub> from deeper levels.



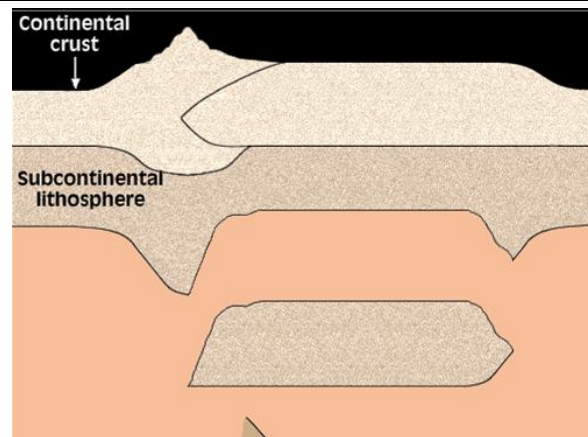
During some continental collisions, large plateaus such as Tibet may form. Three origins for these plateaus have been suggested.



1) Underthrusting of continental crust and lithosphere, which buoyantly elevates the plateau.



2) Compressive shortening and thickening of both the crust and the lithosphere, followed by isostatic rebound to form the plateau.



3) Delamination of the thickened lithosphere following collision.

Some of the Earth's highest mountains are formed during continental collisions. Shown here is Mt. Everest in the Himalayas, almost 9 km in elevation and still rising at the rate of a few mm/yr.



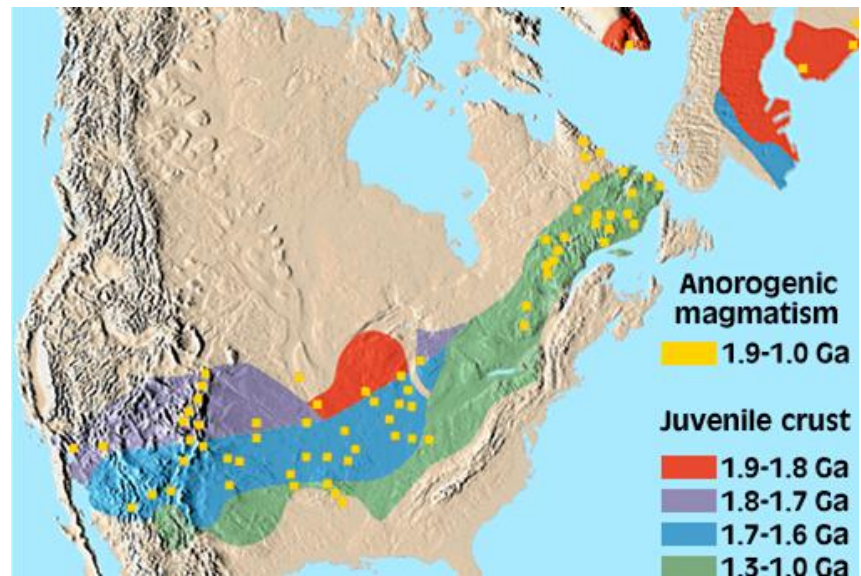
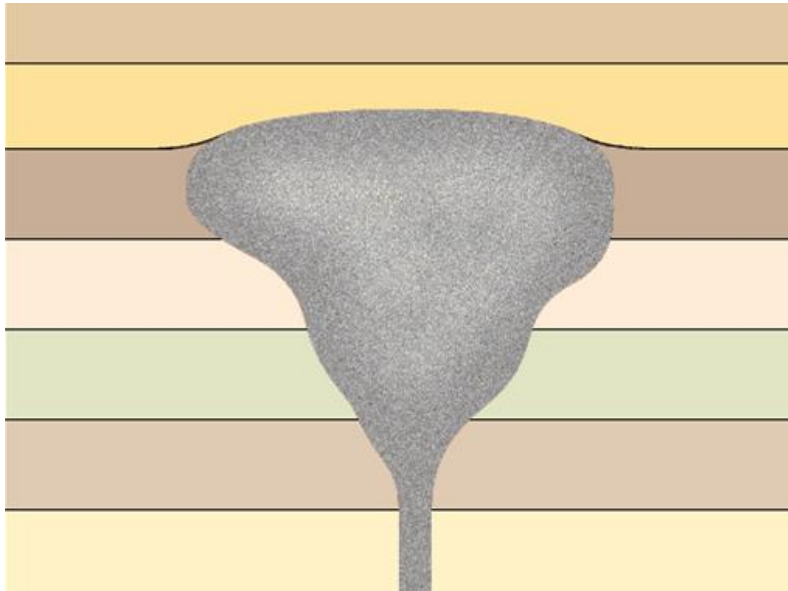
## Granitos orogénicos



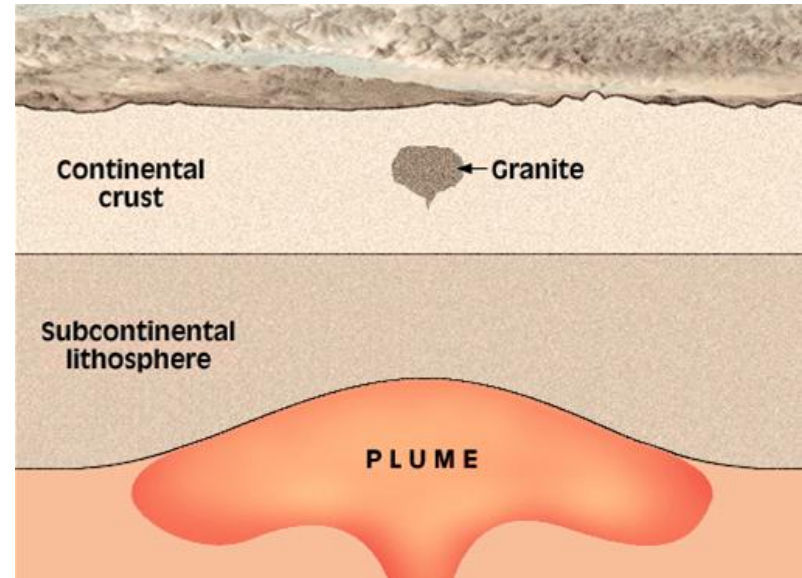
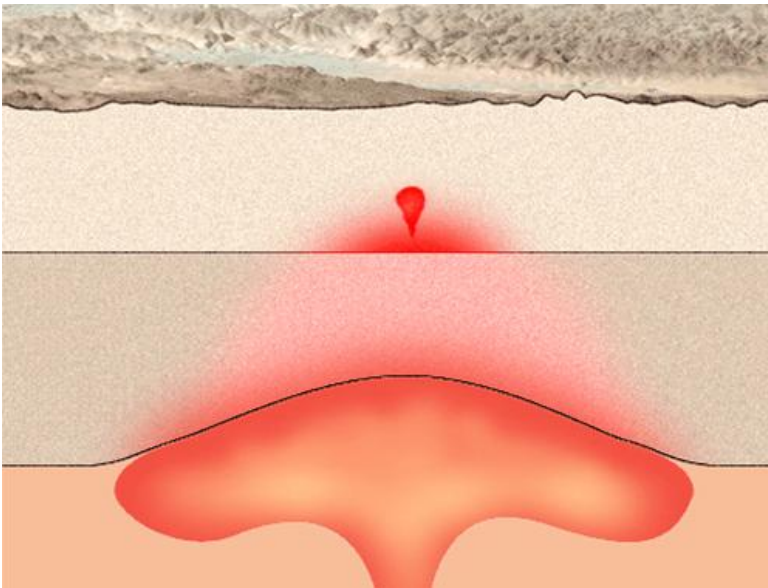
## Granitos anorogénicos

Anorogenic granites are massive relatively undeformed granites with discordant contacts, and appear to have been intruded between orogenic events. Shown here is the Sherman granite (1.4 Ga) from southern Wyoming.

Anorogenic granites occur chiefly in accretionary (juvenile) orogens, and often there is a close spatial and temporal relation between granite magmatism and crustal extension.



A wide belt of 1.9 - 1.0 Ga anorogenic granites and associated anorthosites extends from SW North America to Labrador, across southern Greenland and into the Baltic Shield in Scandinavia and Russia.

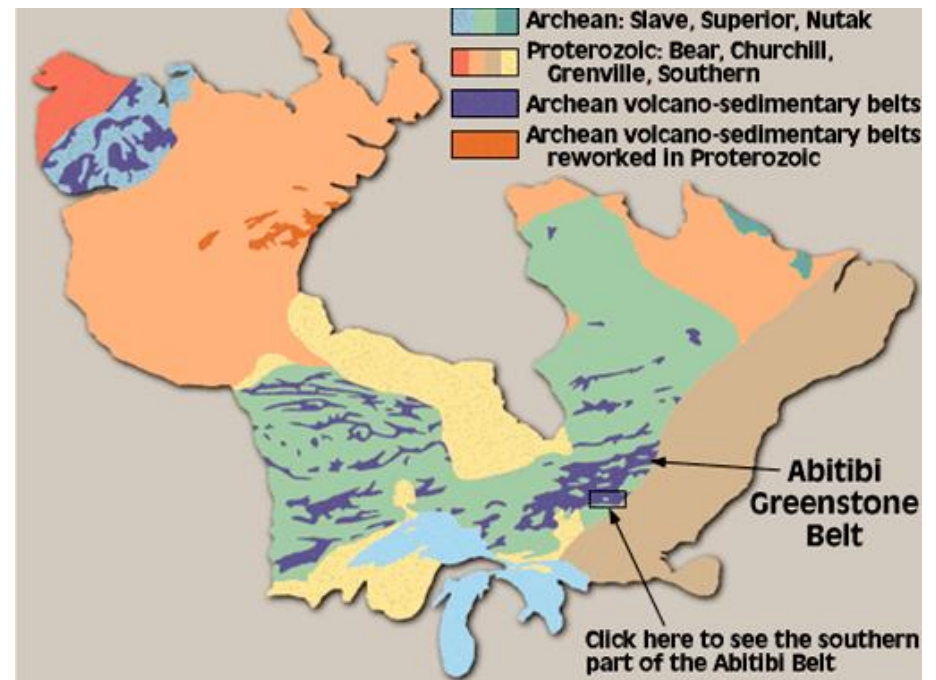
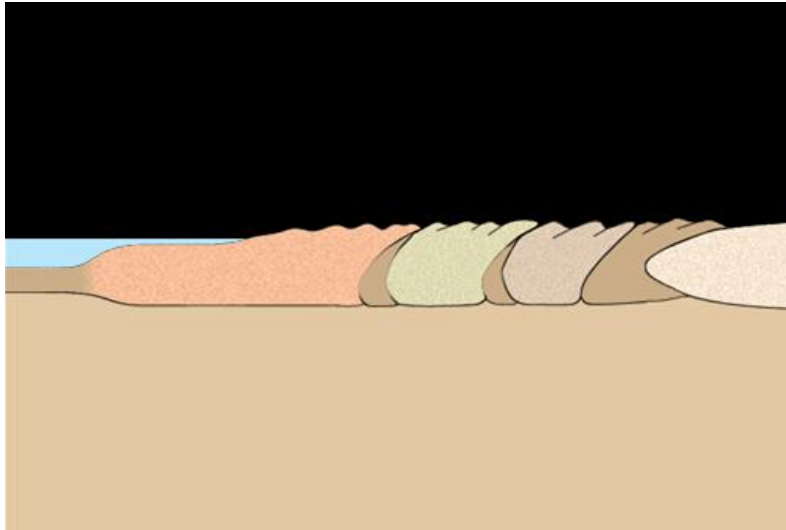


The tectonic setting of anorogenic granites continues to baffle geologists. Perhaps the extensive Proterozoic anorogenic granites formed by partial melting of the lower crust in response to a major mantle plume event?



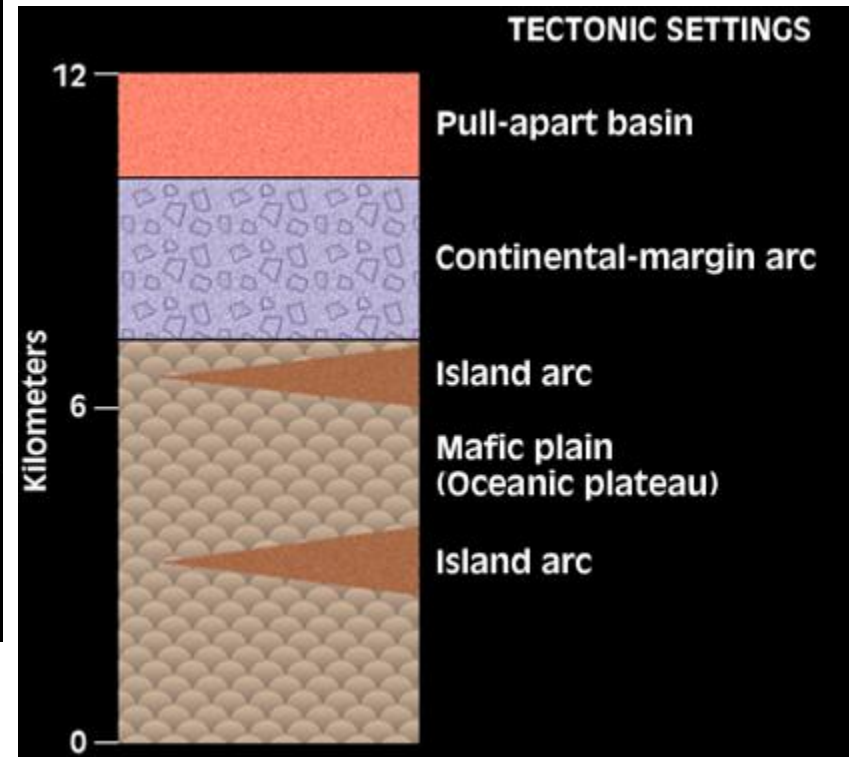
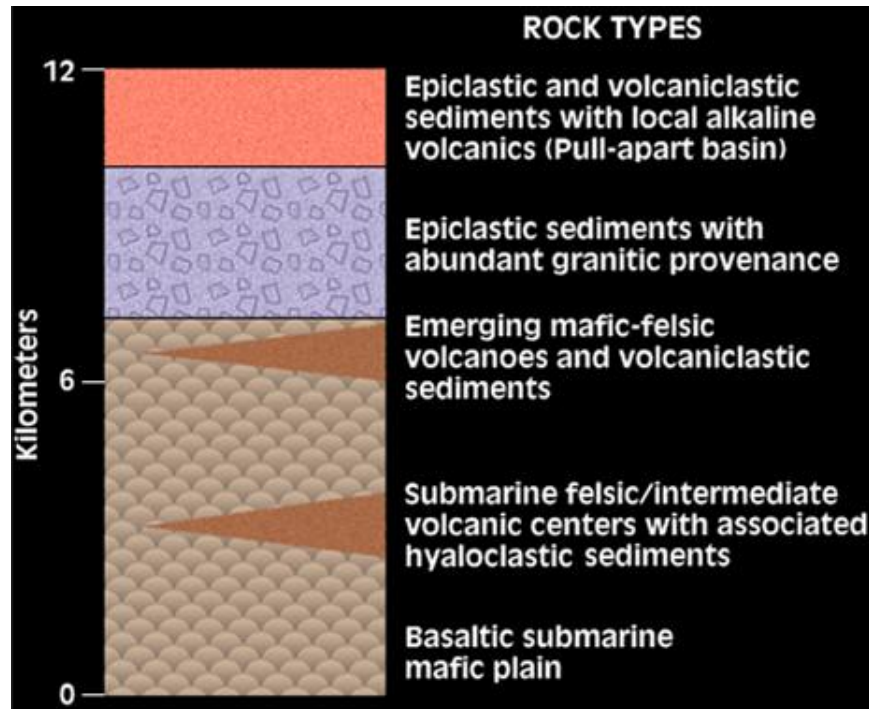
Greenstones are supracrustal rocks in which the combined submarine mafic volcanic and volcanoclastic sediment component exceeds 50%. Shown here are gigantic pillows in Archean greenstone basalts from the Yellowknife area in NW Canada.

From a modern perspective, greenstones appear to have formed in arcs, oceanic plateaus, volcanic islands, and oceanic crust.



Shown here is a map of the Canadian Shield showing the distribution of major Archean greenstone belts.

Two general trends observed with increasing stratigraphic height in Late Archean greenstone successions, are 1) a decrease in the amount of komatiite (ultramafic lava), and 2) an increase in the ratio of volcaniclastics to flows and in the relative abundance of andesitic and felsic volcanics.



These stratigraphic changes reflect an evolution from a mafic plain (oceanic plateau) to submarine stratovolcanoes (island arcs), which may become emergent with time (continental-margin arcs), ending with continental rifting (pull apart basins).



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Plate Tectonics and How the Earth Works**