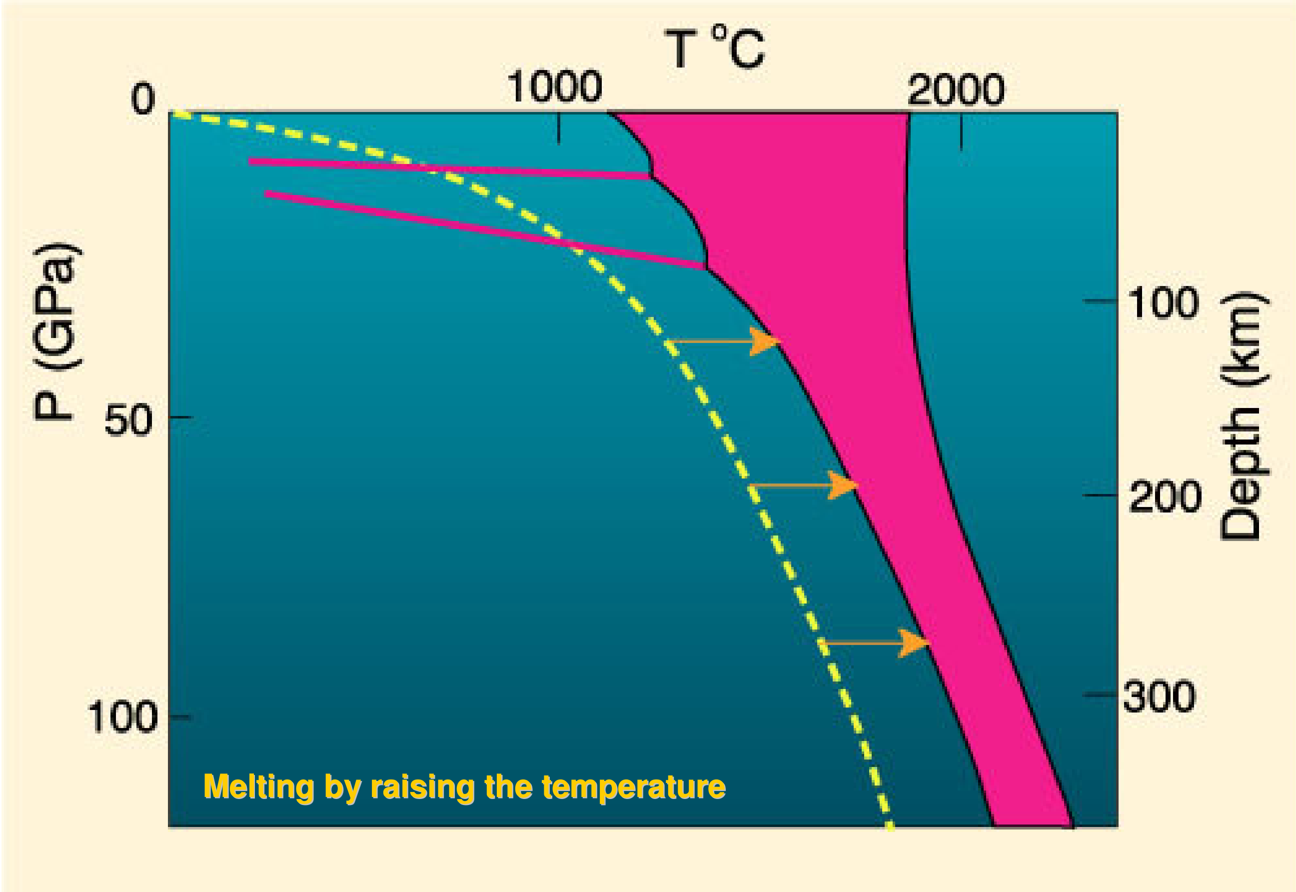
How does the mantle melt?

1) Increase the temperature

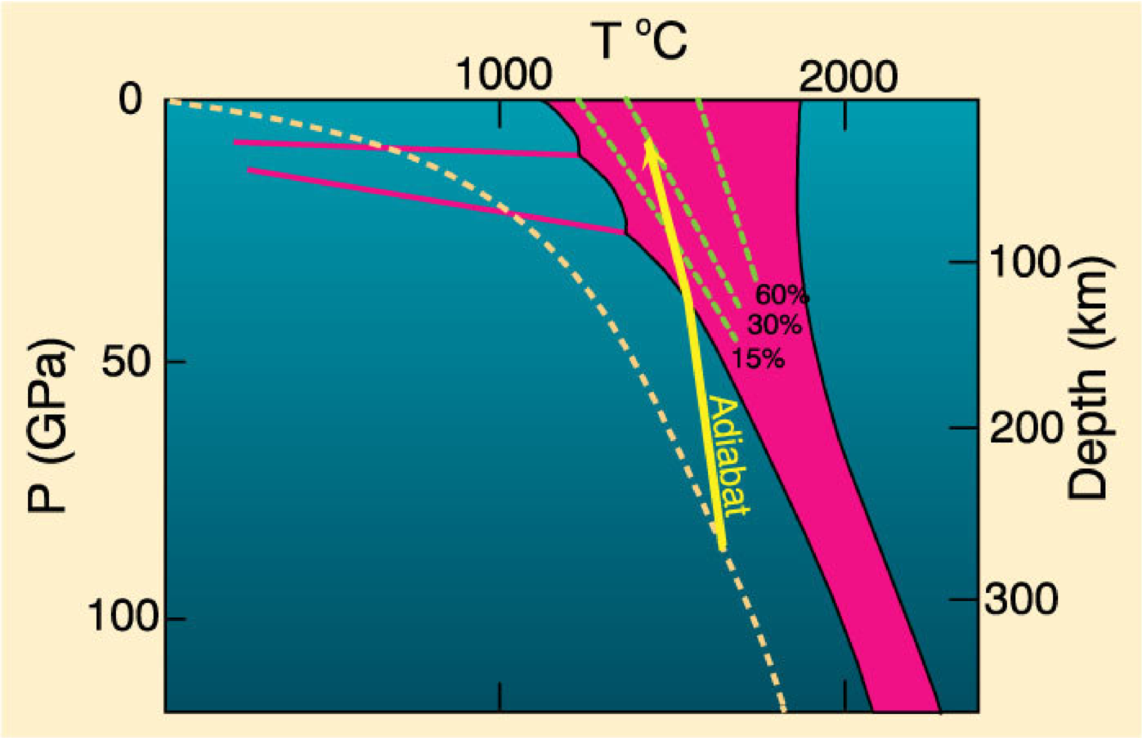
Solidus: Temperature of melting, increases with depth (P)



How does the mantle melt?

2) Lower the pressure
   – Adiabatic rise of mantle with no conductive heat loss
   – Decompression melting could melt at least 30%

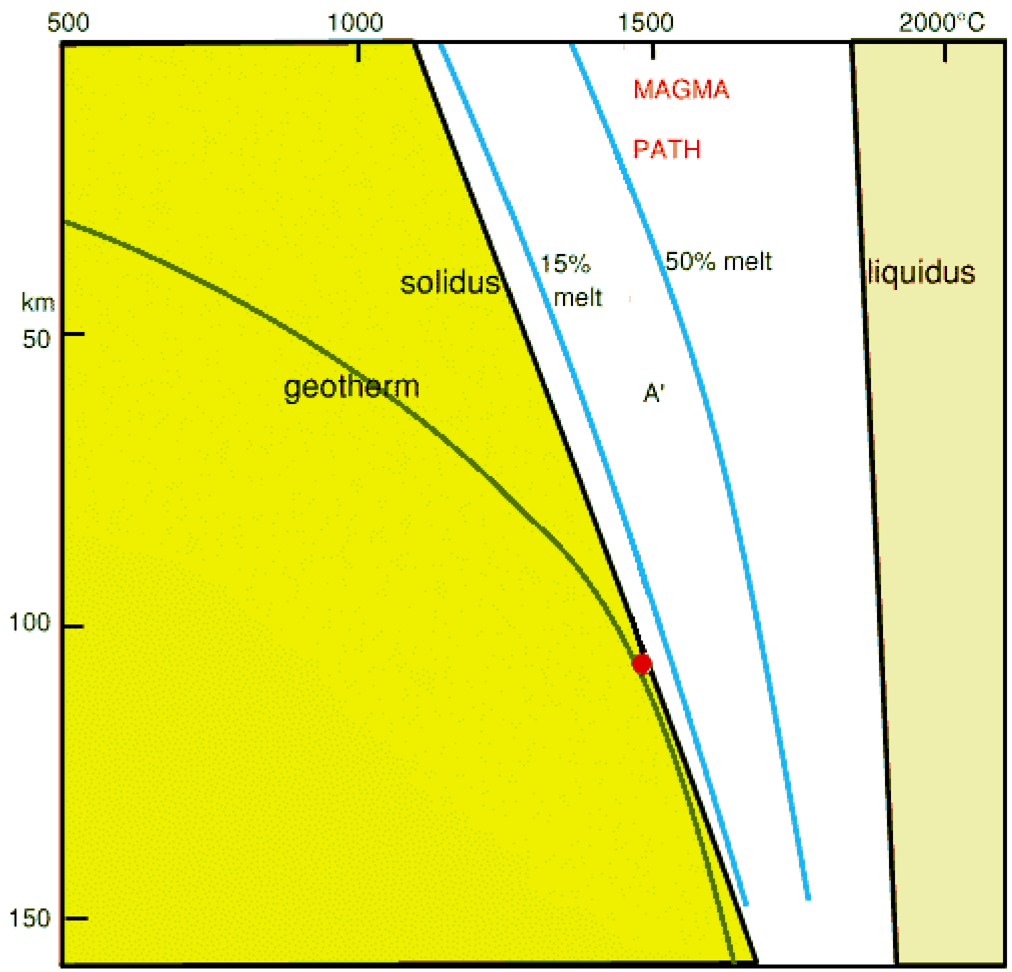
Adiabatic paths: Nearly isothermal decompression



Melting by (adiabatic) pressure reduction. Melting begins when the adiabat crosses the solidus and traverses the shaded melting interval. Dashed lines represent approximate % melting.

http://www.whitman.edu/geology/winter/
John Winter (2001) An Introduction to Igneous and Metamorphic Petrology

Why does the mantle melt?



…because of upwelling and isothermal decompression of the melt

Magma Formation

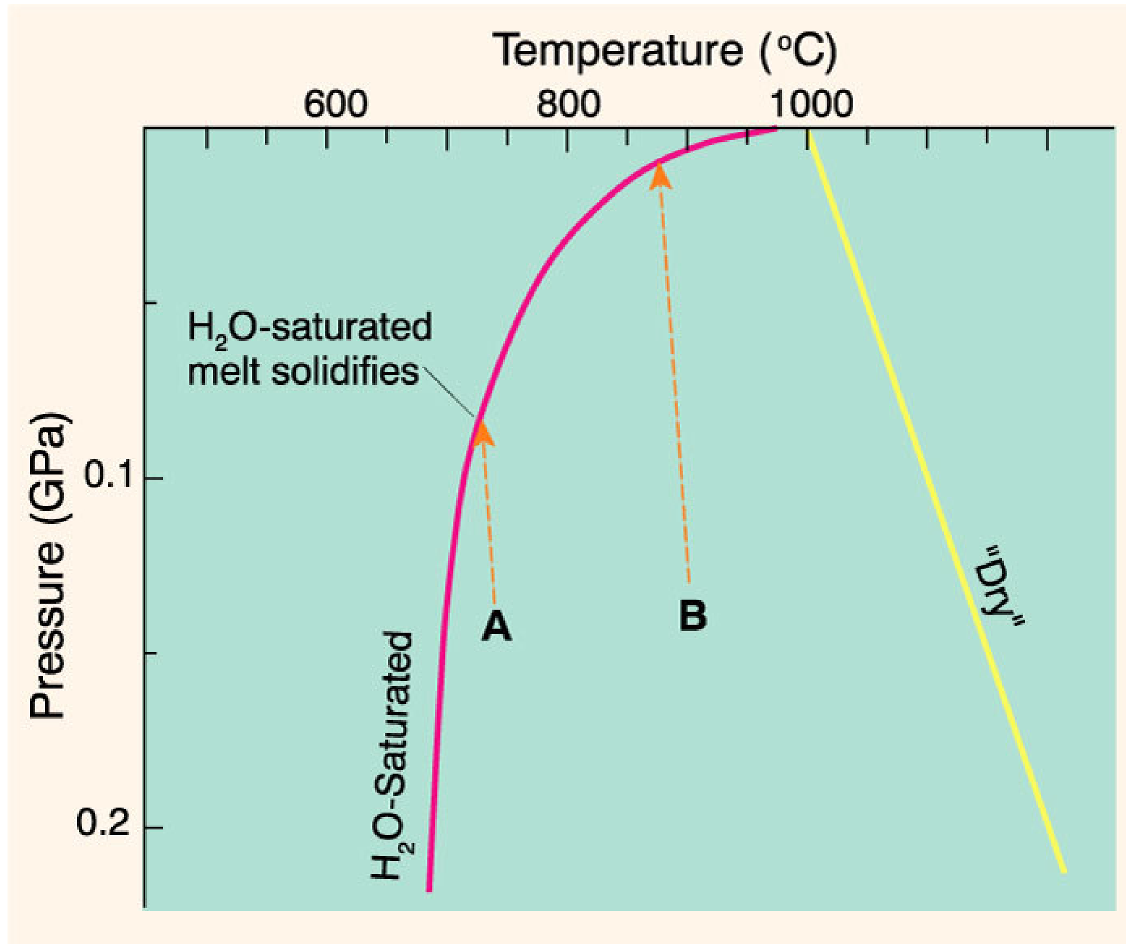
- Two major mechanisms:
  - **Decompression melting**
    - Passive asthenospheric upwelling at mid-ocean ridges
    - Rising plume head at "hot spots"
  - **Fluid-fluxed (volatile-aided) melting**
    - Hydrous melting in subduction zones
    - H_2O released from amphibole, mica, serpentine minerals in subducting crust
    - ***Lowers solidus*** of overlying mantle
    - Magmas generated are different from decompression melts

Magma Formation

Pressure-temperature phase diagram showing the solidus curves for H_2O-saturated and dry granite.

A H_2O-saturated granitoid just above the solidus at **A** will quickly intersect the solidus as it rises and will therefore solidify.

A hotter, H_2O-undersaturated granitoid at **B** will rise further before solidifying.

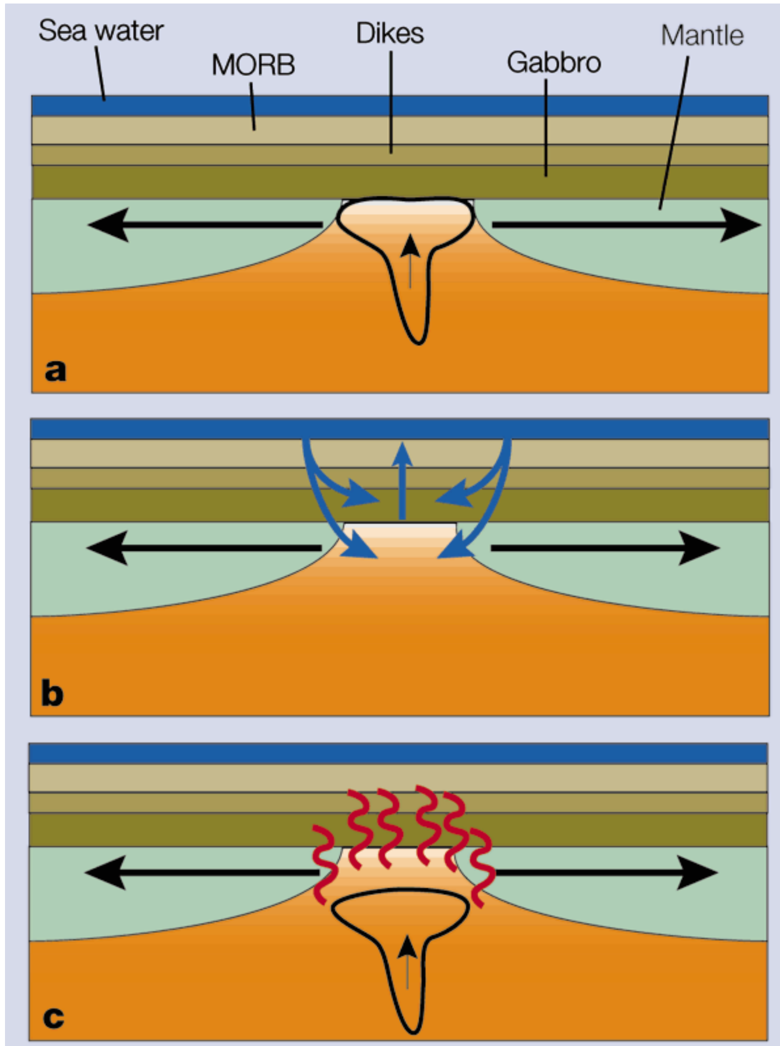


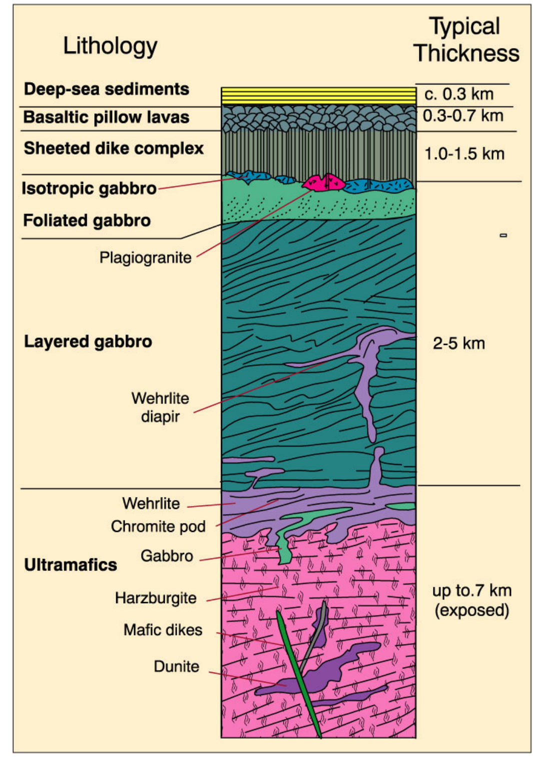
Mantle-alteration model (Benoit et al. 1999)

A: Decompression melting produces a layered oceanic crust.

B: Hydrothermal circulation of sea water (blue) adds water and seawater strontium to the top of the mantle.

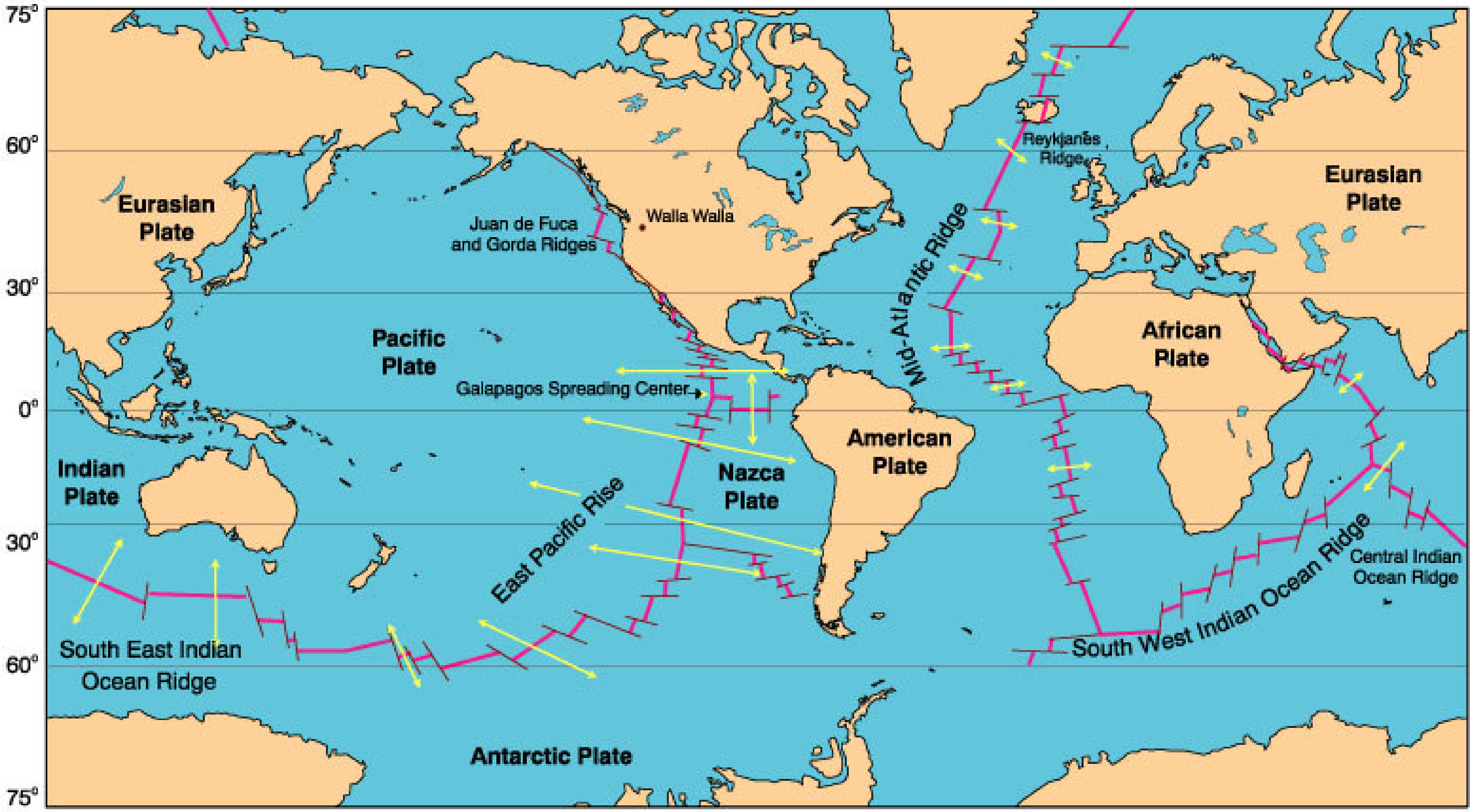
C: Later mantle intrusions heat the altered mantle, forming highly depleted, silica-rich melts which crystallize in veins within the oceanic plate.





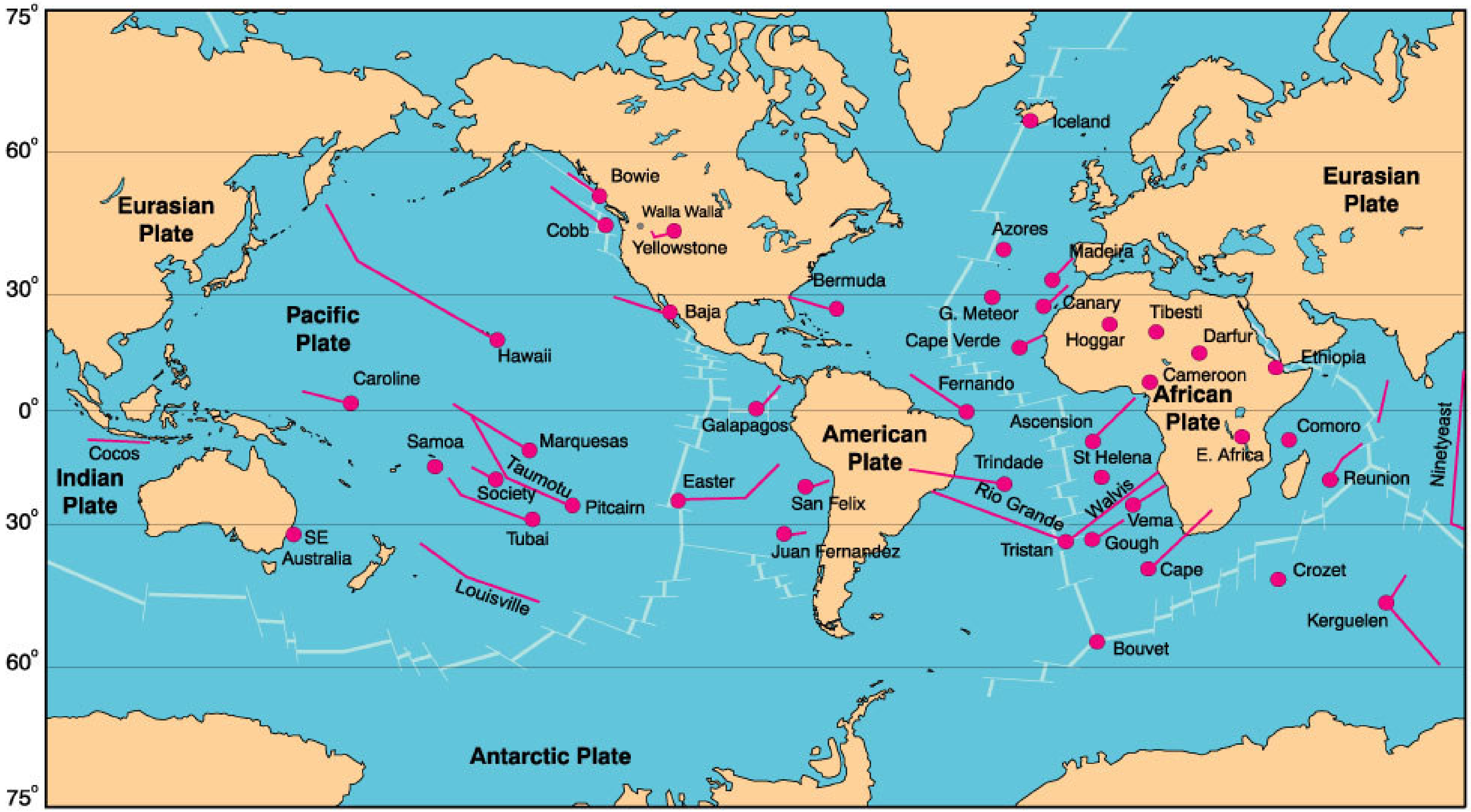
Hauri (1999)

The Mid-Ocean Ridge System - MORB



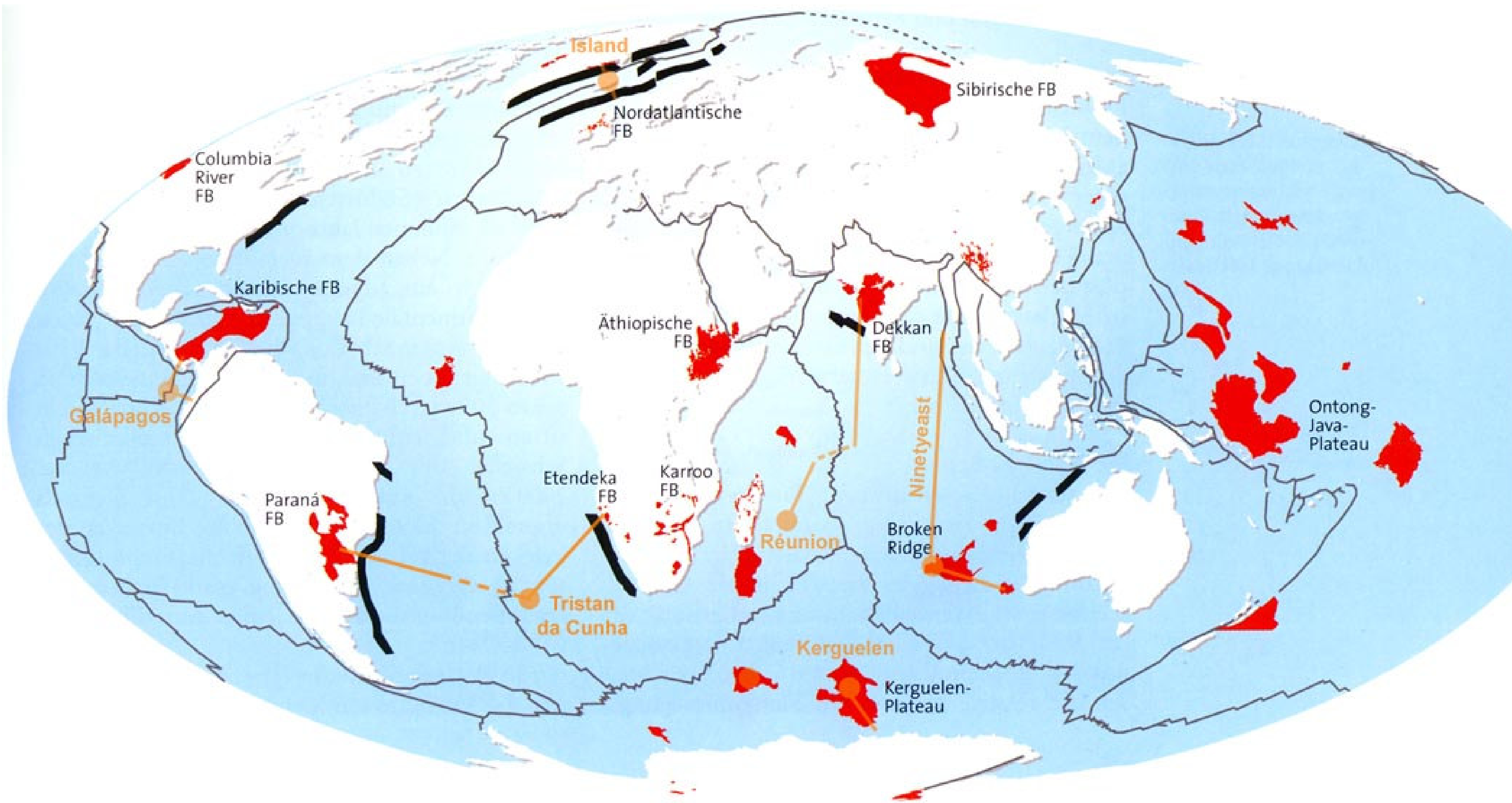
Minster et al. (1974)

Ocean islands and seamounts - OIB



Crough (1983)

Large Igneous Provinces (LIP's)



(Coffin und Eldholm 1994, Schmincke 1999)

Why are MORB's, OIB's and LIP's so important?

MORBs, OIBs and LIP's sample a great expanse of oceanic mantle in places where crustal contamination is minimal and provide incomparable evidence to the nature of the mantle

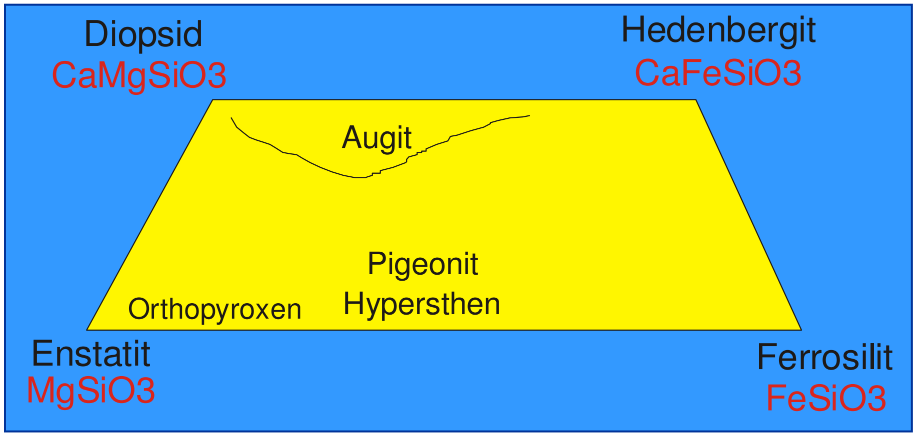
Basalttypen

- Tholeiitbasalt

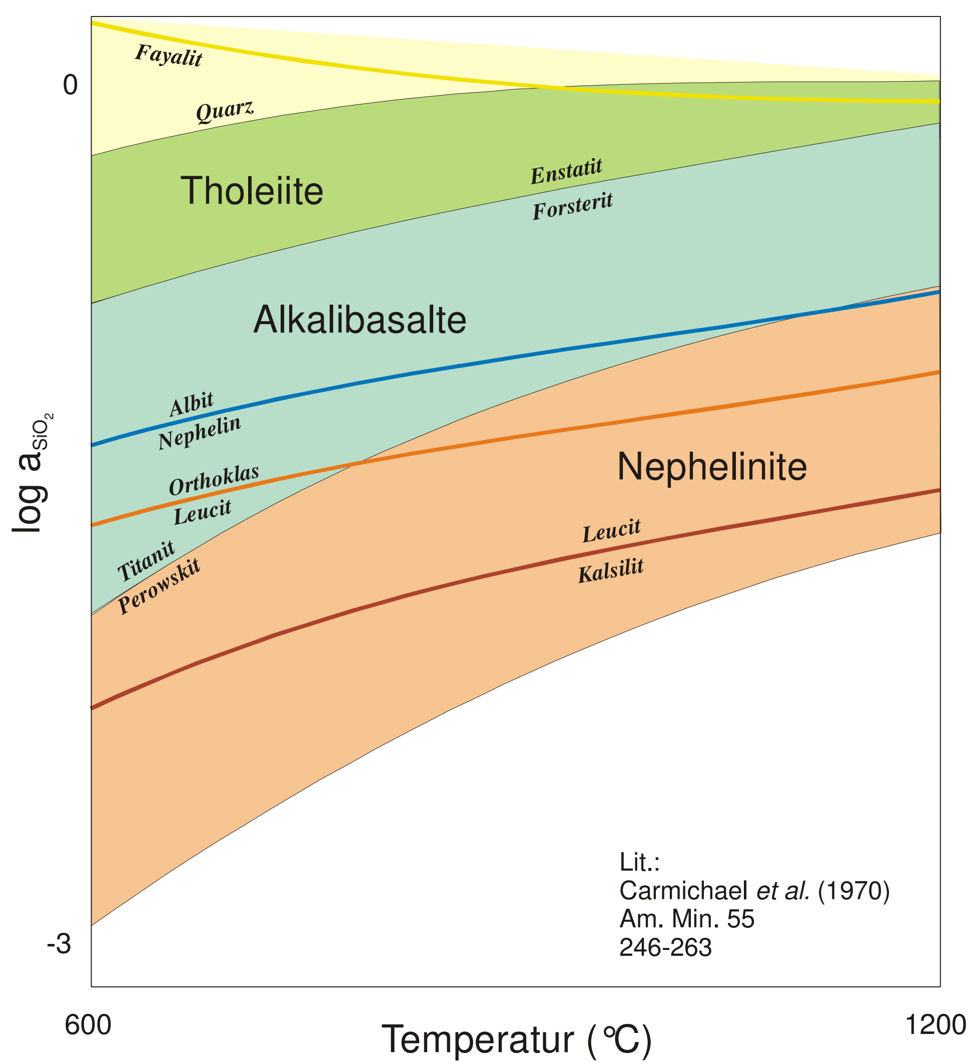
  ~50% SiO_2
  Mg-reicherOlivin (Fe-reich in Qz-Tholeiiten
  Ca-reicher Plg
  ± Augit (Cpx)
  ± Opx (Hypersthen)
  Pigeonit (Ca-reicher Hypersthen, bzw. Ca-armer Cpx)

- Alkalibasalt

  ~45% SiO_2
  Olivin (in der Grundmasse)
  Ca-reicher Plg
  Augit
  ± Nephelin
  kein Opx, kein Pigeonit



Silica activity and magma series



- Fayalite: Fe_2SiO_4
- Enstatite $MgSiO_3$
- Forsterite Mg_2SiO_4
- Albit $NaAlSi_3O_8$
- Nephelin $NaAlSiO_4$
- Orthoklas $KAlSi_3O_8$
- Leucit $KAlSi_2O_6$
- Titanit $CaTiSiO_5$
- Perowskit $CaTiO_3$
- Kalsilit $KAlSiO_4$

Two principal types of basalt in the ocean basins

Tholeiitic Basalt and Alkaline Basalt

- Tholeiites are generated at mid-ocean ridges
  - Also generated at oceanic islands, subduction zones
- Alkaline basalts generated at ocean islands
  - Also at subduction zones