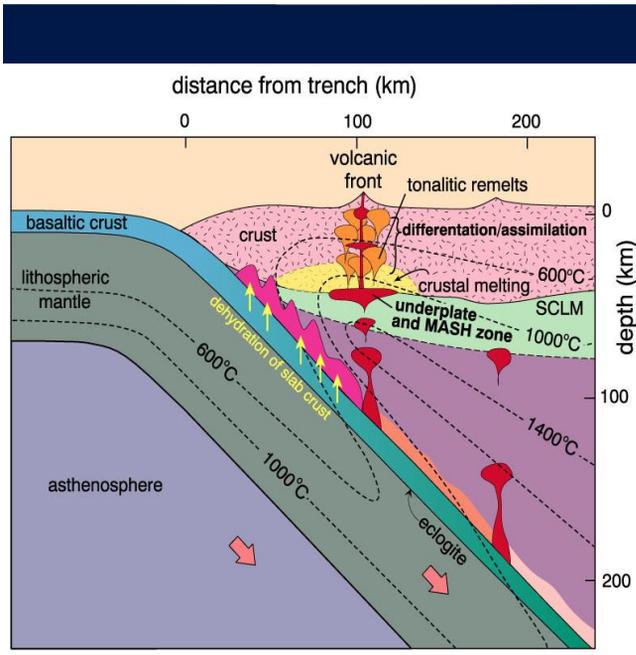


## FATORES QUE INFLUEM NA GERAÇÃO DE MAGMAS NOS **ARCOS**

- A **água** liberada por **reações metamórficas** na placa oceânica que mergulha sob continente cumpre duas funções: produzir a **fusão parcial do manto peridotítico** na cunha astenosférica e promover um **enriquecimento metassomático** do manto pelo aporte de elementos solúveis. A menor densidade dos **magmas basálticos e andesíticos** produzidos faz com que esses ascendam através do manto e se concentrem na base da crosta continental.
- A **cristalização em profundidades** de estes magmas produzem liberação da água dissolvida e do calor no entorno da intrusão, promovendo a **fusão parcial da crosta**.



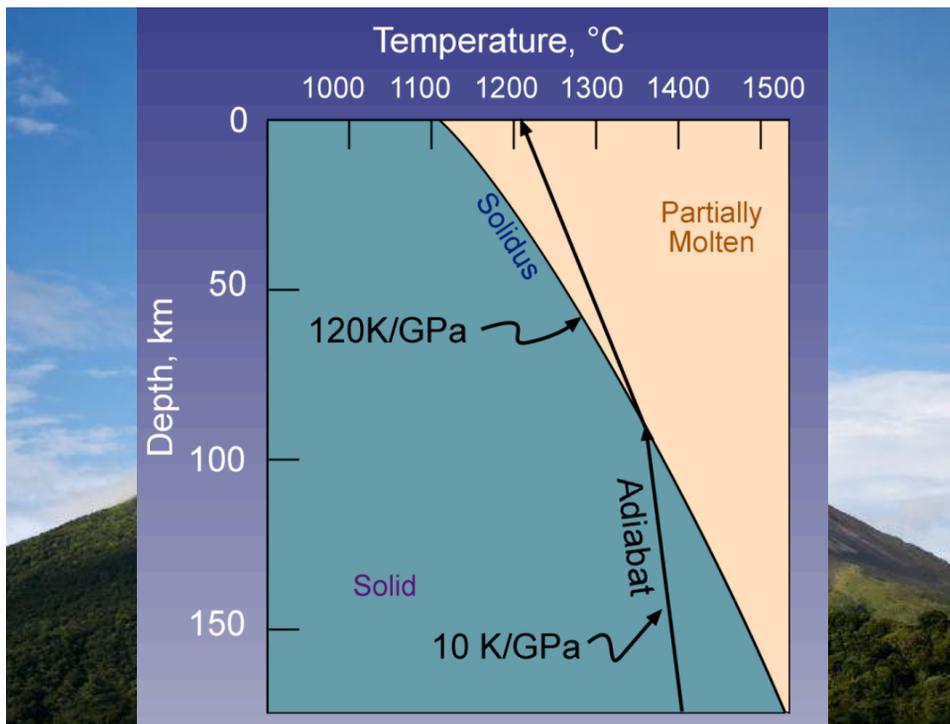
Secção esquemática de uma zona de subducção numa margem continental ativa onde se observa desidratação da placa oceânica que mergulha sob o continente, a hidratação e fundido da cunha de manto, zona de *underplate*, onde se desenvolvem os processos de MASH (*Melting, Assimilation, Storage, Homogenization*) e os fenômenos de diferenciação que se desenvolve na crosta.

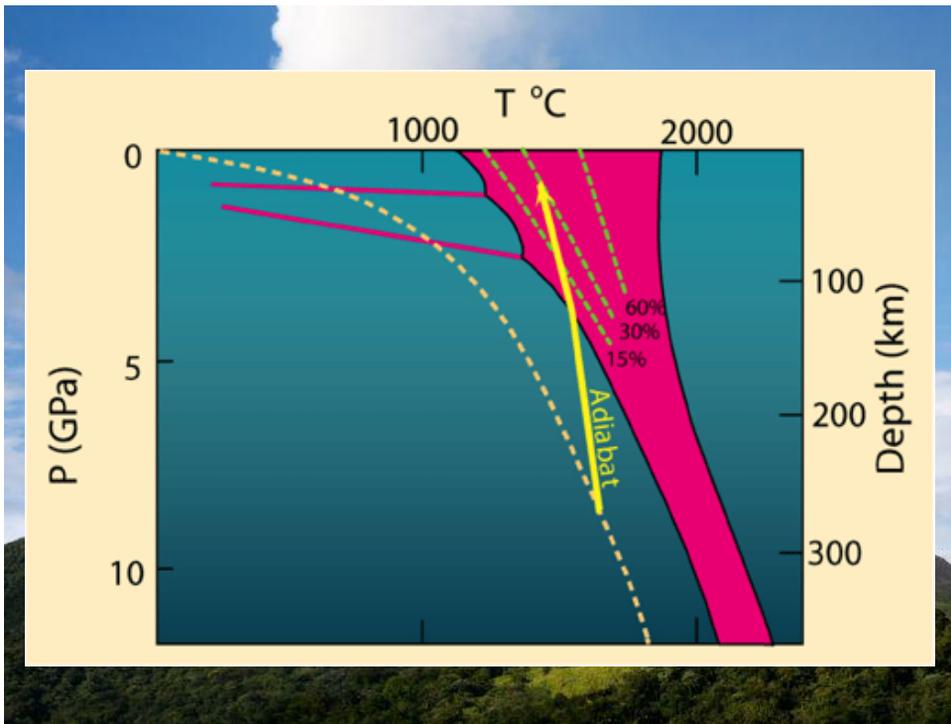
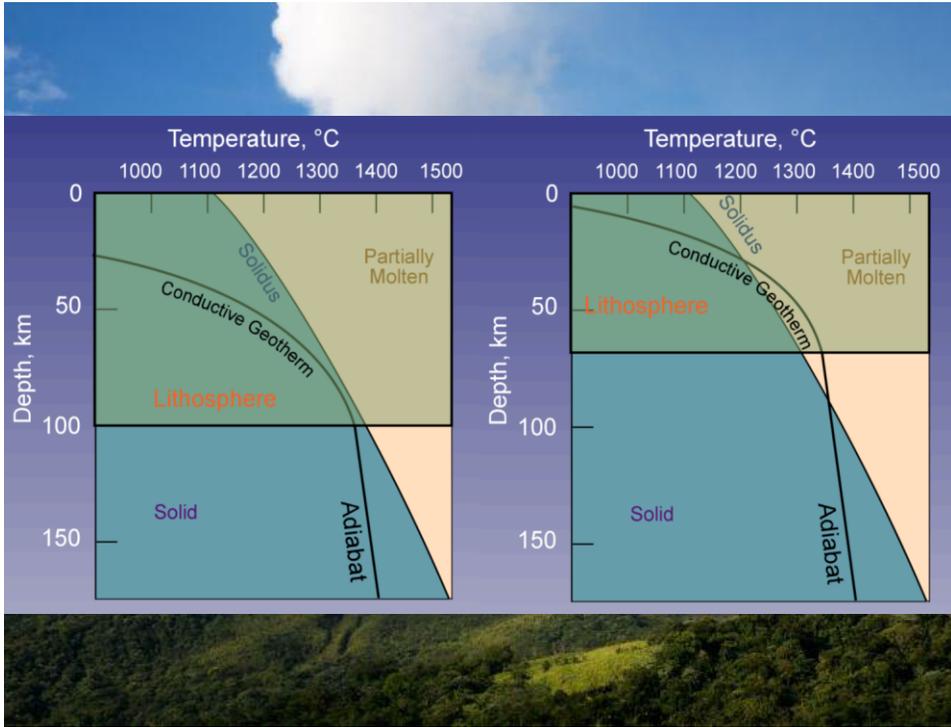
## GERAÇÃO DOS MAGMAS

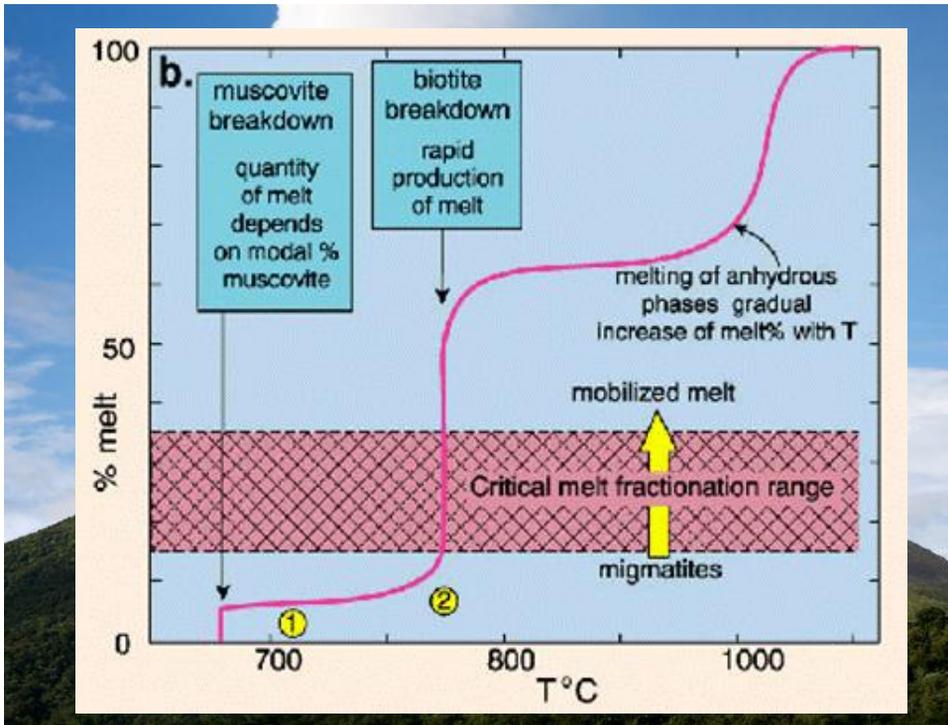
- A **quantidade de água** presente é essencial para a geração de grandes volumes de magmas félsicos.
- A **água** pode provir tanto da **desidratação dos minerais hidratados** como de fontes externas.
- Em **rochas com minerais hidratados**, o aumento de temperatura pode gerar a desidratação destes minerais e a liberação de água favorece um maior grau de fusão parcial do que em condições anidras à mesma temperatura.

## GERAÇÃO DE MAGMAS

- A água, de modo geral, é fornecida pelas reações metamórficas de desidratação dos sedimentos e rochas sedimentares, rochas vulcanoclástica, vulcânicas e intrusivas hidratadas (espilitos e queratófiros) da crosta oceânica no fundo oceânico.
- A água liberada e calor favorecem a **anatexia** nas rochas da base da crosta continental, independentemente de sua natureza.



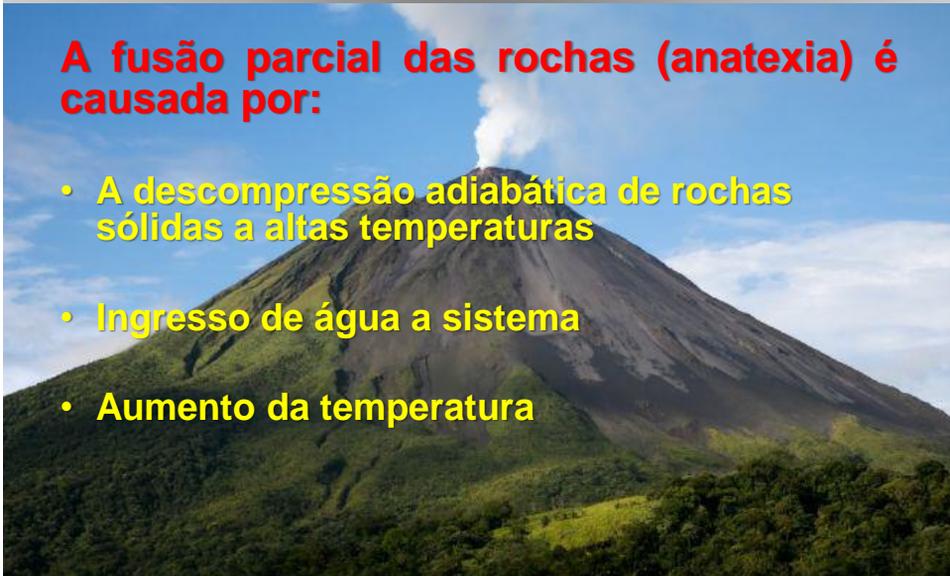




## GERAÇÃO DOS MAGMAS

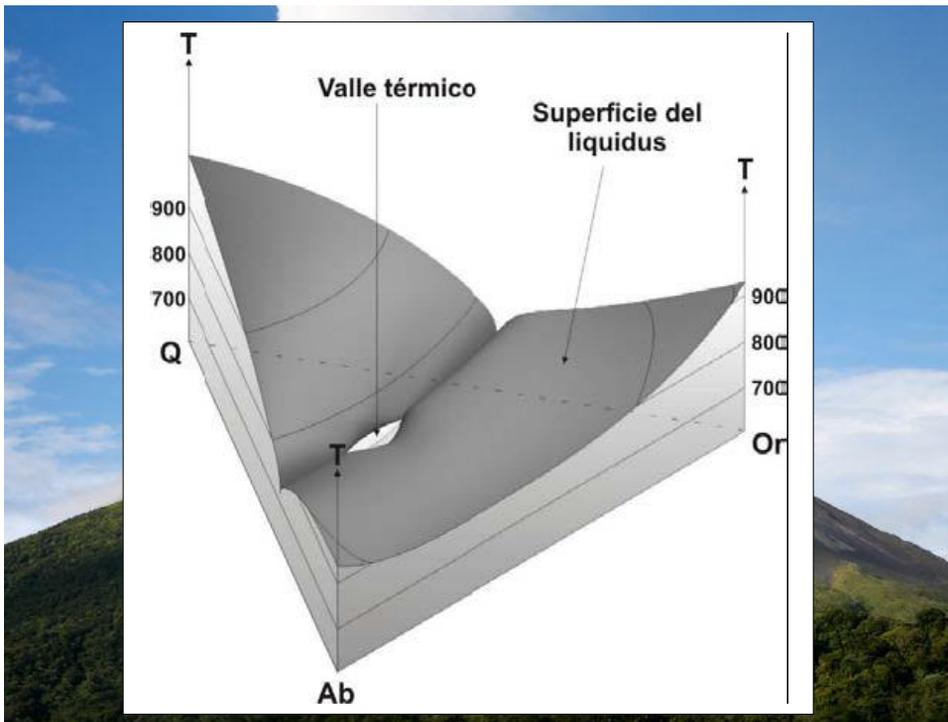
**A fusão parcial das rochas (anatexia) é causada por:**

- A descompressão adiabática de rochas sólidas a altas temperaturas
- Ingresso de água a sistema
- Aumento da temperatura



## FUSÃO MÍNIMA

- Todos os sistemas magmáticos se fracionam em maior ou menor intensidade para uma associação de quartzo + feldspato fundido → que magmas de composições graníticas constituam o principal produto do sistema residual petrogenético
- O sistema ternário demonstra, portanto, que os magmas graníticos poderiam ser gerados tanto a partir de processos de diferenciação de magmas como a partir do fundido parcial (anatexia) de rochas da crosta continental, quando se quebram os minerais de mínimo ponto de fusão.



# FUSÃO MÍNIMA GRANÍTICA

Position of the H<sub>2</sub>O-saturated ternary azeotropic in the albite-orthoclase-silica system at various pressures. The shaded portion represents the composition of most granites. Included are the compositions of the Tuolumne Intrusive Series (Figure 4-32), with the arrow showing the direction of the trend from early to late magma batches. Experimental data from Wyllie *et al.* (1976). From Winter (2001) *An Introduction to Igneous and Metamorphic Petrology*. Prentice Hall

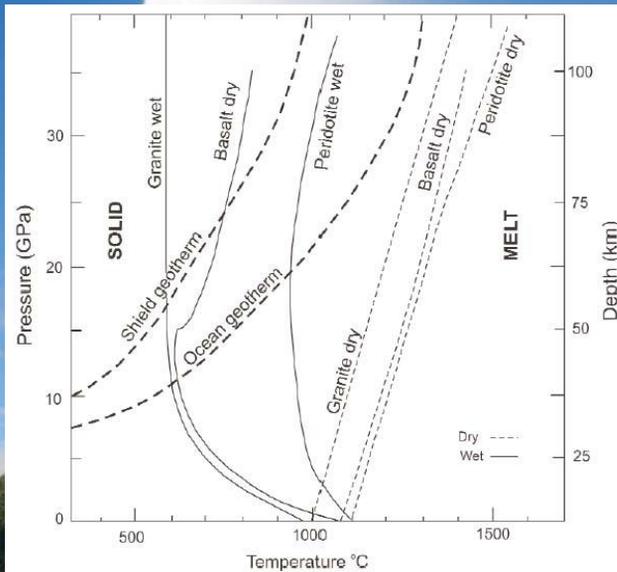
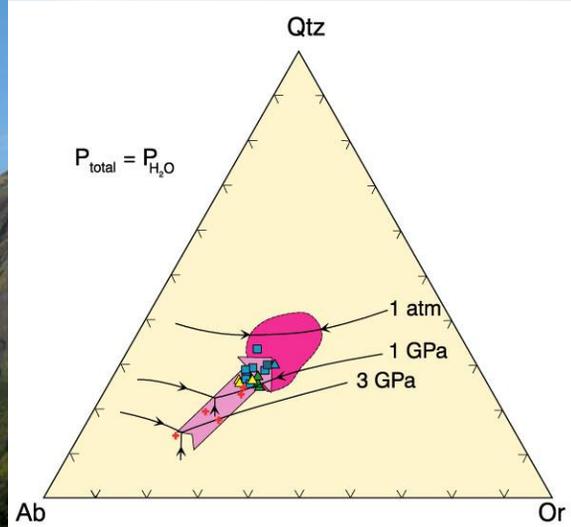


Figure 8. The effect of water on magma genesis. Phase diagram emphasizing the role of water in magma source rock (modified from Winter 2001) showing a comparison between the dry and water-saturated *solidi* for granite, basalt and peridotite, and typical shield and oceanic geotherms. The breakdown curves for hydrous phases in the mantle such as amphibole and phlogopite are shown.

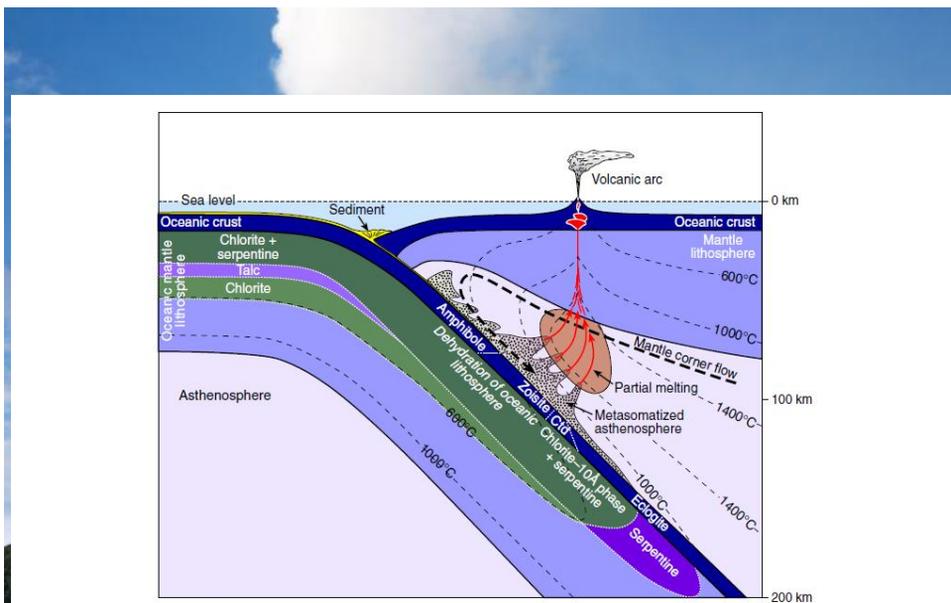
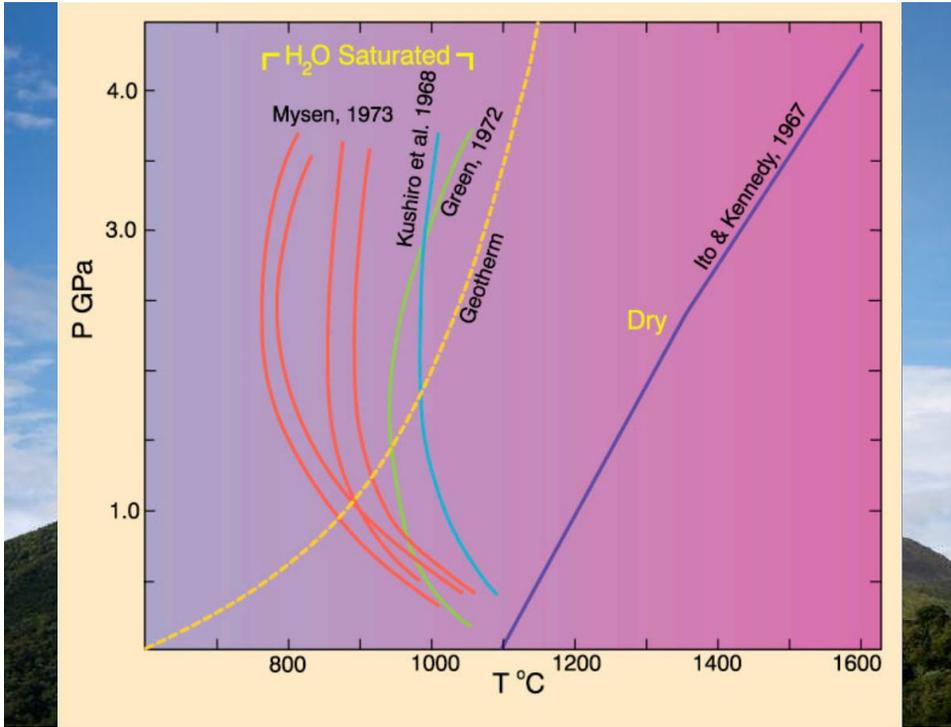


Fig. 1. Structure and processes beneath an oceanic island arc (sources: Tatsumi and Eggin, 1995; Schmidt and Poli, 1998; Winter, 2001; Poli and Schmidt, 2002; Fumagalli and Poli, 2005). Primary hydrous basaltic arc magmas are derived from partial melting of the metasomatized asthenospheric mantle wedge. Mineral zones shown in the subducting plate indicate lower limits of stability of hydrous phases in the basaltic oceanic crust and peridotitic mantle lithosphere. Abbreviation: Cld = chloritoid.

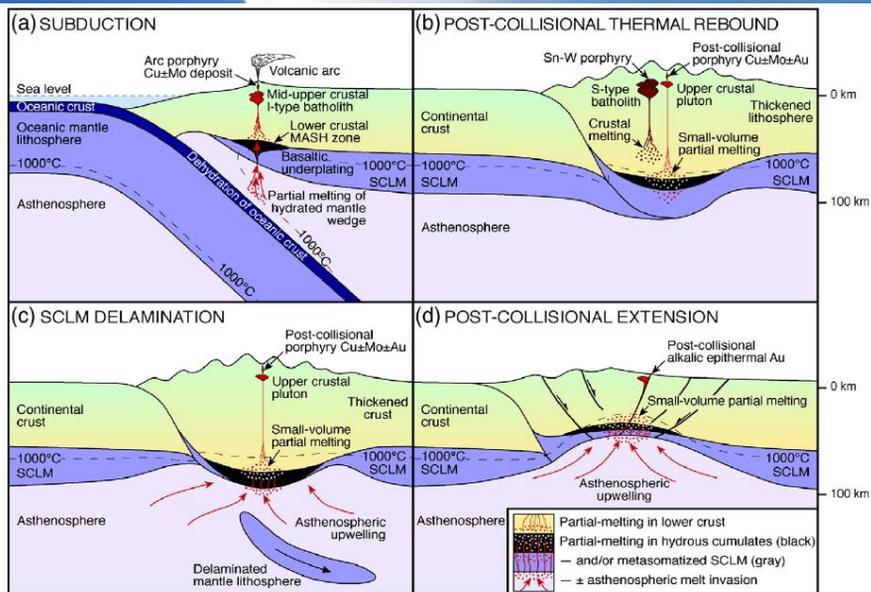
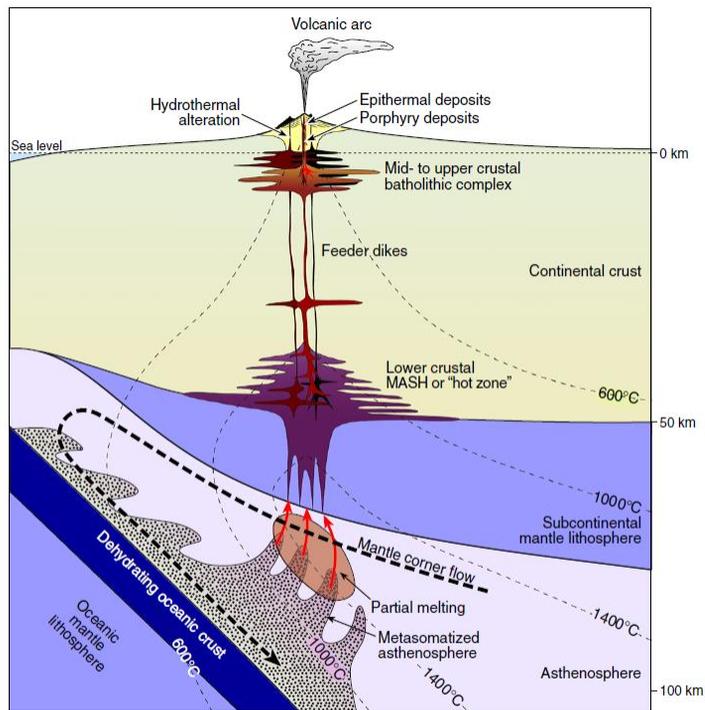
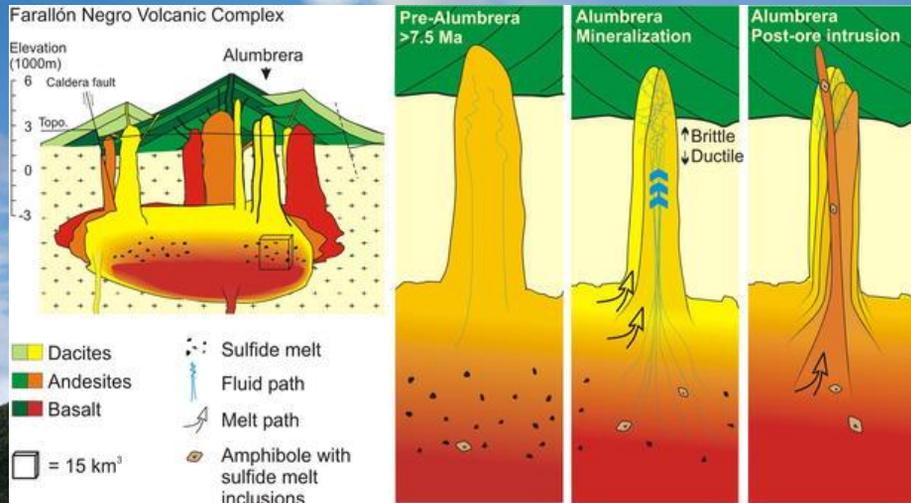


Fig. 4. Post-subduction tectonic environments conducive to the formation of porphyry and epithermal deposits by remobilization of previously subduction-modified lithosphere (modified from Richards, 2009). (a) Porphyry  $\text{Cu} \pm \text{Mo}$  deposits formed in normal arc settings; a continental arc is shown, but similar processes can occur in mature island arcs. (b-d) During post-subduction tectonic processes, previously subduction-modified sub-continental lithospheric mantle (SCLM) or lower crustal hydrous cumulate zones residual from previous arc magmatism (black layer) may undergo small-volume partial melting. Such magmas may remobilize  $\text{Au}$  as well as  $\text{Cu} \pm \text{Mo}$  left behind in residual sulfide phases by arc magmatism, leading to the potential formation of porphyry  $\text{Cu} \pm \text{Au} \pm \text{Mo}$  and alkalic-type epithermal  $\text{Au}$  deposits. Magmas may be characterized by high  $\text{Sr}/\text{Y}$  and  $\text{La}/\text{Yb}$  ratios due to the presence of hornblende ( $\pm$  garnet, titanite) in the amphibolitic lower crustal source rocks. See text for discussion.

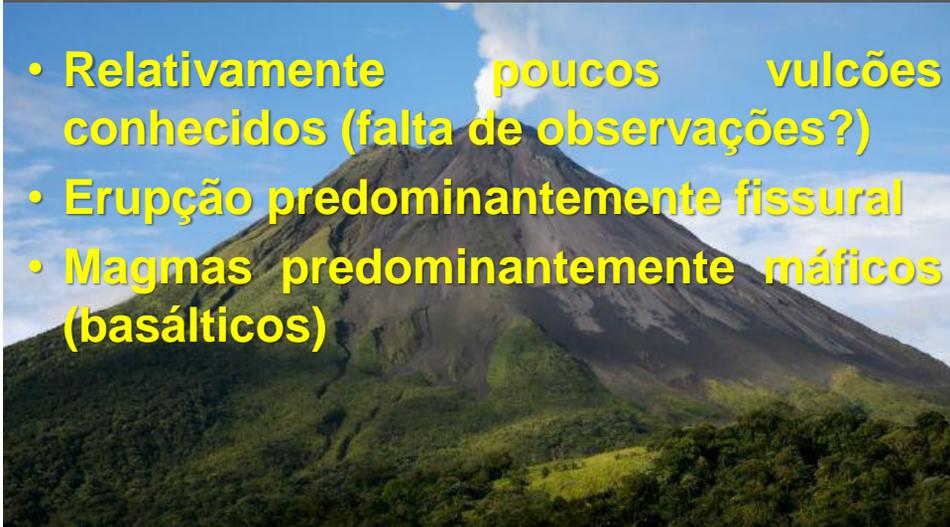
## Depósito tipo pórfiro de Bajo de la Alumbraera, Argentina



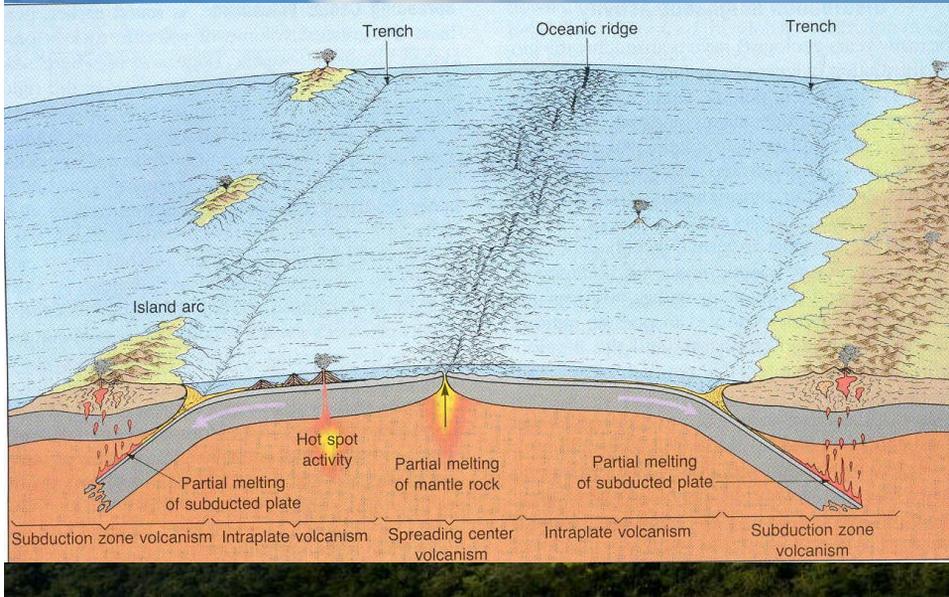
Halter et al. 2005. Magma evolution and the formation of porphyry Cu-Au ore fluids: evidence from silicate and sulfide melt inclusions. *Mineralium Deposita* 39: 845 - 863

## Vulcanismo nas Margens Divergentes

- Relativamente poucos vulcões conhecidos (falta de observações?)
- Erupção predominantemente fissural
- Magmas predominantemente máficos (basálticos)



## Limites Divergentes de Placas



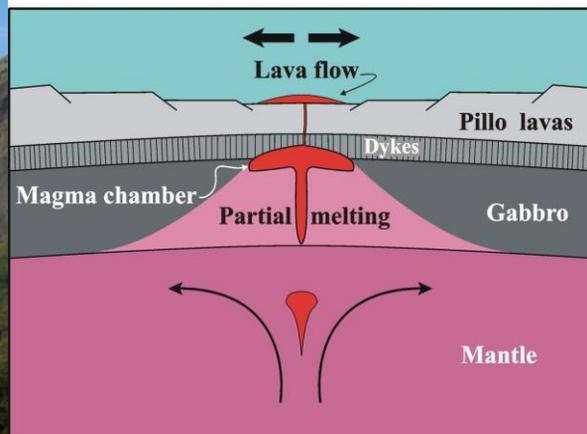
## VULCANISMO NAS DORSAIS OCEÂNICAS

### Vulcanismo subaquoso

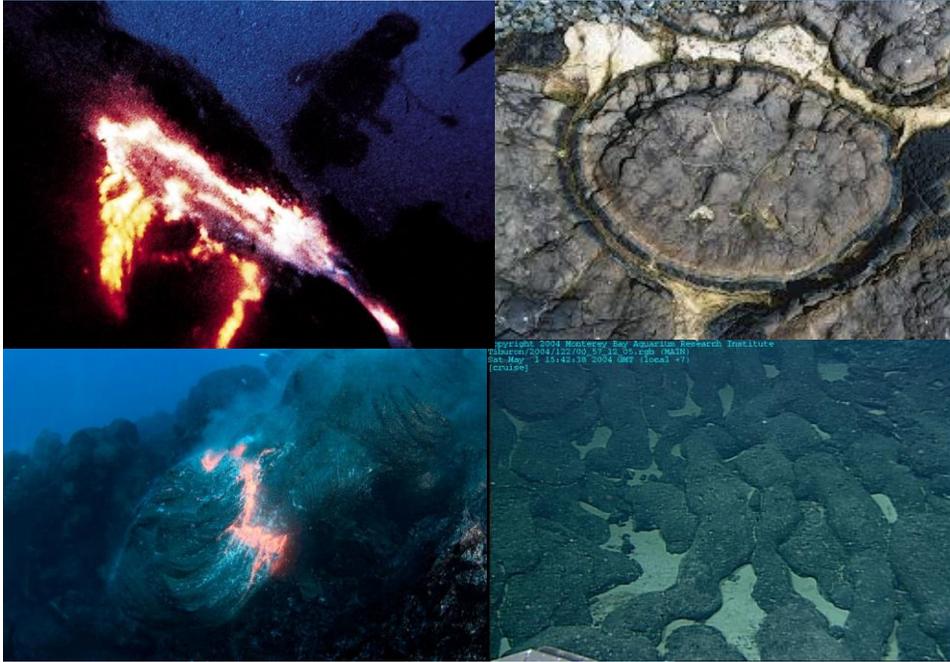
A intrusão de magmas máficos gera crosta oceânica

Derrames basálticos de *pillow* lavas e fragmentais (autoclásticos) predominam nos vulcões submarinos

Volcanoes along the oceanic ridge



## Erupção de lava basáltica



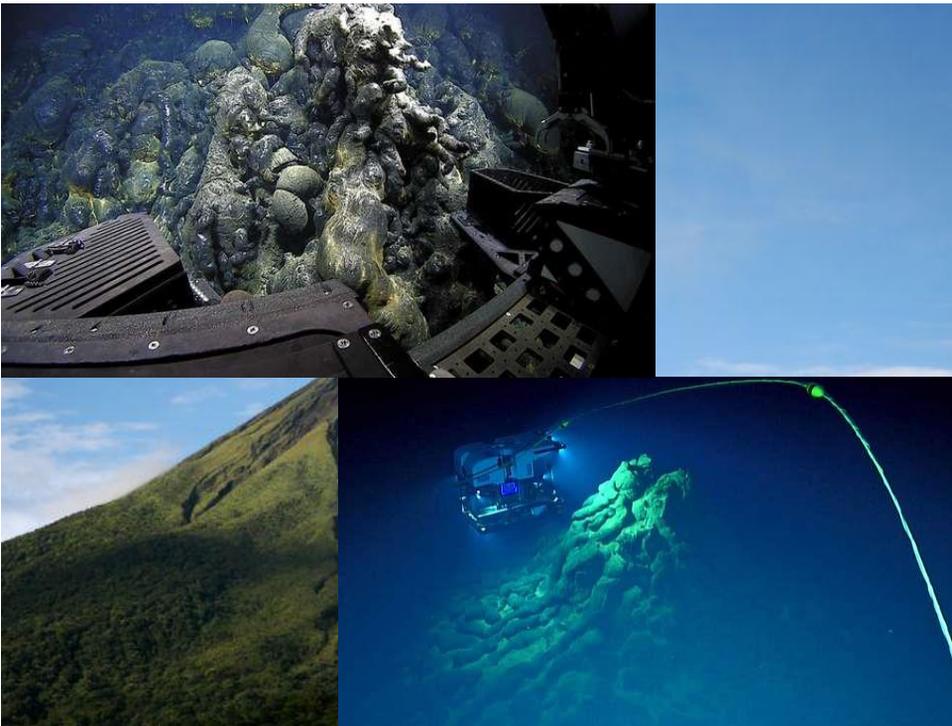
## Pillow Lavas

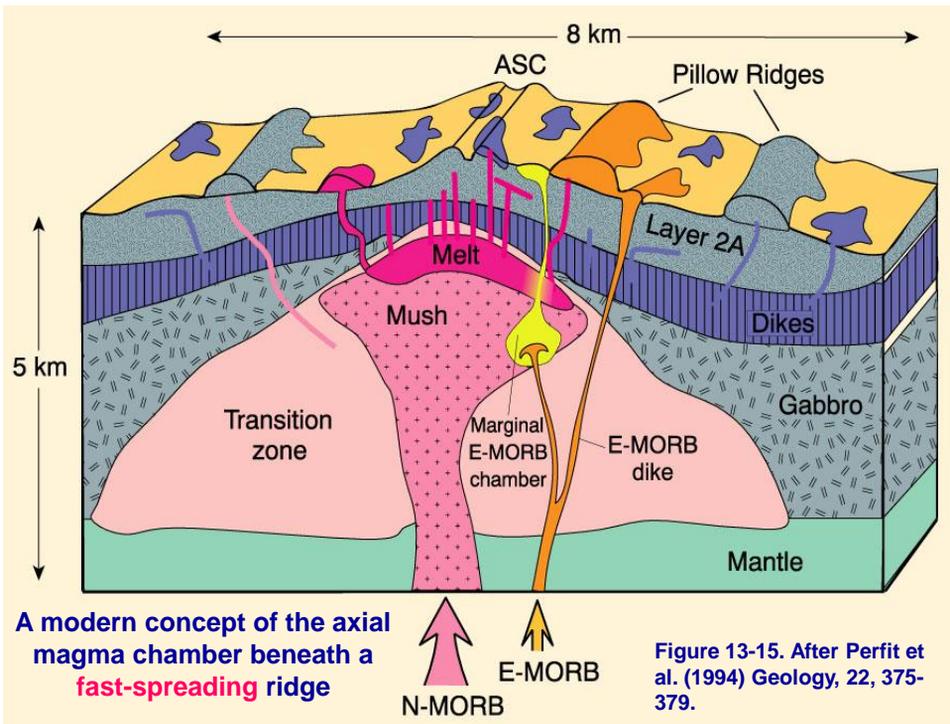


[http://volcanoes.usgs.gov/Products/Pglossary/ancientse  
q.html](http://volcanoes.usgs.gov/Products/Pglossary/ancientse<br/>q.html)



# *Pillow Lavas Basálticas*

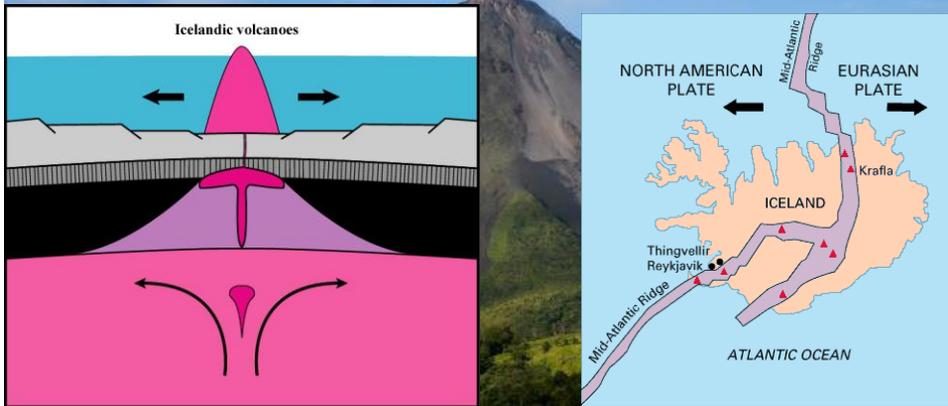




A modern concept of the axial magma chamber beneath a fast-spreading ridge

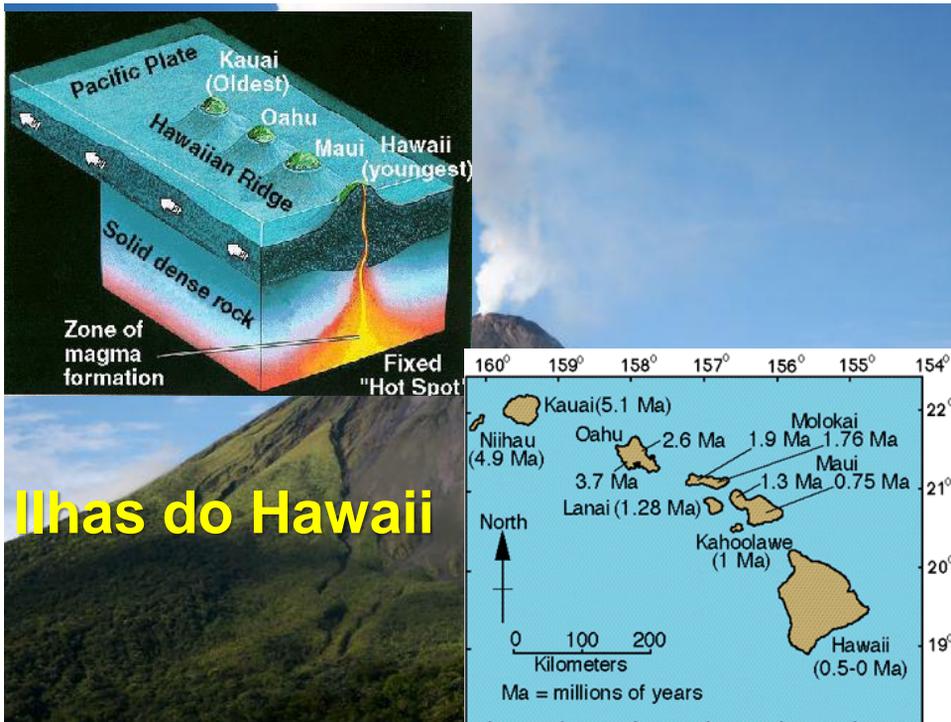
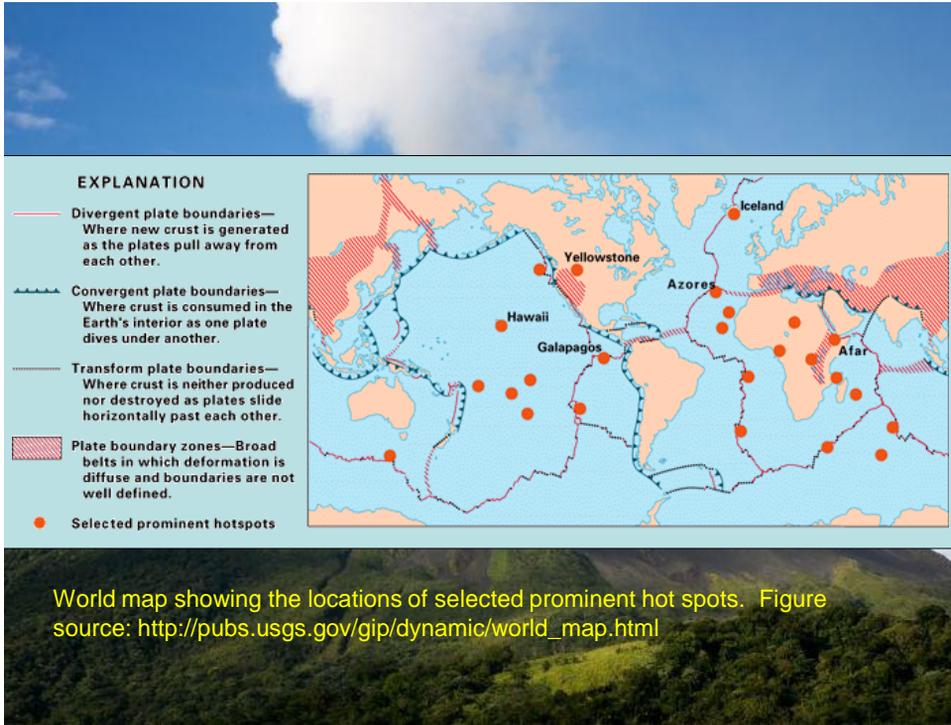
Figure 13-15. After Perfit et al. (1994) *Geology*, 22, 375-379.

Se associam predominantemente ao vulcanismo fissural nas dorsais mesoceânicas

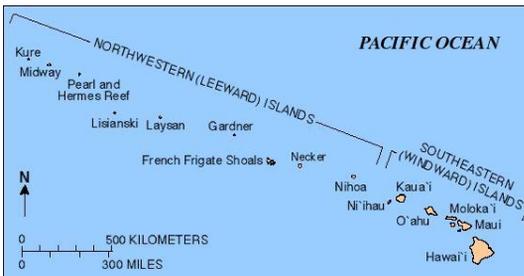
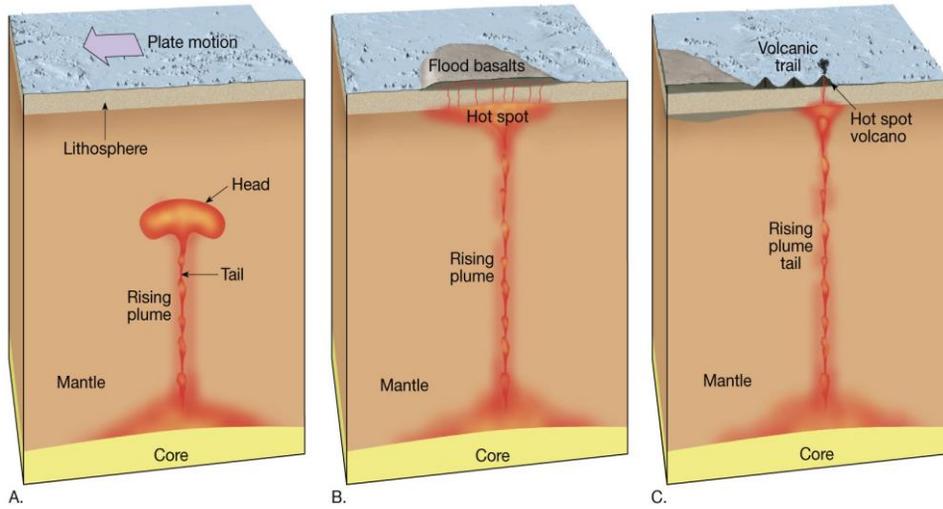


## Plumas Mantélicas (*Hot Spots*)

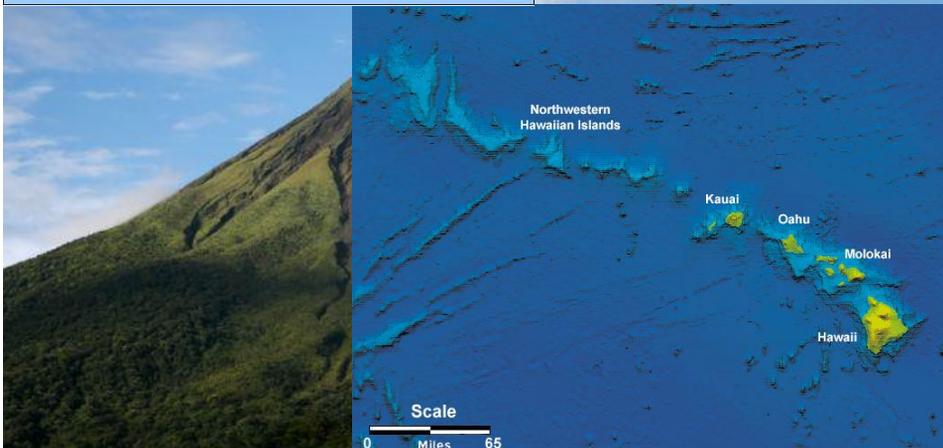
- Magmas ascendem de regiões muito profundas na Terra
- Magmas máficos → predominantemente basaltos
- Geralmente resulta em vulcões do tipo escudo, com erupções calmas, que forma ilhas oceânicas pela sobreposição de inúmeros derrames

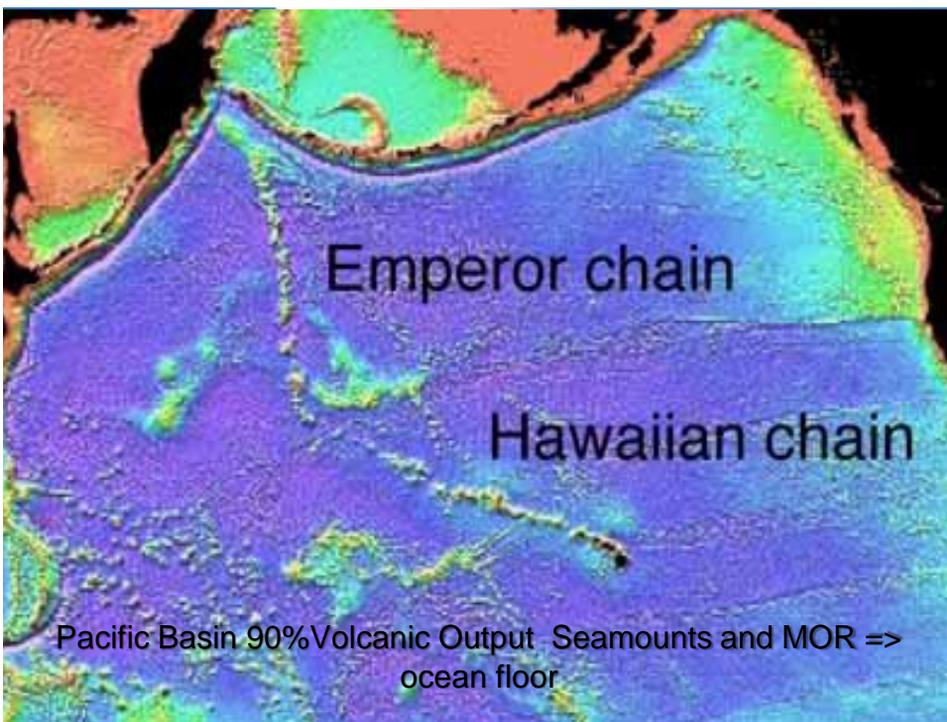
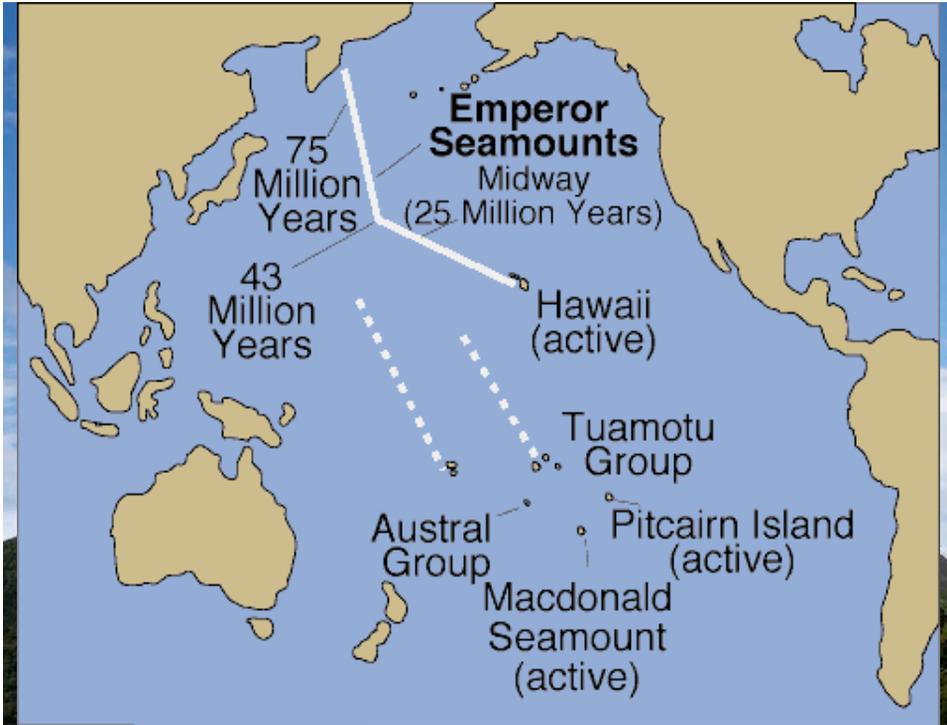


## O vulcanismo se forma em um ponto fixo, com a placa tectônica se movendo sobre o ponto quente

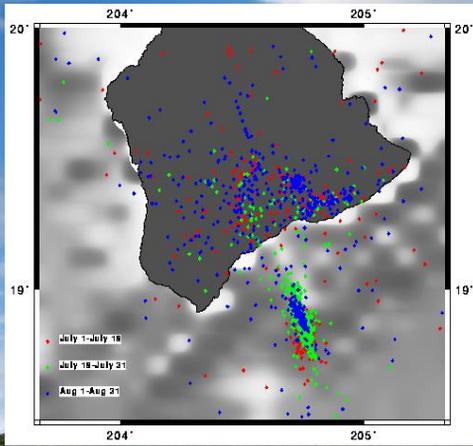


As ilhas do Hawaii são compostas por vulcões inativos e ativos

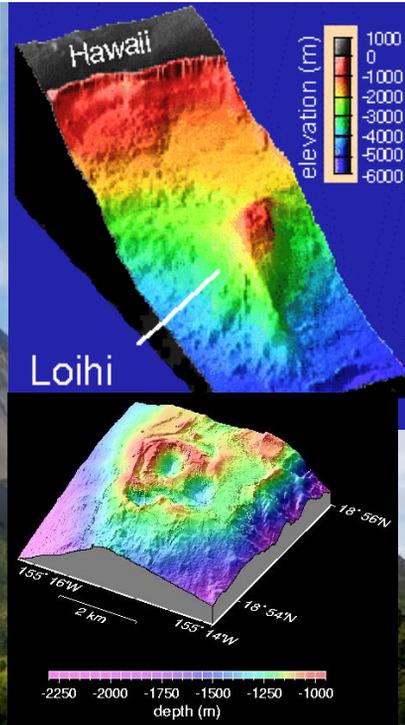


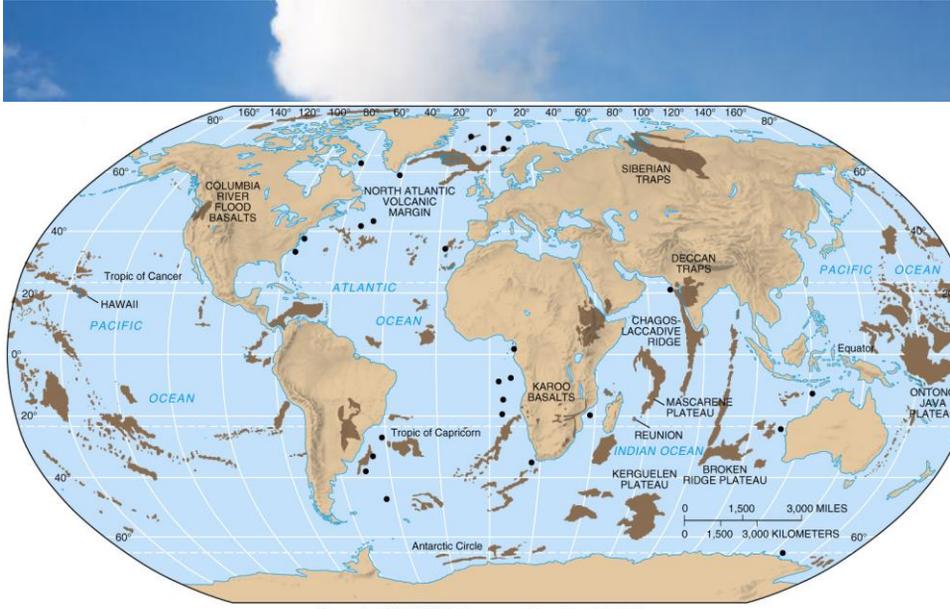


Até 1996 Loihi era considerado um  
*seamount* inativo

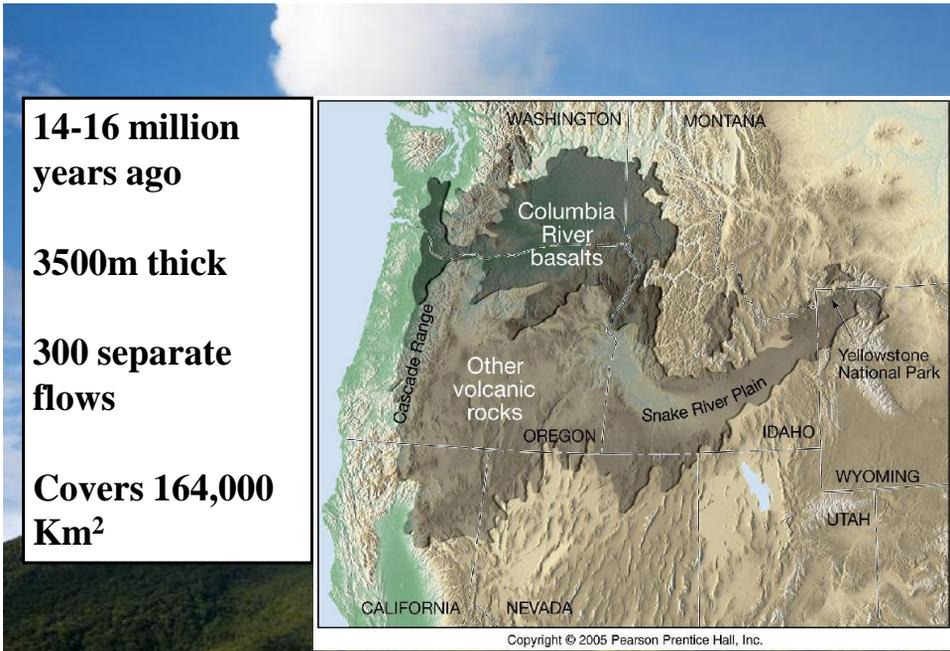


As erupções começaram em 1996,  
precedidas por um agrupamento de  
pequenos terremotos, resultado do  
movimento ascendente do magma.





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About 55 million years ago, while the North Atlantic opened up, enormous outpourings of basalt lava covered western Scotland, Northern Ireland, and eastern Greenland. Creaga Ghail, Mull.



Thick stacks of lava flows built up in a few million years. Most flood basalts erupt from long fissure systems, not from a central vent. Bearraich. Mull



Floddigarry, Isle of Skye



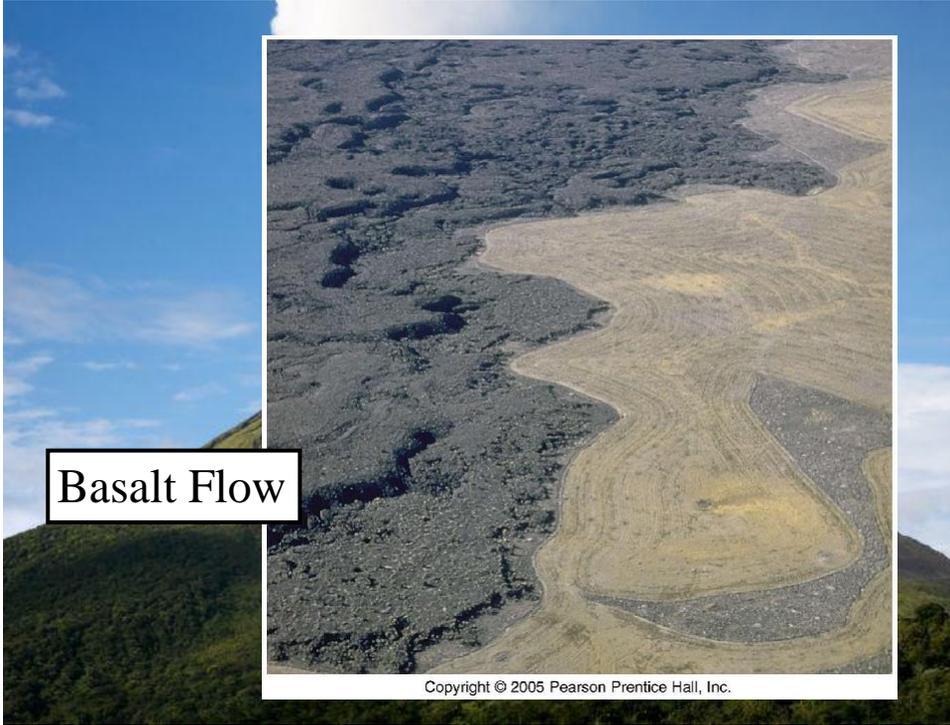
Eruption of the Columbia River Basalts, WA, peaked about 16 million years ago, and 95% of the volume erupted in less than 1 million years.

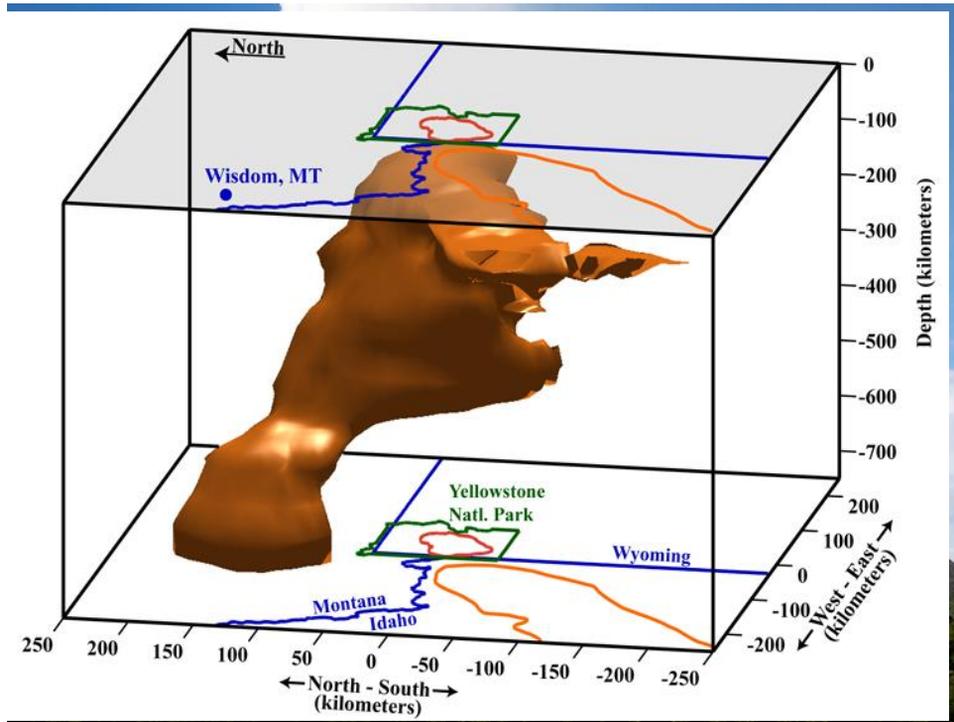
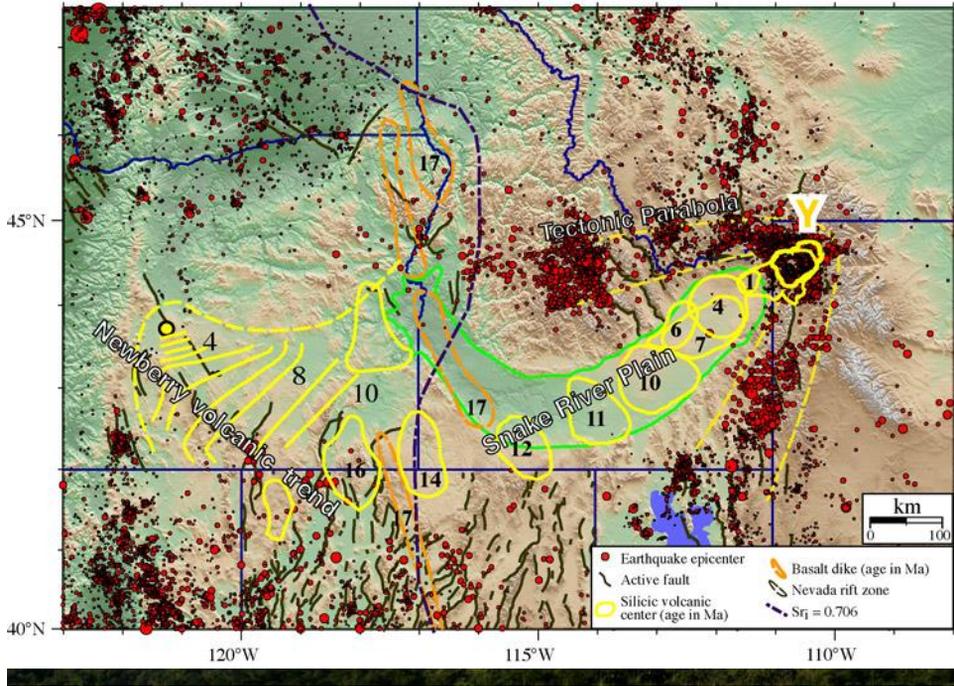


Many Columbia River Basalt flows show prismatic joints, from interactions with surface water. Palouse River WA

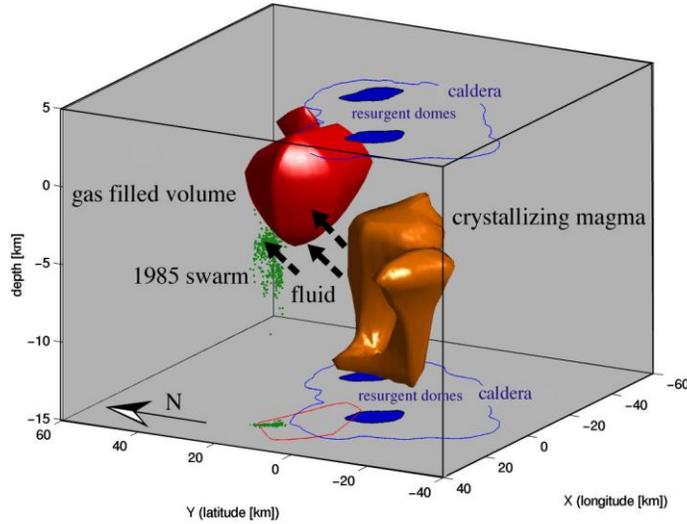


There was enough time between flows for thick soils to develop. From Wishram Heights WA

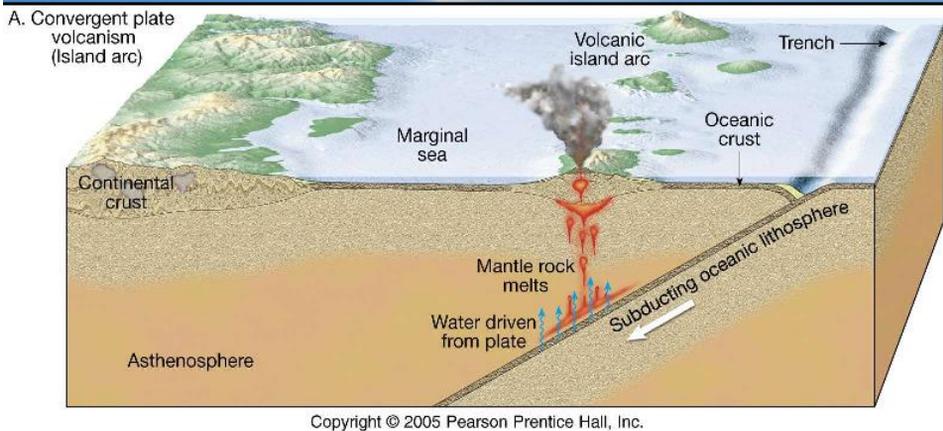




### Tomographic Image (P-wave velocities) of Yellowstone's Magmatic System

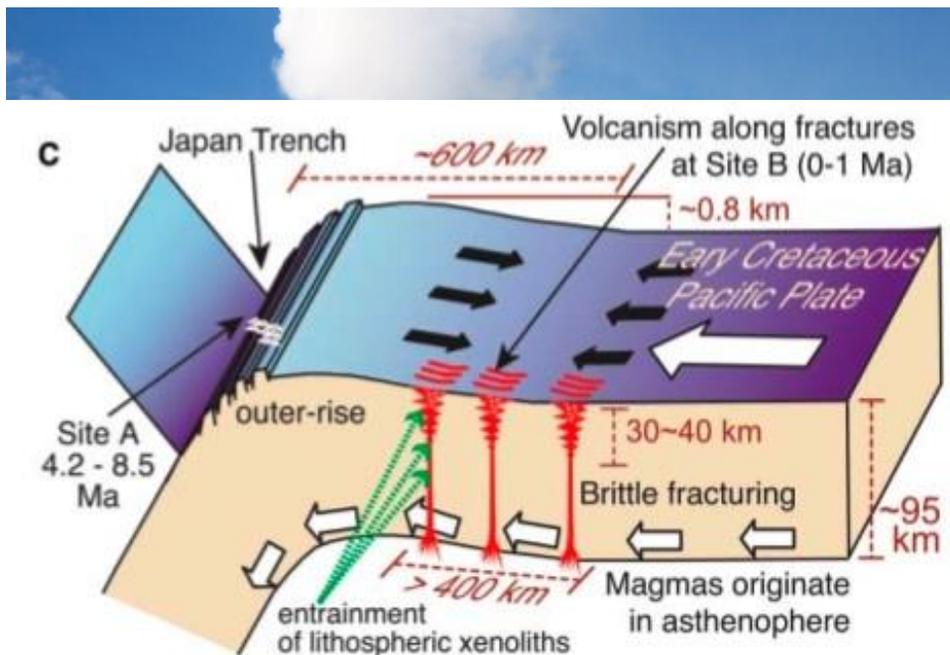


## Limites Convergentes de Placas

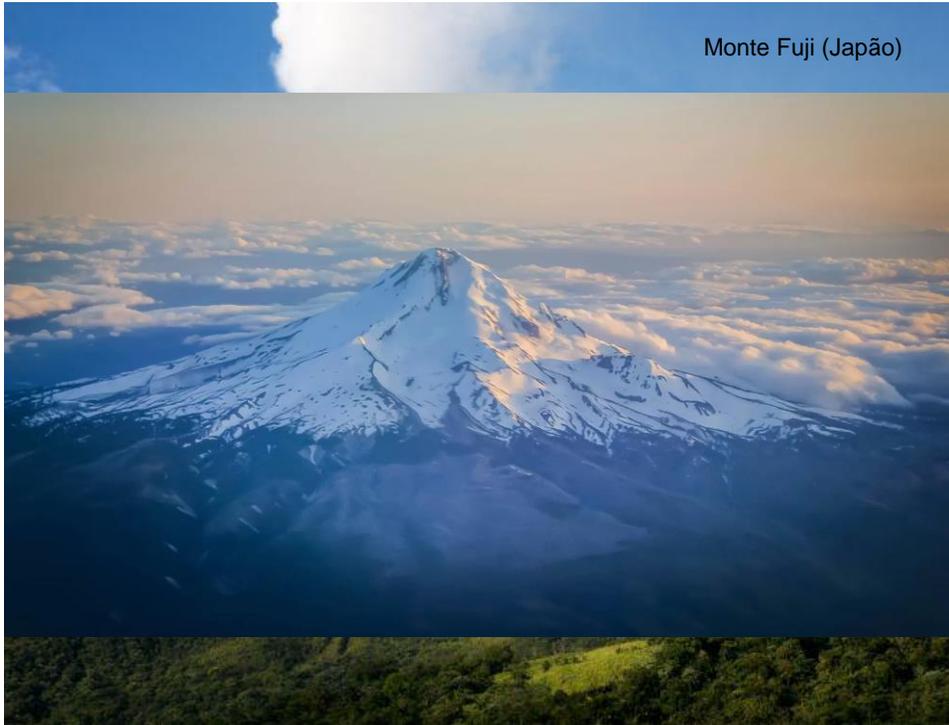


## Magmatismo em Arcos de Ilhas

- 1) Cadeias arqueadas de ilhas acompanhando zonas de subdução ensimática
- 2) Magmatismo distinto das ilhas vulcânicas
  - Composição mais diversificada e mais silicosa
  - Os basaltos geralmente são subordinados
  - O vulcanismo é mais explosivo
  - Estratovulcões são os vulcões mais comuns nesse ambiente tectônico, ao invés do tipo escudo nas ilhas oceânicas



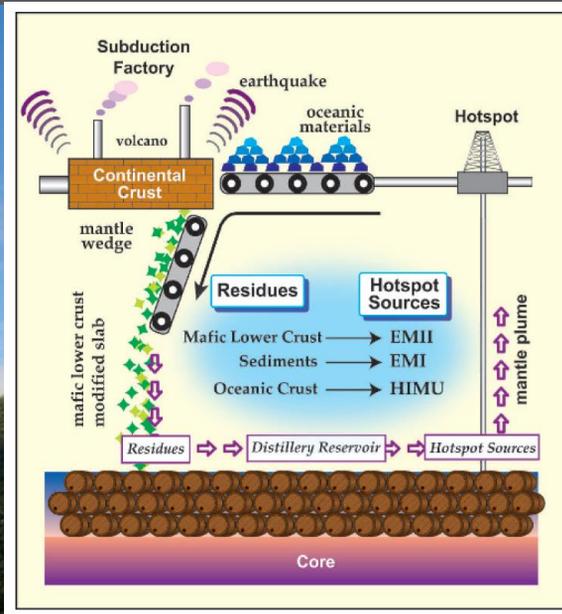
Hirano et al. (2006)



## GERAÇÃO DO MAGMA

- A crosta oceânica subductada é parcialmente fundida, resultando em magmas relativamente mais ricos em sílica (andesíticos)
- O magma ascende na placa que está sobre a subducção → vulcões se alinham com a subducção e constroem o arco de ilhas
- Refusão a crosta neoformada resulta em magmas mais ricos em sílica (dacíticos a riolíticos), num processo de maturação dos arcos de ilhas
- Inclusão de outros materiais subductados na fonte do magma

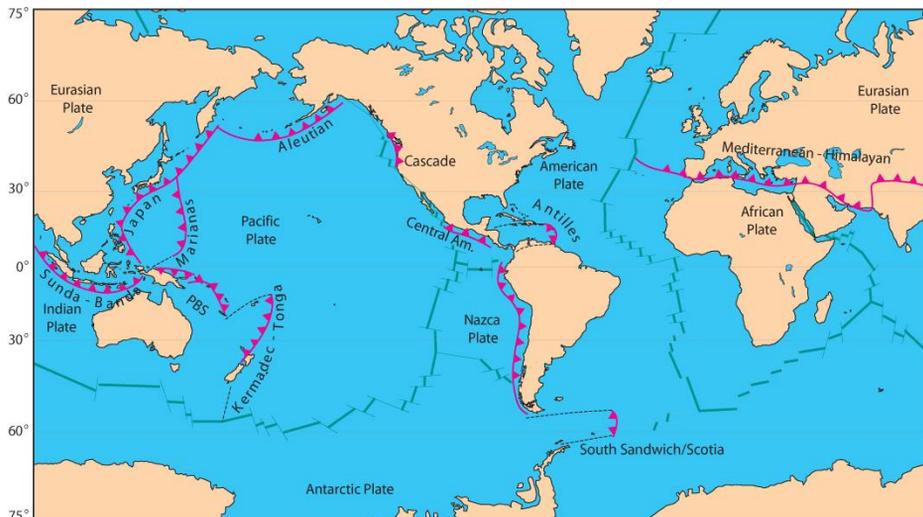
## A FÁBRICA NA ZONA DE SUBDUÇÃO



Oceano-Oceano → Arco de Ilhas (IA - *Island Arc*)

Oceano-Continente → Arco Continental (CA - *Continental Arc*)

Margem Continental Ativa → *Active Continental Margin (ACM)*

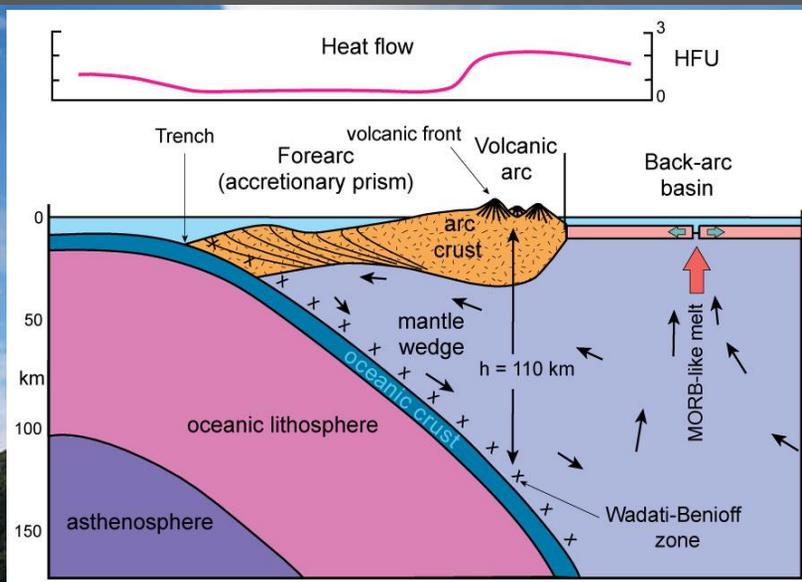


Principal subduction zones associated with orogenic volcanism and plutonism. Triangles are on the overriding plate. PBS = Papuan-Bismarck-Solomon-New Hebrides arc. After Wilson (1989) *Igneous Petrogenesis*, Allen Unwin/Kluwer.

## Produtos da Subducção

- Associações ígneas cálcio-alcálicas características
- Evolução geológica e metamórfica características
- Formação de cadeias de montanhas (orogênese)
- Evolução complexa. O magmatismo depende da velocidade das placas, espessuras, quantidade de sedimentos, etc

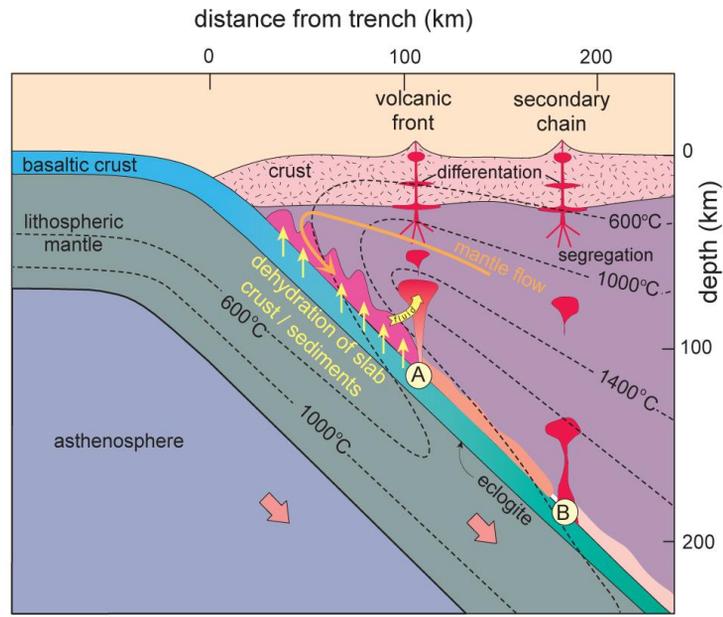
## Estrutura de um Arco de Ilhas



Schematic cross section through a typical island arc after Gill (1981), *Orogenic Andesites and Plate Tectonics*, Springer-Verlag. HFU= heat flow unit ( $4.2 \times 10^{-6} \text{ joules/cm}^2/\text{sec}$ )

# Processos Geológicos

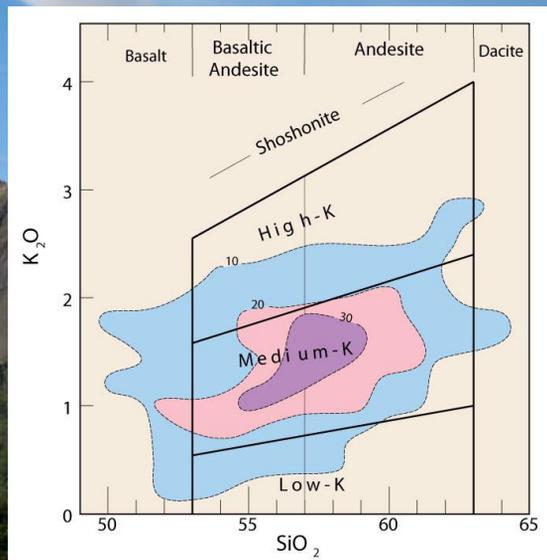
A proposed model for subduction zone magmatism with particular reference to island arcs. Dehydration of slab crust causes hydration of the mantle (violet), which undergoes partial melting as amphibole (A) and phlogopite (B) dehydrate. From Tatsumi (1989), *J. Geophys. Res.*, 94, 4697-4707 and Tatsumi and Eggins (1995). *Subduction Zone Magmatism*. Blackwell, Oxford.

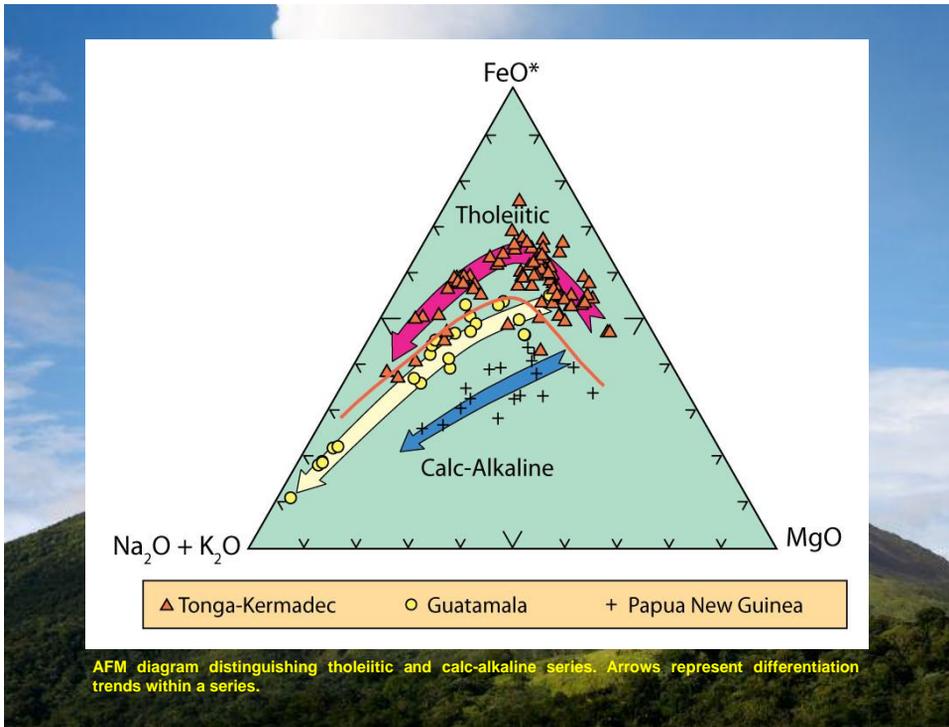


# TIPO DO MAGMA



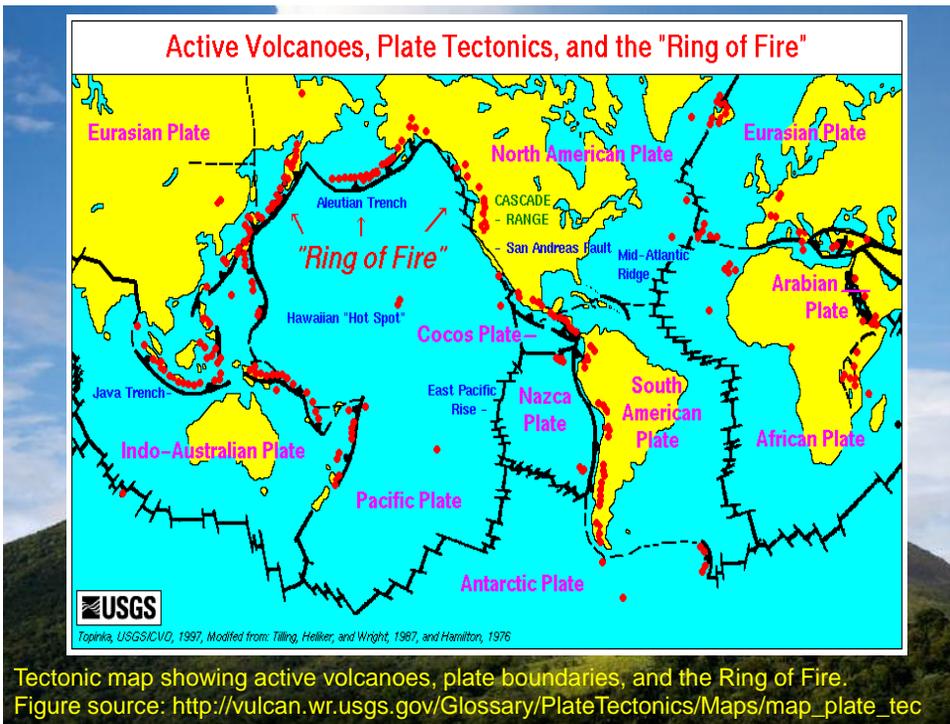
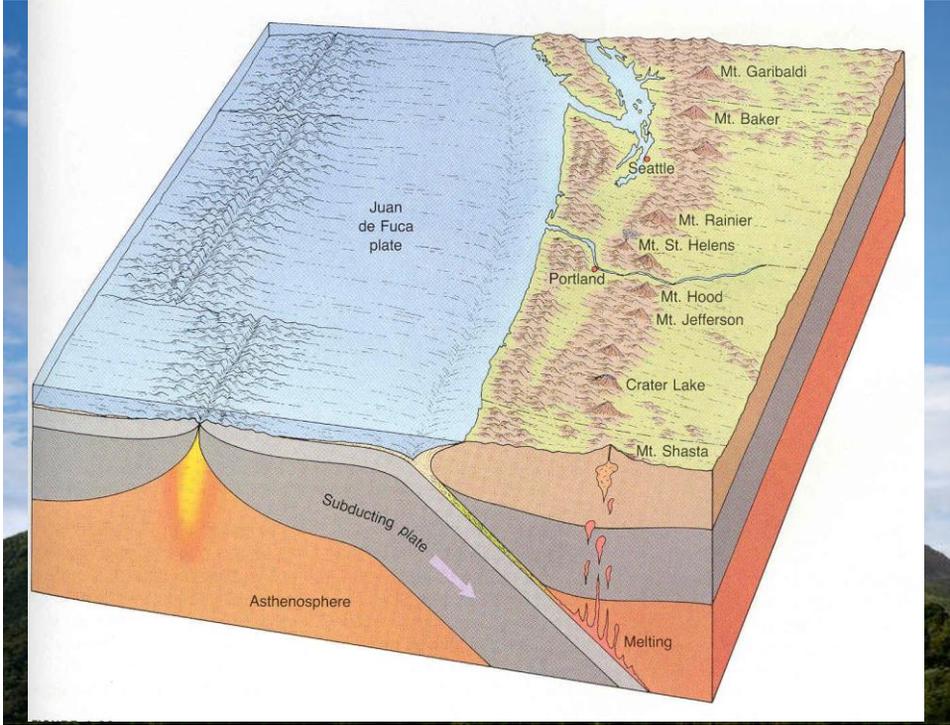
The three andesite series of Gill (1981). A fourth very high K shoshonite series is rare. Contours represent the concentration of 2500 analyses of andesites stored in the large data file RKOC76 (Carnegie Institute of Washington).





## ARCOS MAGMÁTICOS CONTINENTAIS

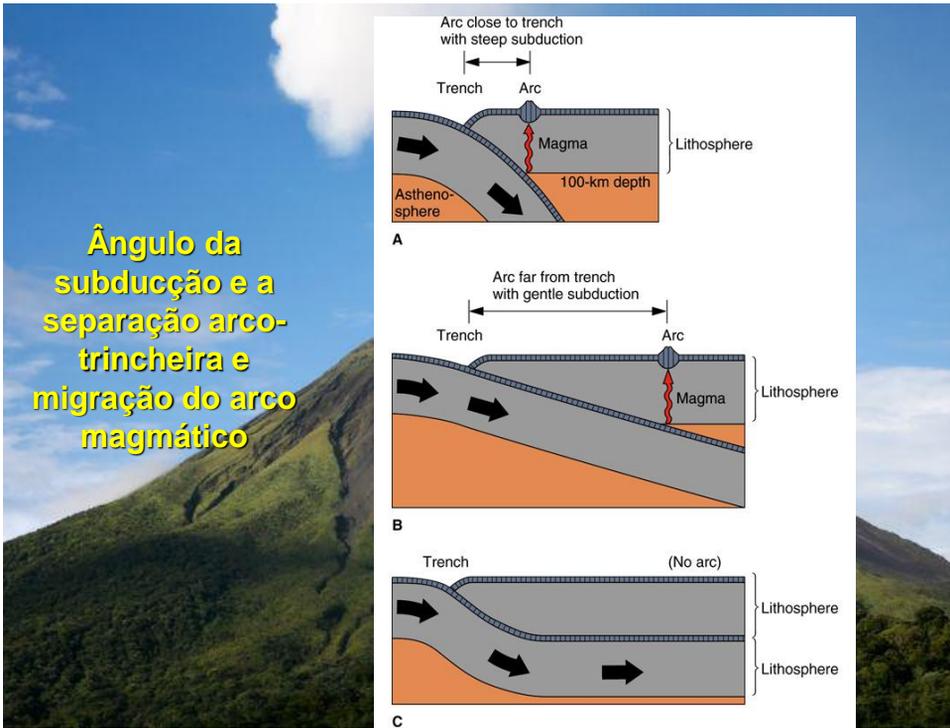
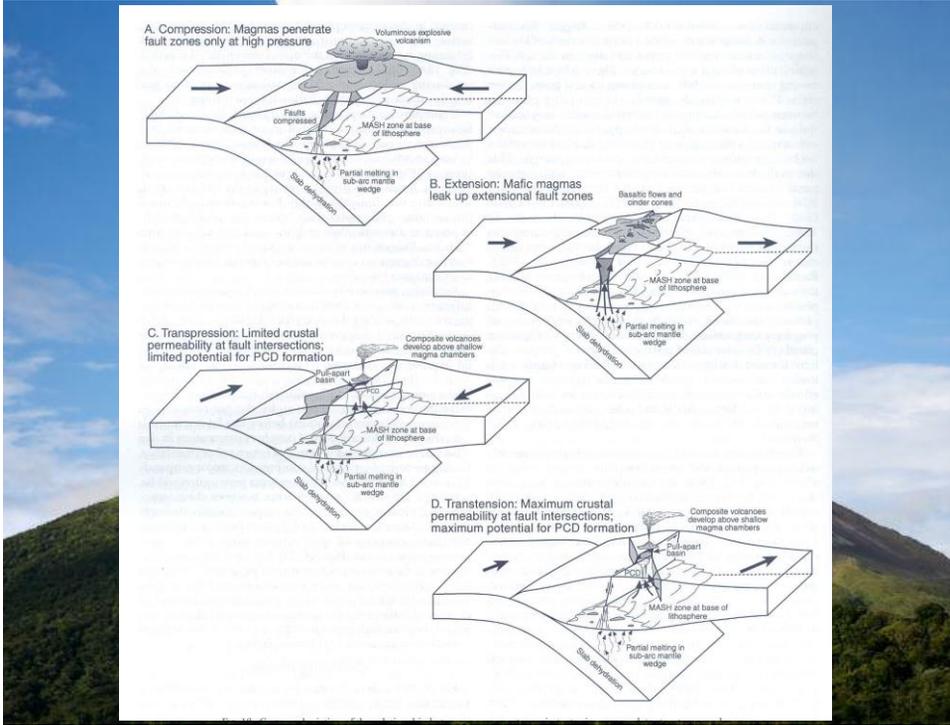
- O tipo de magmatismo produzido no ambiente de margem ativa é bem mais complexo que o magmatismo do ambiente de arco de ilhas, devido à passagem do magma pela crosta continental, o que introduz outras variações em função das diferentes fontes, contaminação, assimilação, mistura de magmas, etc.



## Vulcanismo em Margens Convergentes Continentais

- Os vulcões se forma predominantemente em falhas paralelas à zona de subducção
- Caldeiras vulcânicas
- O magma é formado pela fusão do manto superior e da crosta inferior (andesitos)





# FLAT SUBDUCTION

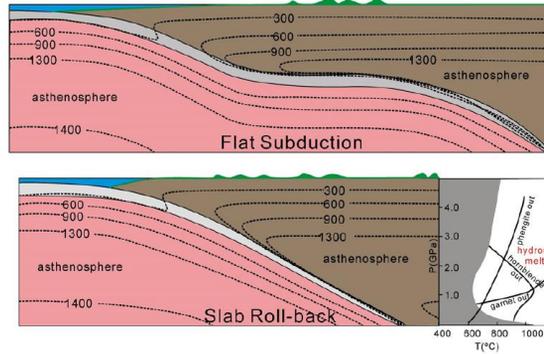
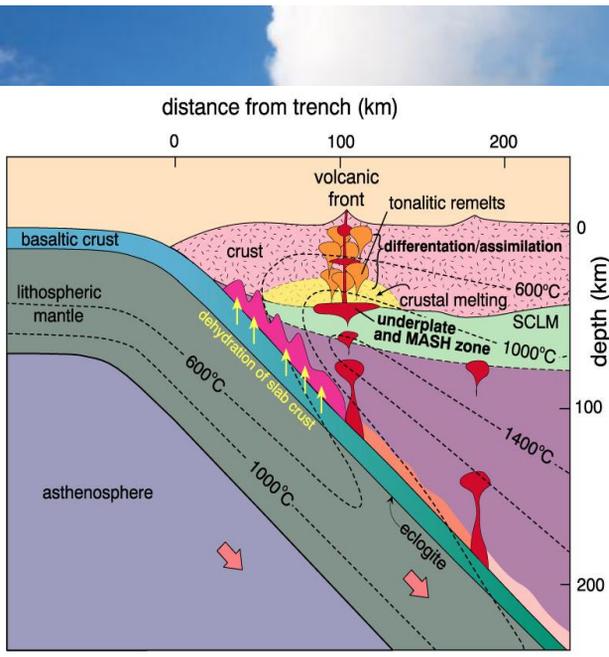
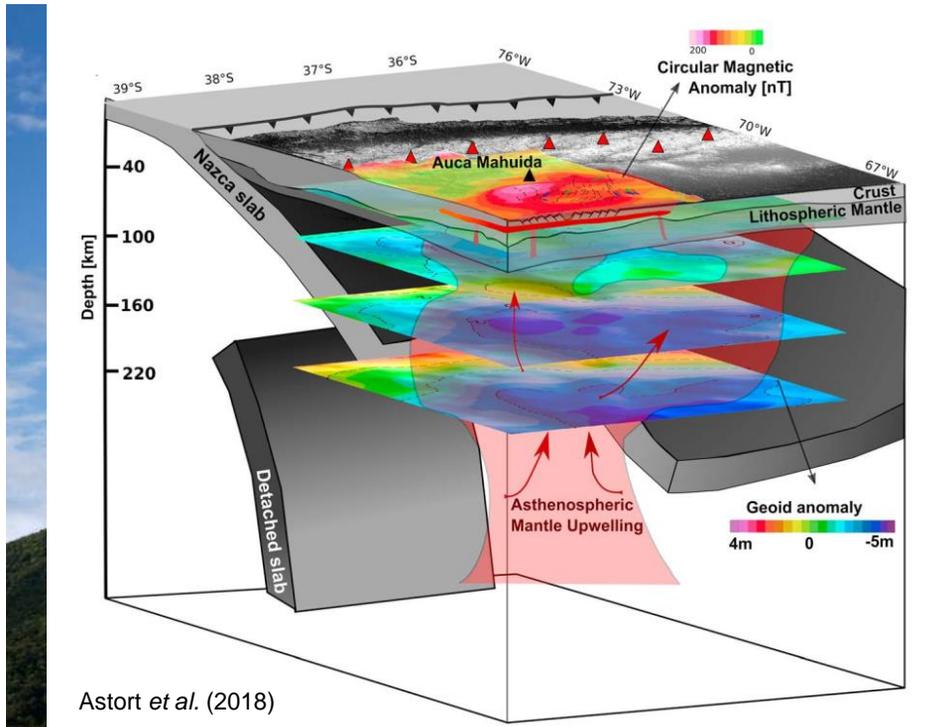


Fig. 8. A cartoon of a slab rollback model. The front edge of a flatly subducted plate reached the Dabaoshan region, resulted in high oxygen fugacity. Subsequent slab rollback led to decomposition of phengite due to elevated temperature induced by asthenosphere upwelling, releasing abundant F rich fluids, hinterher metamorphosed Mo-enriched sediments in back arc basin partial melting and the mineralization porphyry was formed.

Liu et al. (2012)



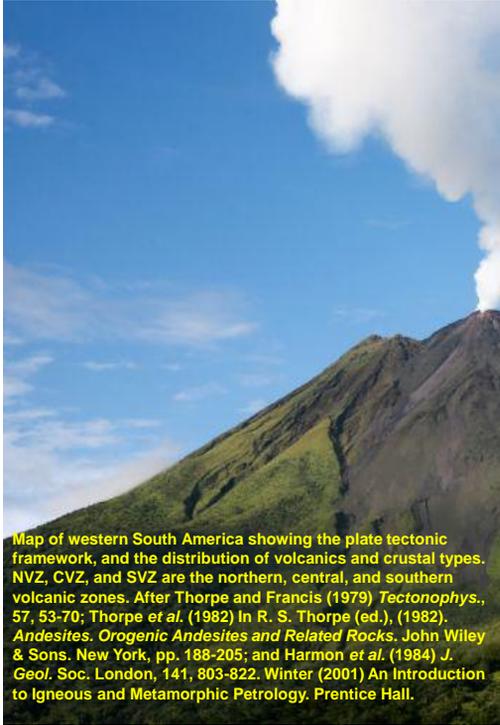
- Seção esquemática de uma zona de subducção numa margem continental ativa onde se observa desidratação da placa oceânica que mergulha sob o continente, a hidratação e fundido da cunha de manto, zona de *underplate* onde se desenvolvem os processos de MASH e os fenômenos de diferenciação que se desenvolve na crosta.



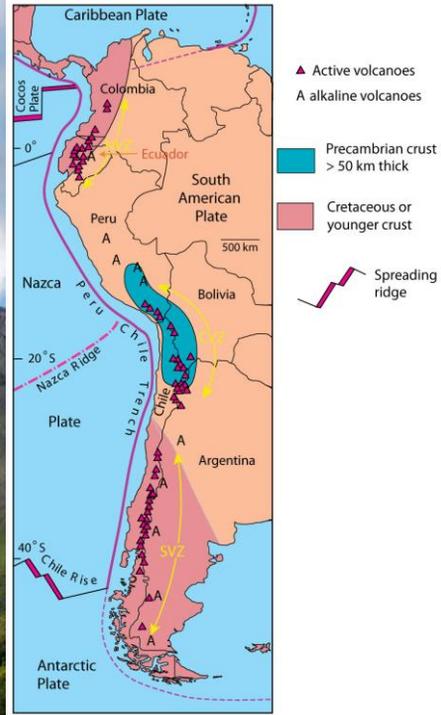
## Vulcanismo Associado a Margens Continentais Convergentes

### Magmas cálcio-alcálinos

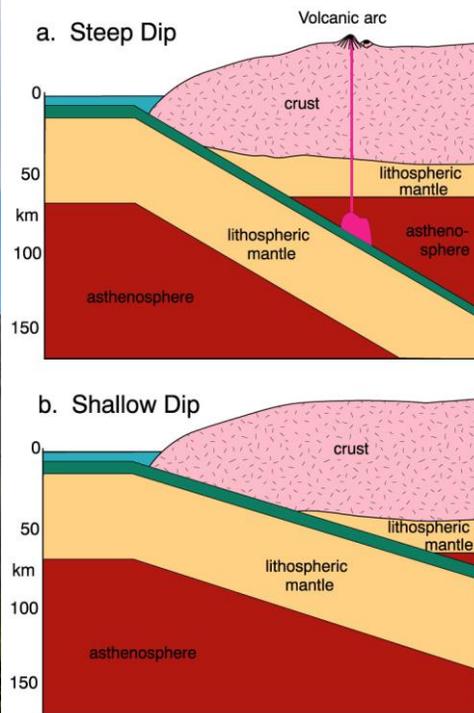
- Estratovulcões
- Flancos íngremes
- Alternância de camadas e leitos de lavas, cinzas e materiais piroclásticos
- Vulcanismo explosivo, devido à viscosidade alta e ao alto conteúdo de voláteis

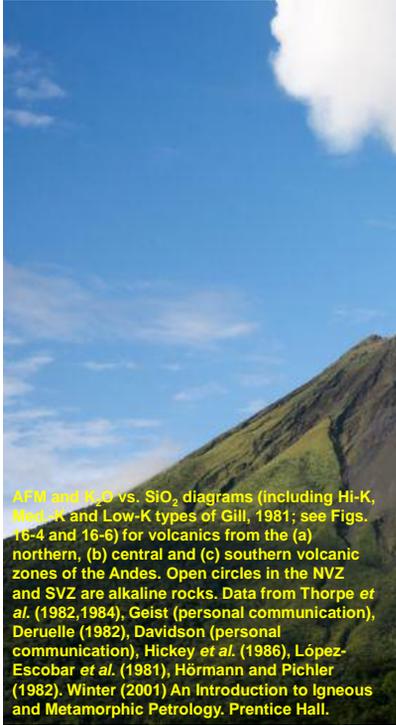


Map of western South America showing the plate tectonic framework, and the distribution of volcanics and crustal types. NVZ, CVZ, and SVZ are the northern, central, and southern volcanic zones. After Thorpe and Francis (1979) *Tectonophys.*, 57, 53-70; Thorpe *et al.* (1982) In R. S. Thorpe (ed.), (1982), *Andesites, Orogenic Andesites and Related Rocks*. John Wiley & Sons. New York, pp. 188-205; and Harmon *et al.* (1984) *J. Geol. Soc. London*, 141, 803-822. Winter (2001) *An Introduction to Igneous and Metamorphic Petrology*. Prentice Hall.

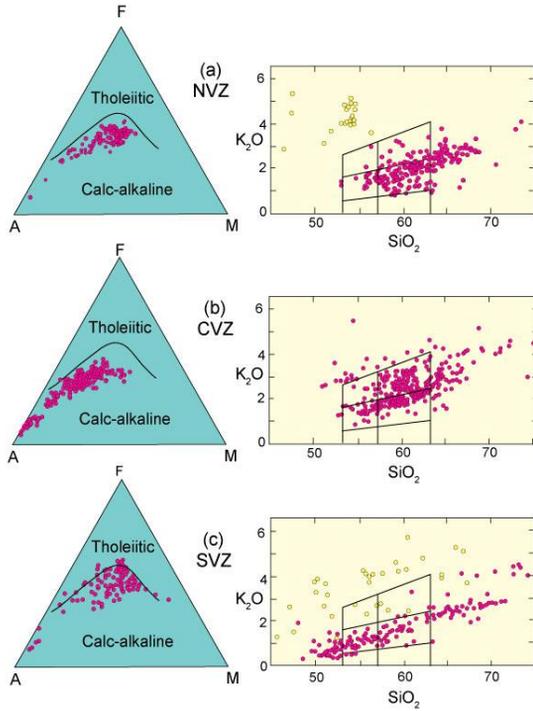


Schematic diagram to illustrate how a shallow dip of the subducting slab can pinch out the asthenosphere from the overlying mantle wedge. Winter (2001) *An Introduction to Igneous and Metamorphic Petrology*. Prentice Hall.

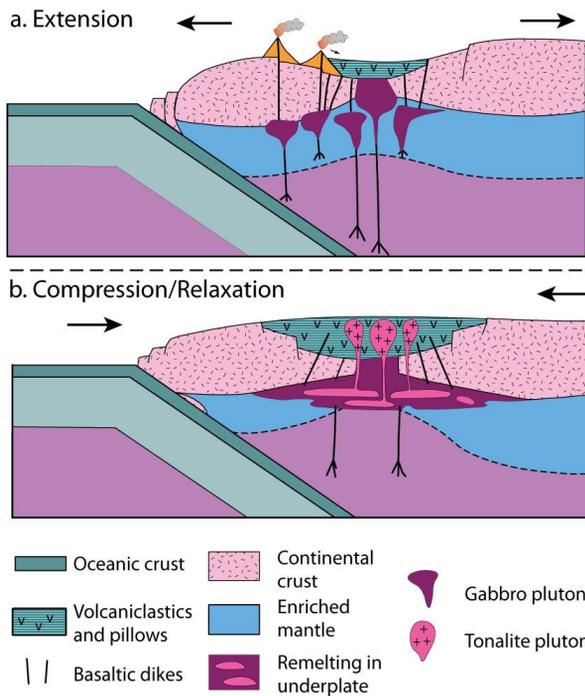




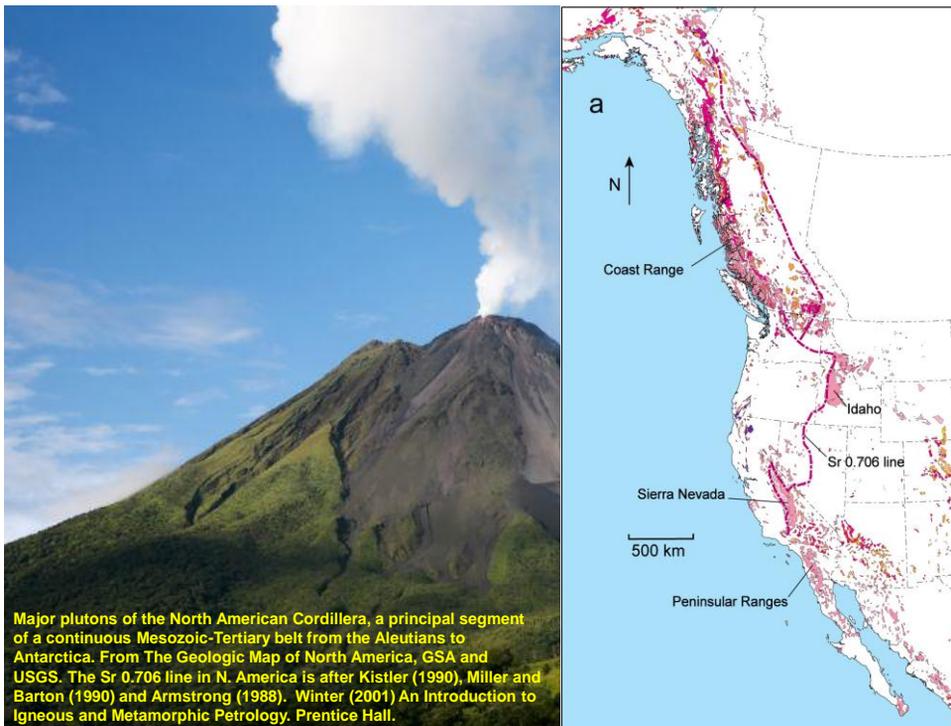
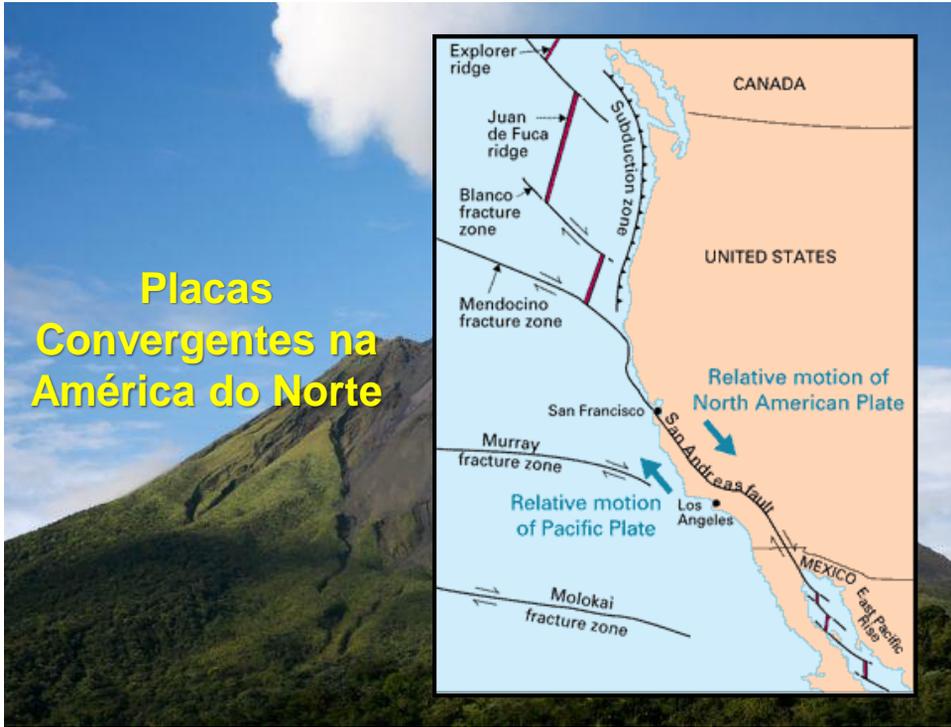
AFM and K<sub>2</sub>O vs. SiO<sub>2</sub> diagrams (including HI-K, Med-K and Low-K types of Gill, 1981; see Figs. 16-4 and 16-6) for volcanics from the (a) northern, (b) central and (c) southern volcanic zones of the Andes. Open circles in the NVZ and SVZ are alkaline rocks. Data from Thorpe *et al.* (1982,1984), Geist (personal communication), Deruelle (1982), Davidson (personal communication), Hickey *et al.* (1986), López-Escobar *et al.* (1981), Hörmann and Pichler (1982). Winter (2001) *An Introduction to Igneous and Metamorphic Petrology*, Prentice Hall.



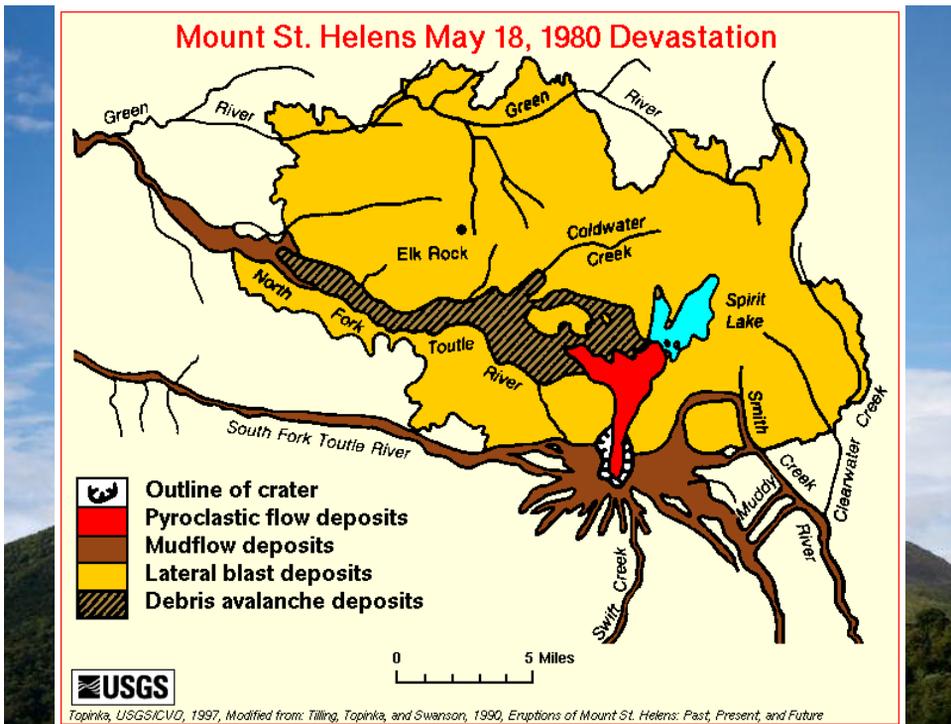
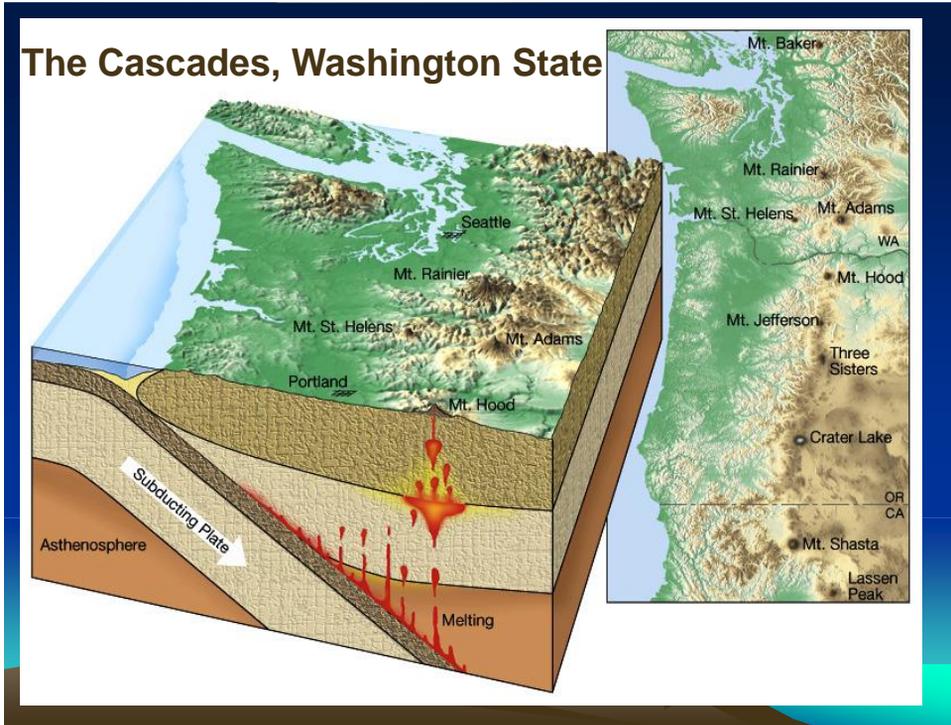
Schematic diagram illustrating (a) the formation of a gabbroic crustal underplate at a continental arc and (b) the remelting of the underplate to generate tonalitic plutons. After Cobbing and Pitcher (1983) in J. A. Roddick (ed.), *Circum-Pacific Plutonic Terranes*. *Geol. Soc. Amer. Memoir*, 159, pp. 277-291.



**Placas  
Convergentes na  
América do Norte**



Major plutons of the North American Cordillera, a principal segment of a continuous Mesozoic-Tertiary belt from the Aleutians to Antarctica. From The Geologic Map of North America, GSA and USGS. The Sr 0.706 line in N. America is after Kistler (1990), Miller and Barton (1990) and Armstrong (1988). Winter (2001) An Introduction to Igneous and Metamorphic Petrology. Prentice Hall.



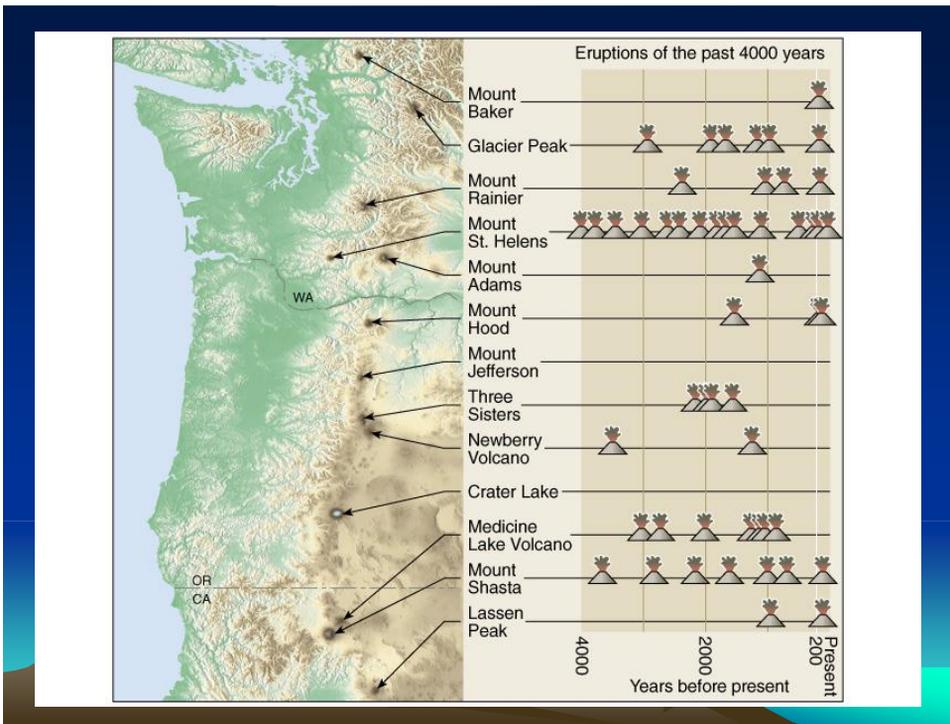
## Mt. St. Helena Antes da erupção de 1980

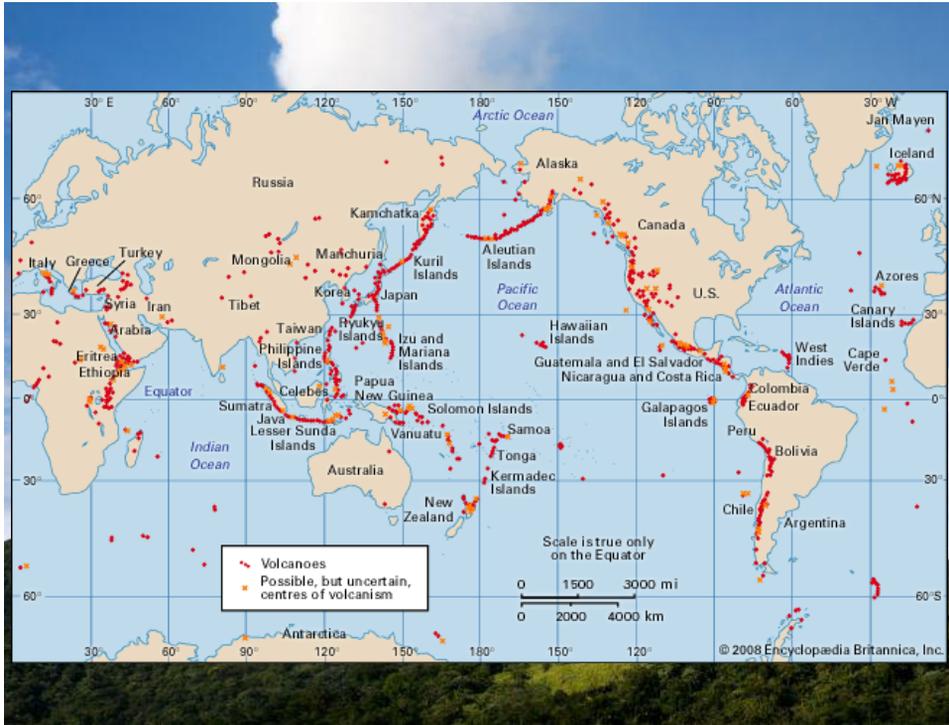


## Mt. St. Helena Depois da erupção de 1980



## ERUPÇÃO DIRIGIDA (*DIRECT BLAST*)



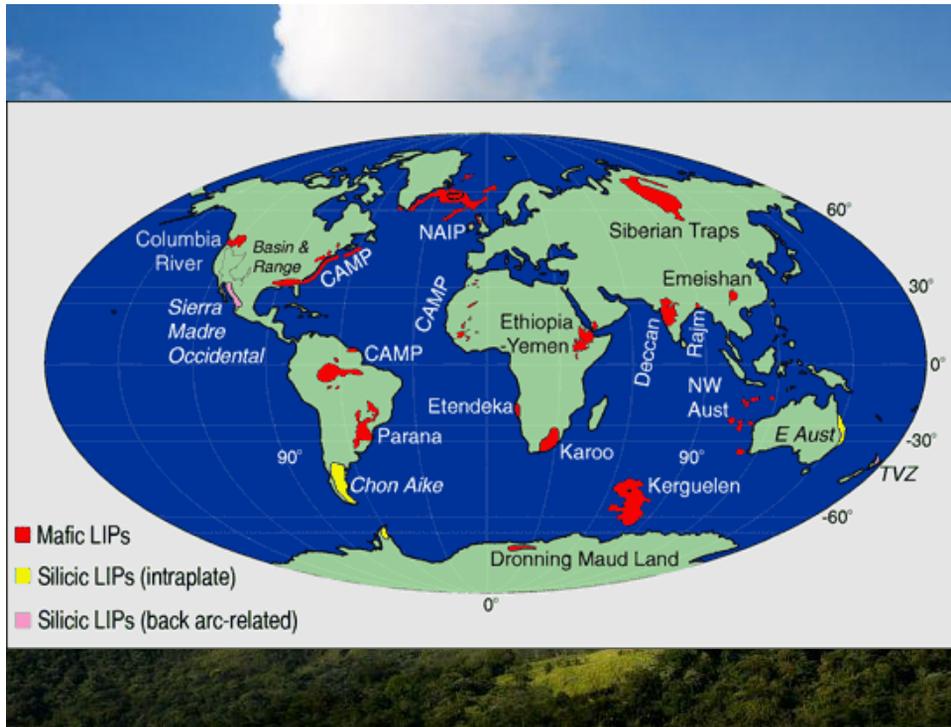


## Large Igneous Province (LIP) Silicic Large Igneous Province (SLIP)

Implies a province of igneous origin that is large

Clearly, the term LIP should cover large volcanic and intrusive igneous provinces, of whatever emplacement mechanism and composition.

However, the term LIP has been applied to and used only for “flood basalt” provinces that have been the subject of great interest and extensive research recently (e.g., *Macdougall, 1988; Mahoney & Coffin, 1997; Sheth & Pande, 2004; Kerr et al., 2005; Foulger et al., 2005; Saunders, 2005; see [www.largeigneousprovinces.org](http://www.largeigneousprovinces.org)*).





**Slide Final Aula 3**