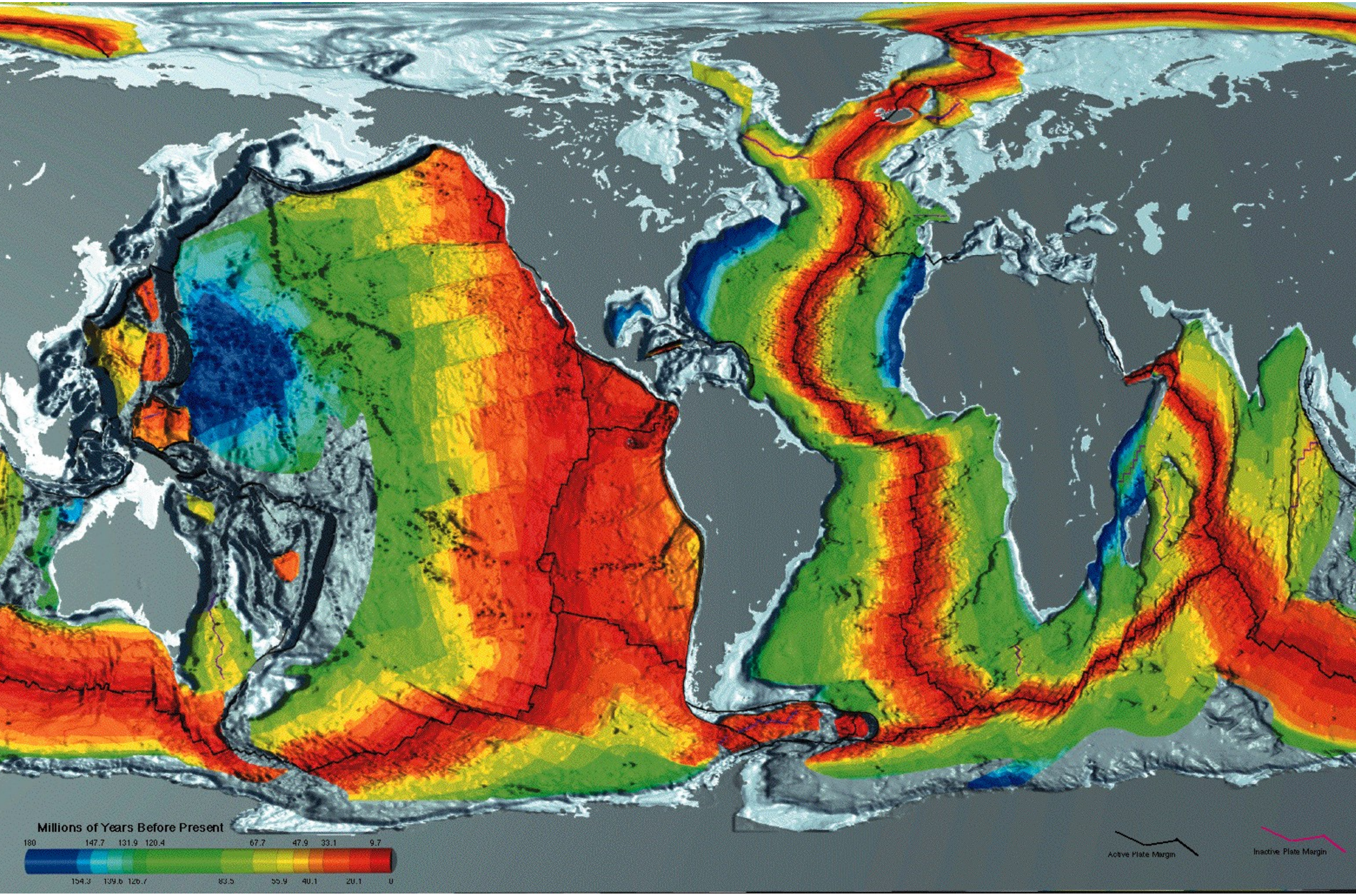
Introducction in die Mineralogy, geology and sedimentology

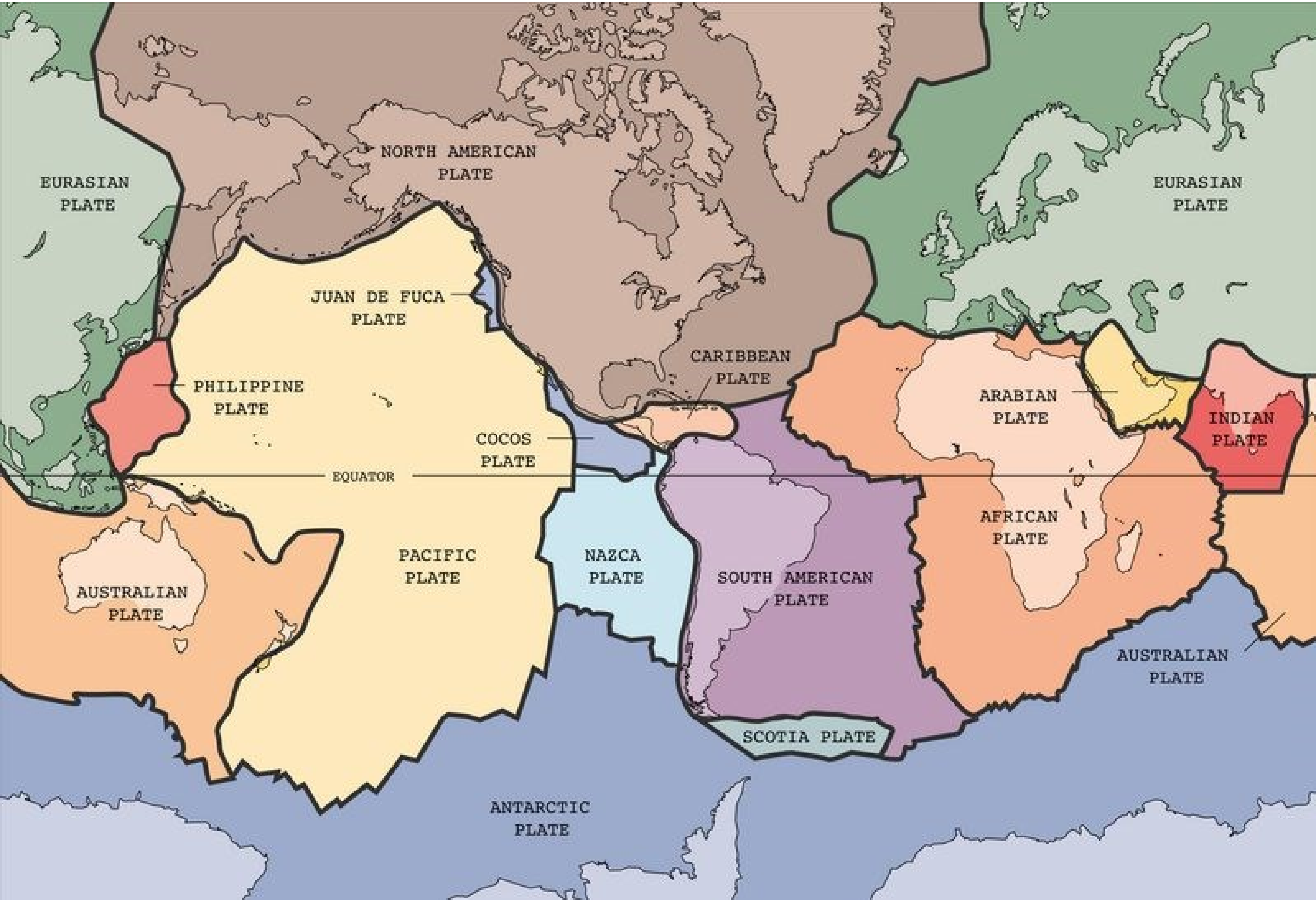
Plate tectonics

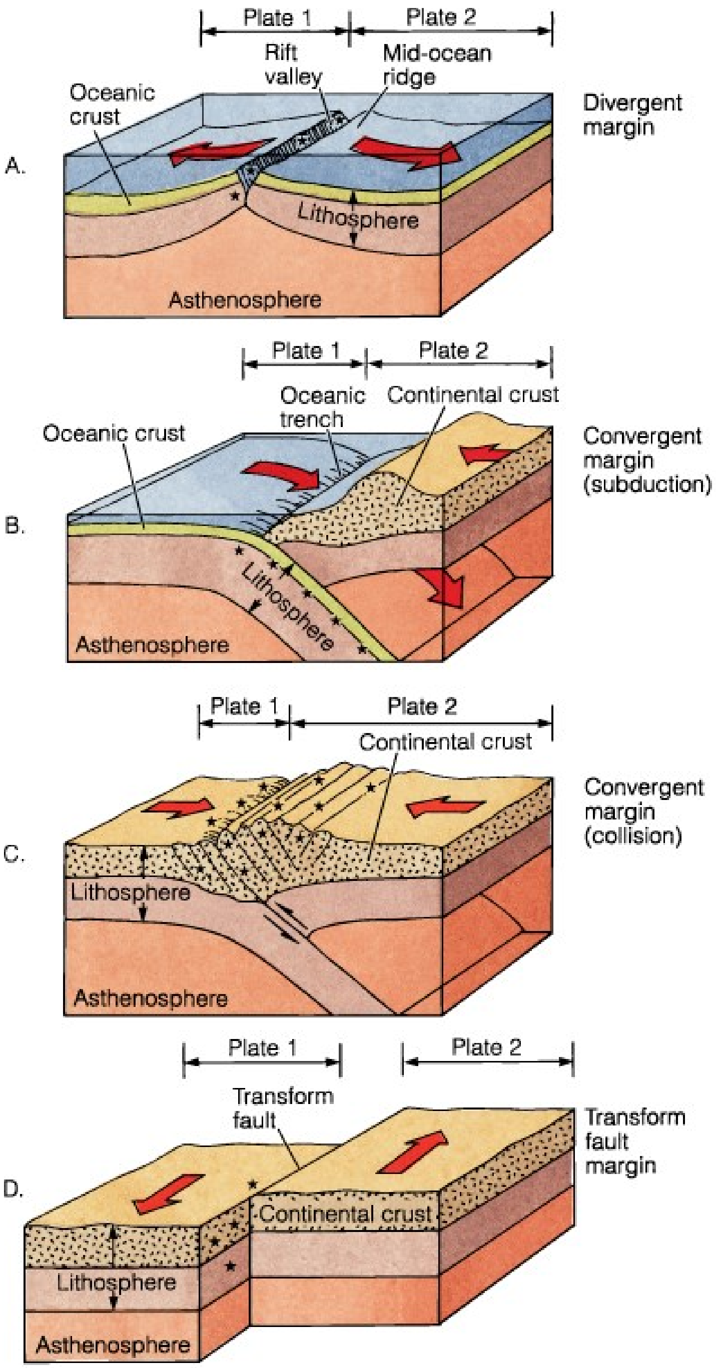
Rolf Kilian

Ages of ocean floors: Note the different spreading rates in the Midatlantic Ridge and East Pacific Rise and that there are few remanants of oceanic crust older than100 Ma.



Earth‘s Plate Tectonic Framework





Ozeanic rift

(Mid-Ocean Ridge)

Subduktion zone at a continental margin

= Aktive Continental Margin (e.g. Andes)
= Destructive Plate Margin

Continent-Continent-Collision Zone

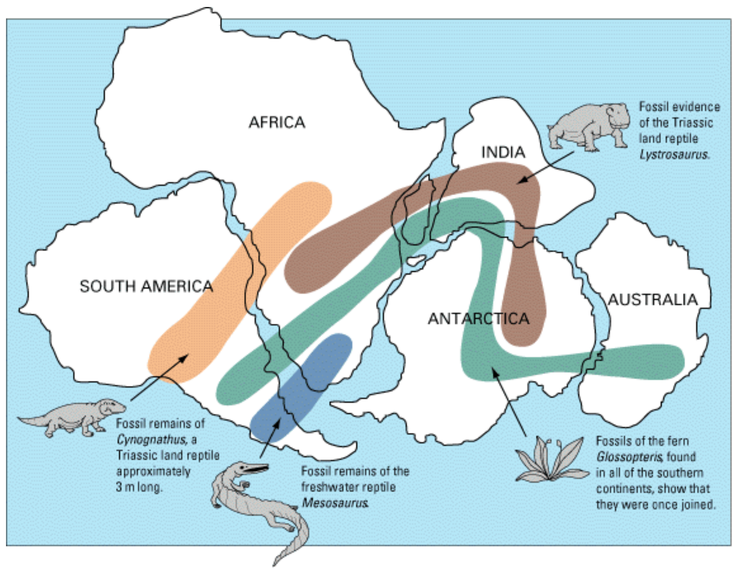
Transformfault Zone

Geological milestones of the last 90 Years

- 1915 Hypothesis of Continental Drift (Alfred Wegener)
  - Kontinent forms fit together
  - Kontinents are drifting
- 1929 Discovery of Mid-Ocean Ridges
- 1936 Mantle Convection
  - Convection cells in a plastic Earths interior
- 1960's Plate tectonic
  - Magnetic stripes of ocean floors

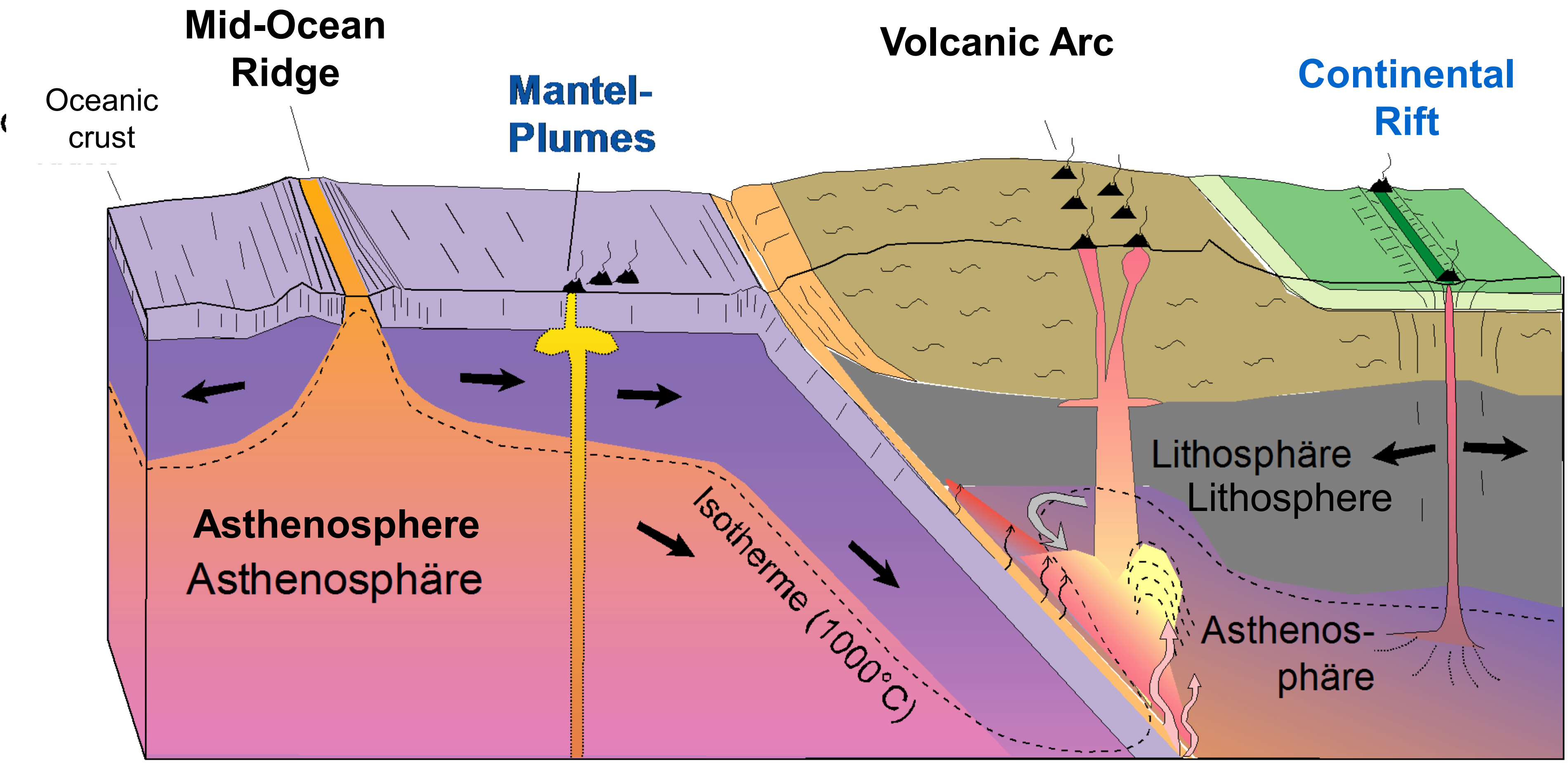
    ➔ seafloor spreading
  - Hypocenters of Earthquakes

    indicate subduction zones (Benioff-Zone)



Paläogeographische Zusammenhänge

Major components of the Plate Tectonic Model:

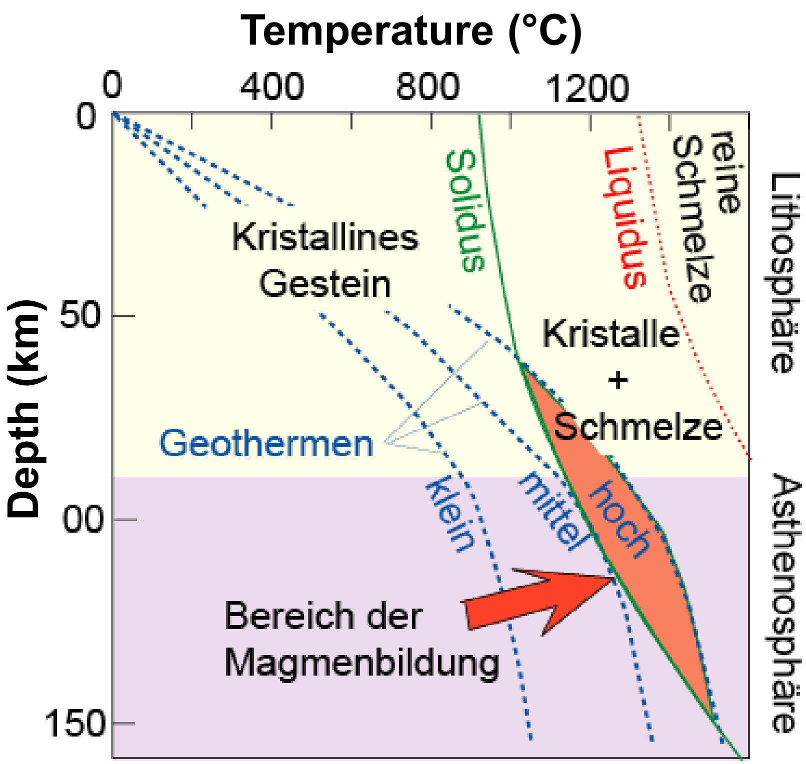


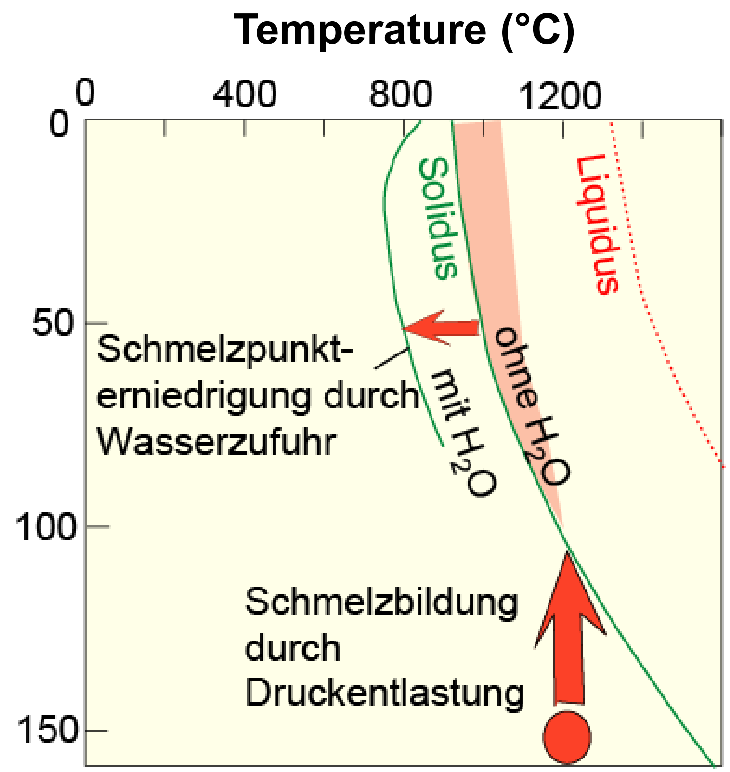
Magma genesis

There are two relevant types of magma formation within the crust-mantle system of the Earth:

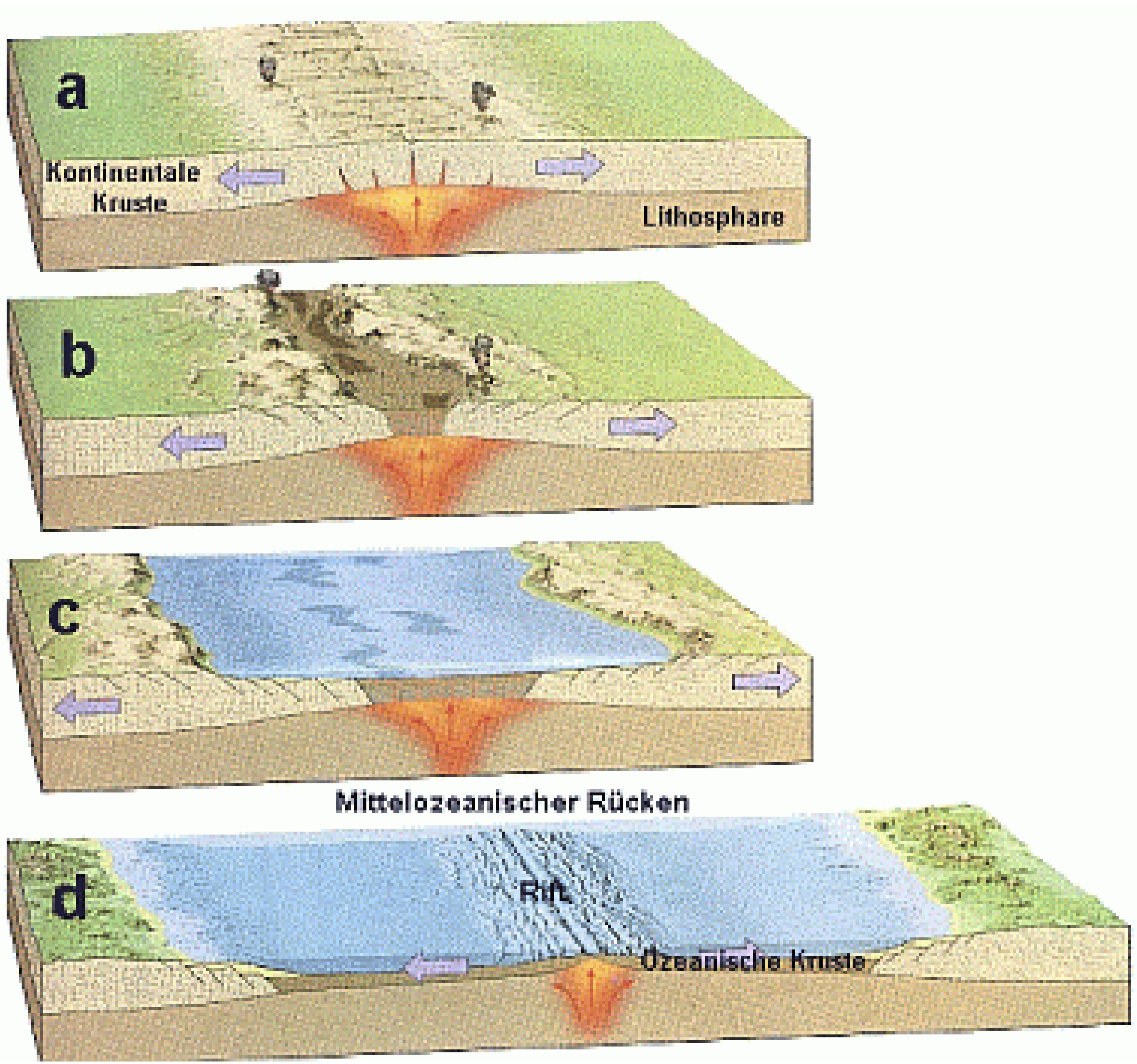
1. **Dehydratation melting ocurs when the thermal and pressure stability of hydrated minerals becomes exeeded (e.g. amphibole and biotite):**
   => Increase in water partial pressure
   => Decrease in melting point . Typical scenario for subduction realted magmas.

2. **Decopression melting occure when rocks experience an adiabatic decompression (without significant cooling). This causes a melting when lower pressures were reached. Typical for mantle plumes and mid-ocean ridges.**

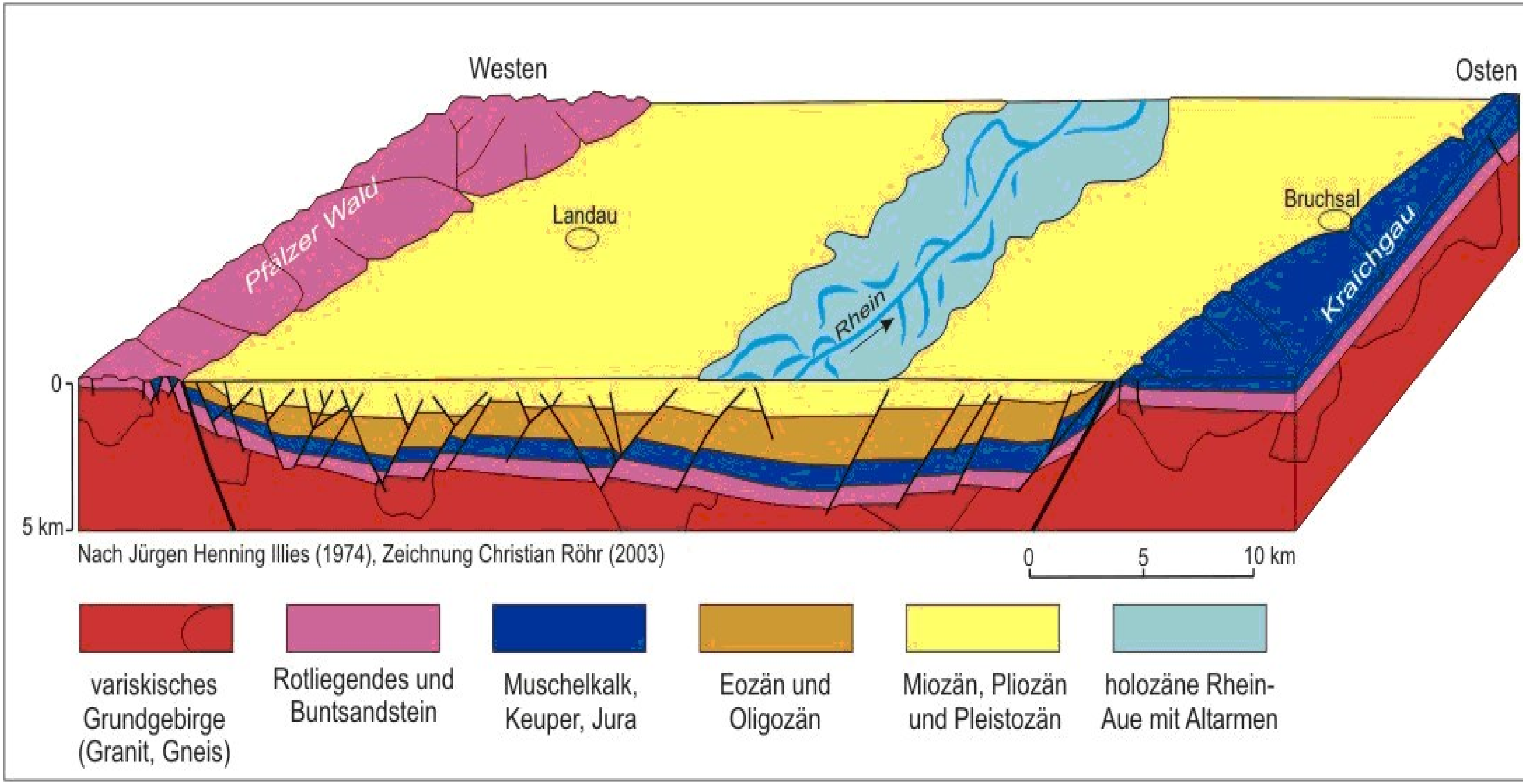




1.1.2 Development of Midocean Ridge

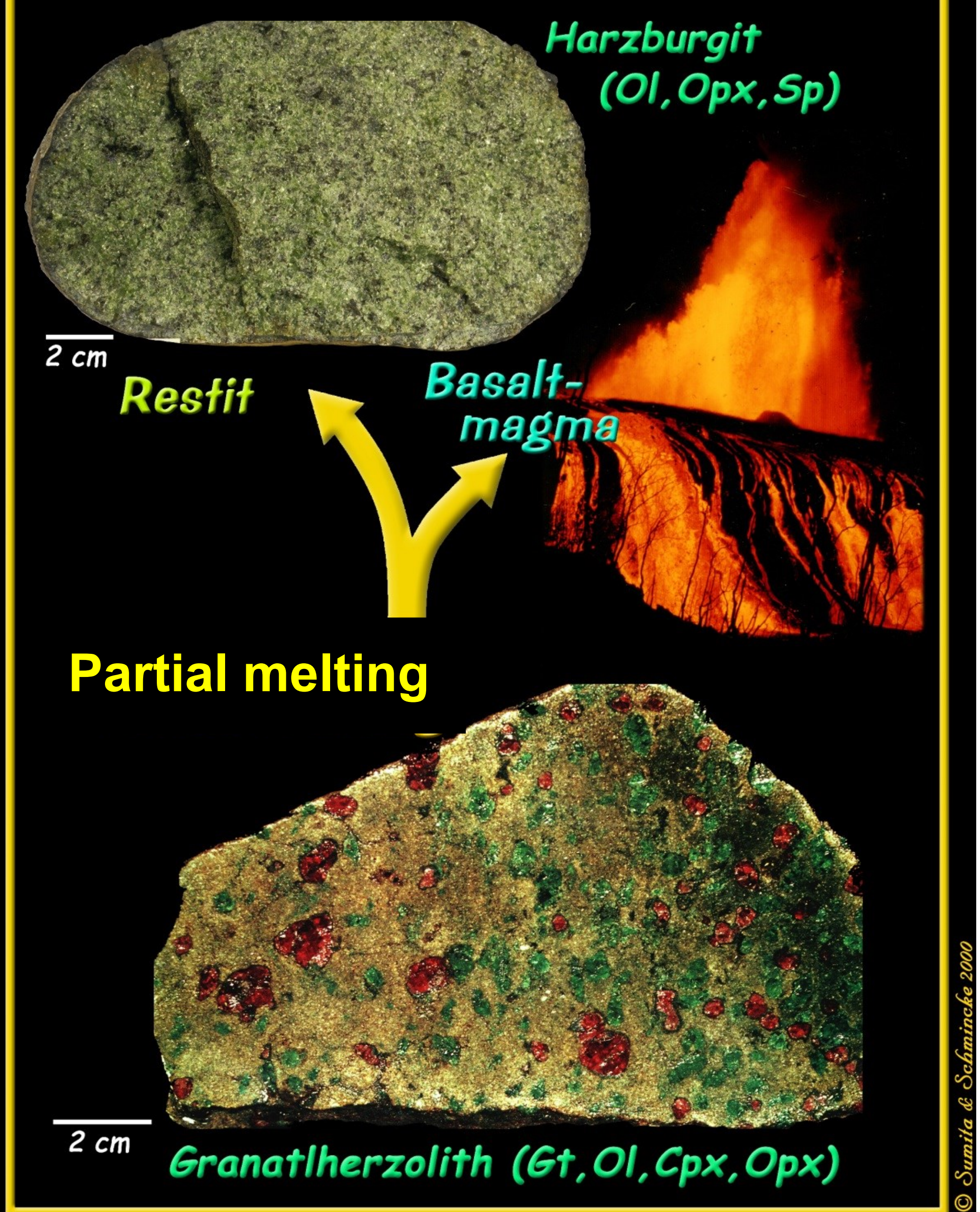


Continental Rifting: Example of the Upper Rhine Valley in southernmost Germany

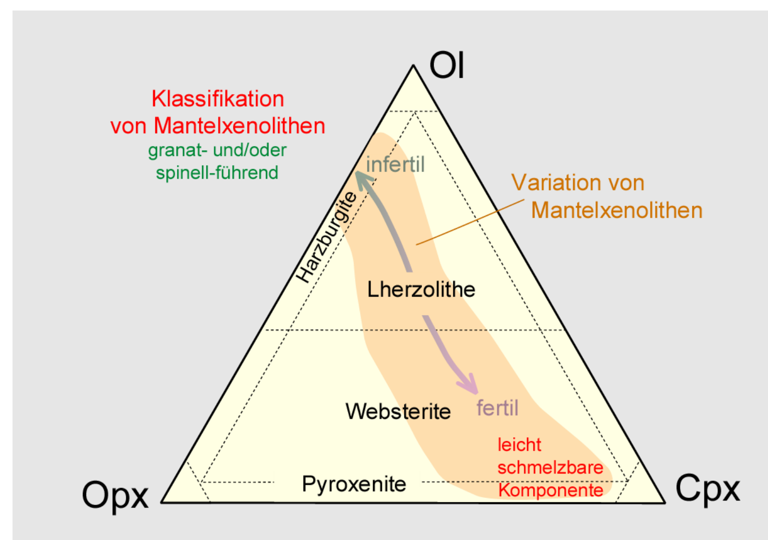


Nach Jürgen Henning Illies (1974), Zeichnung Christian Röhr (2003)

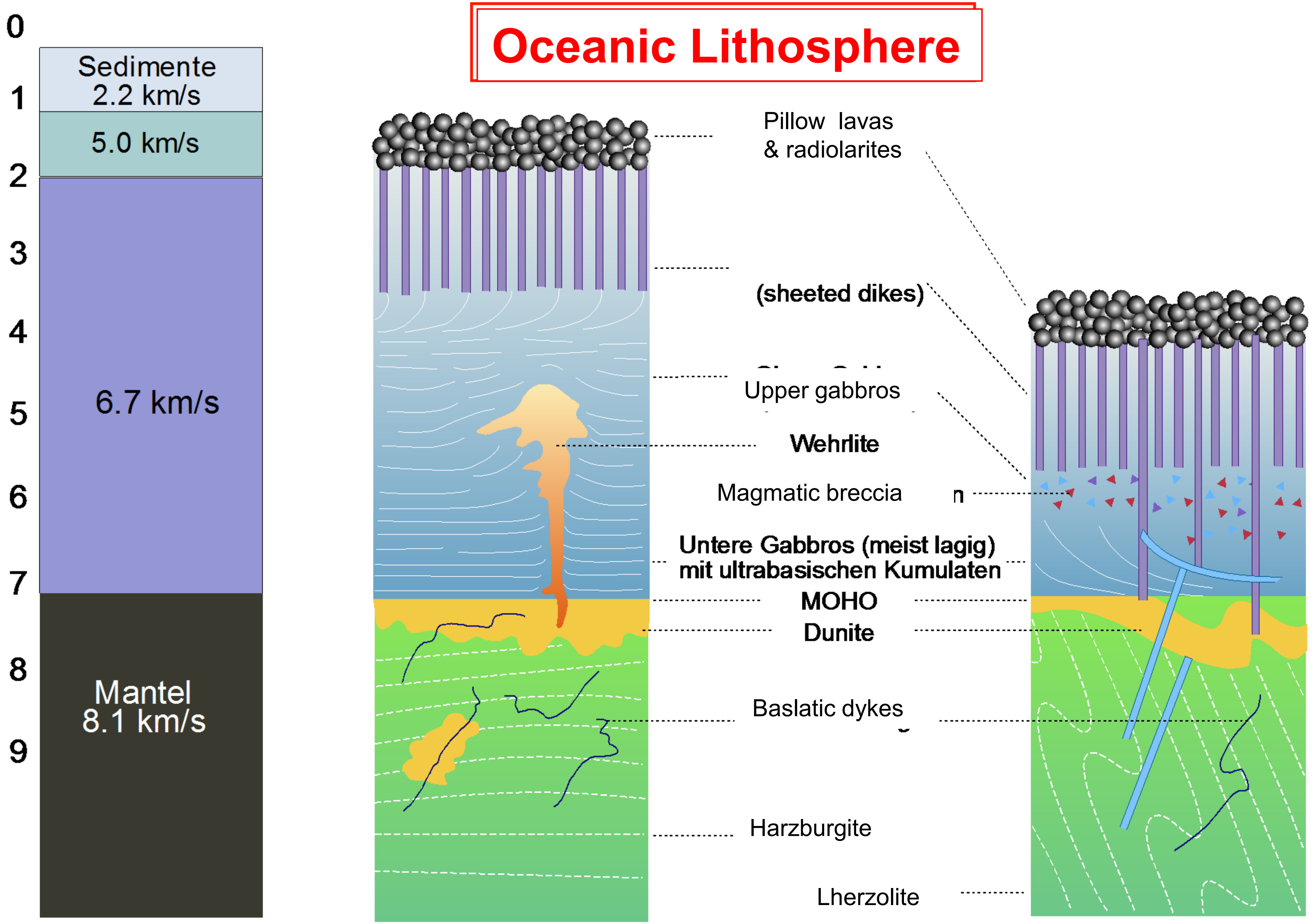
How does a basalt magma forms



The figure left shows the formation of a basalt magma from a lherolithic mantle peridotite which contains **yello-greenish olivine, dark-brown othopyroxene**, **dark-greenish clinopyrocene crystalls** and **red garnet crystals**. During the partial melting **garnet** and **clinopyroxene** became preferentially fused, since they have lower melting points. Thus the basaltic melt has much higher CaO (3 => 10 wt.%) and Aluminum (3 => 17 wt.%). This melting process also let to a harzburgitic residuum (Restite) which is infertile in composition as the trend in the pridotite triangle classification below illustrates.



Oceanic Lithosphere

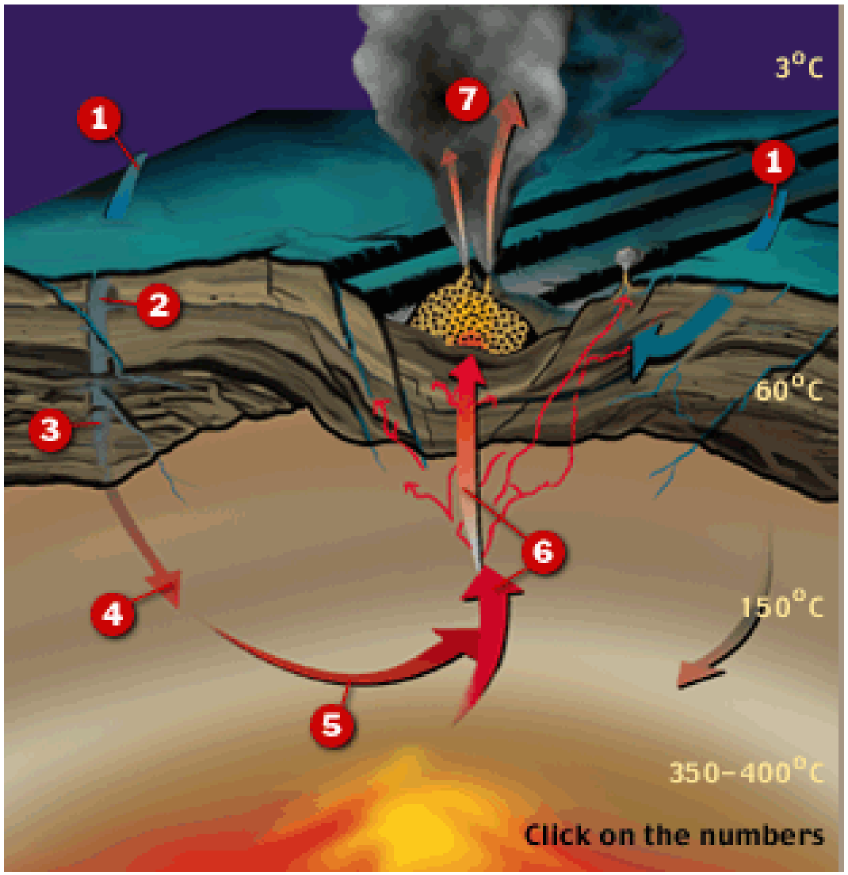


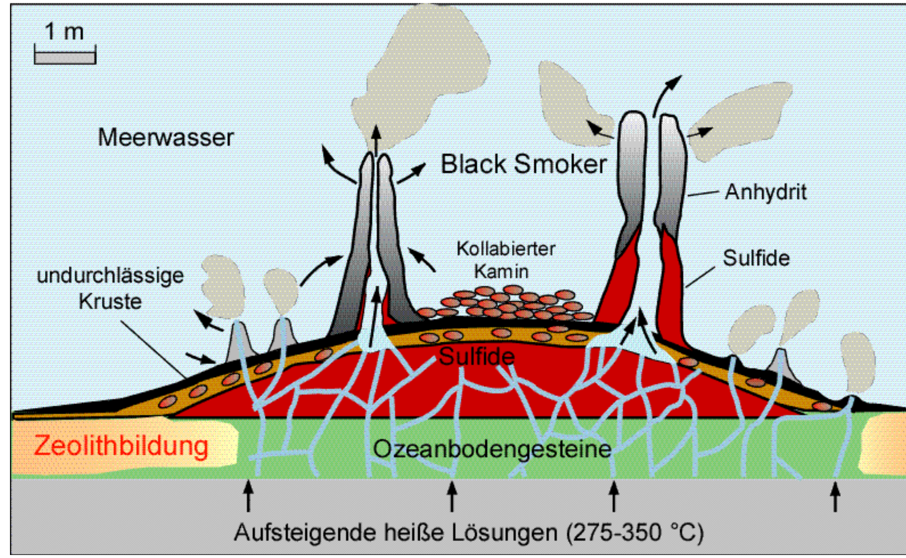
Lithosphere

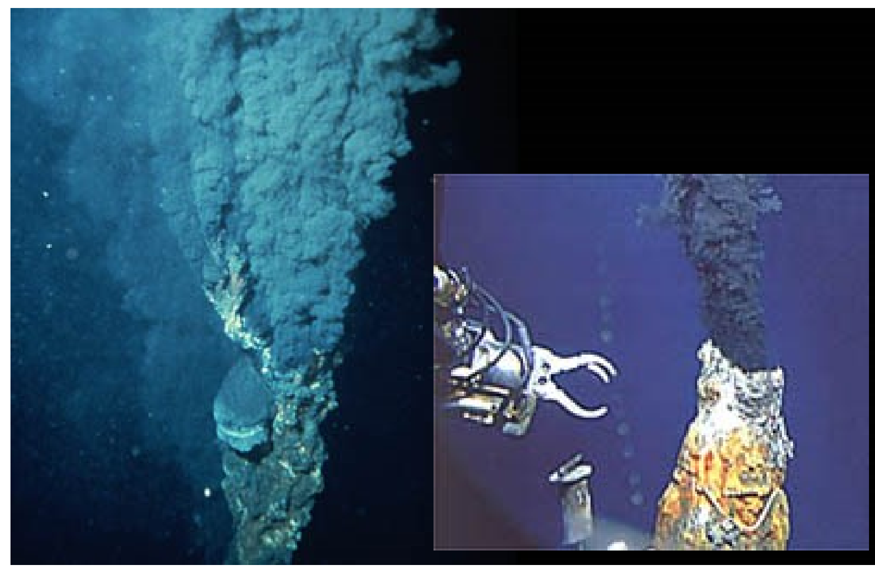
Harzburgite type

Lherzolite type

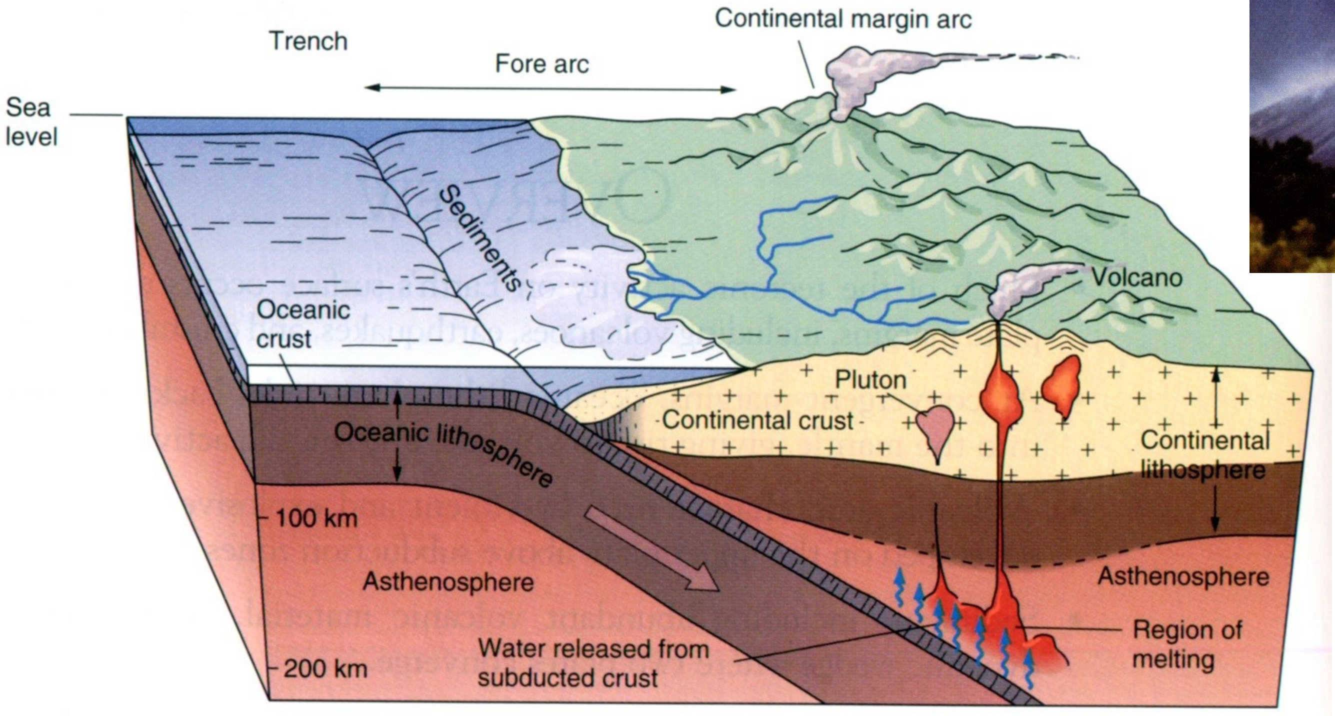
Hydrothermal activity at an oceanic spreading centre







1.2 Convergent plate boundary
1.2.1 Subduction-related volcanism

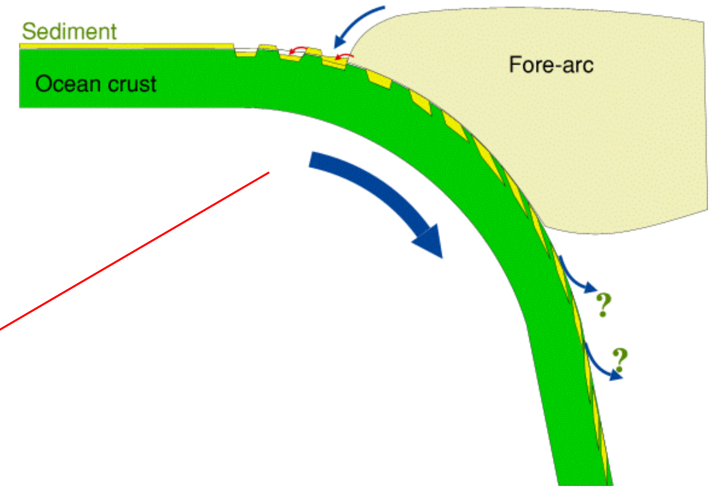


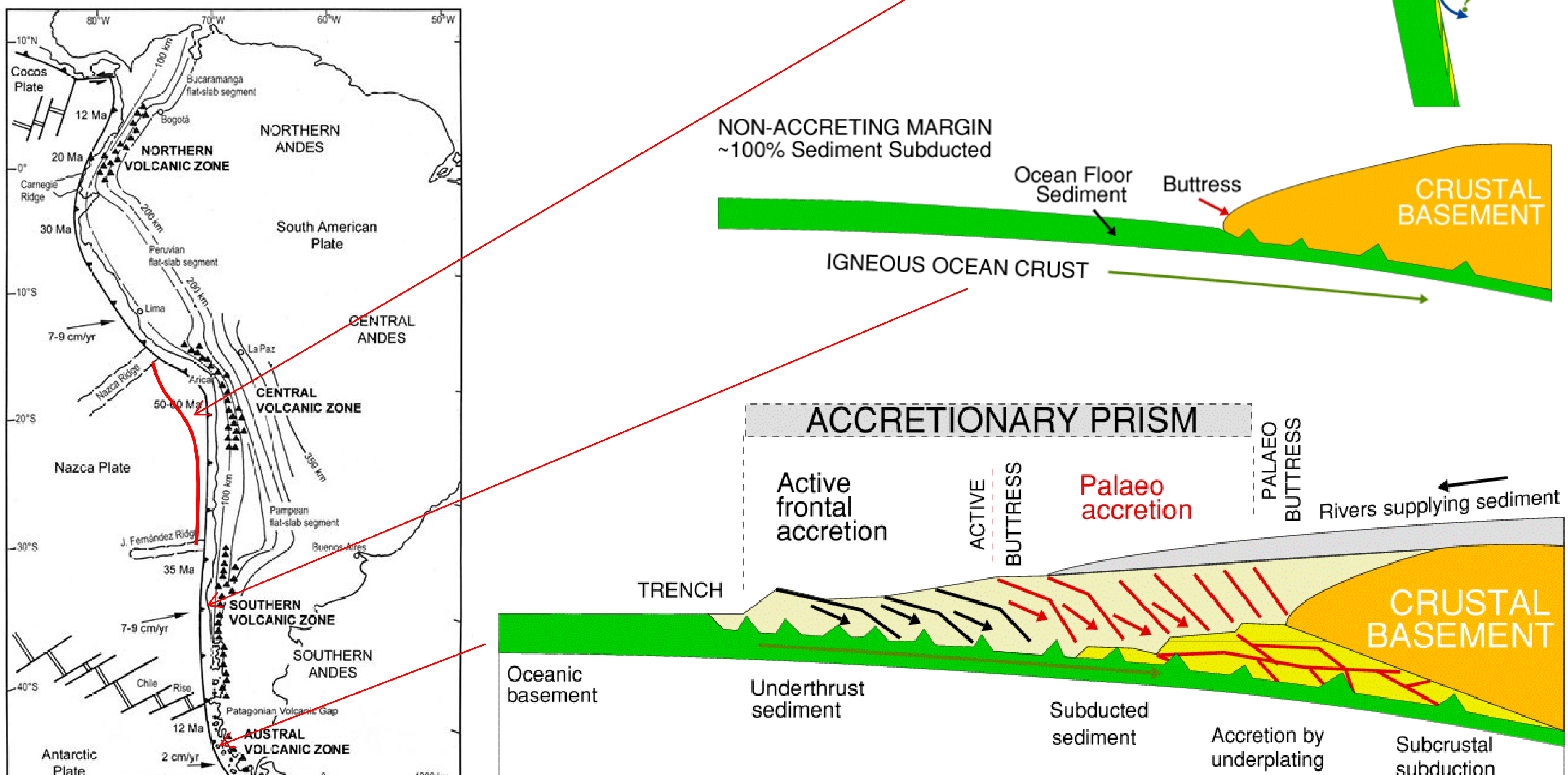
Oben: Tolbachik Vulkan, Kamchatka, Rußland. Rechts: Profil durch einer Subduktionszone mit kontinentale Kruste. Beide aus Davidson et al. 1997 „Exploring Earth“ Prentice Hall

Accretion versus subduction erosion?

Possible variables:

- Convergence velocity
- Subduction angle
- Amount of sediments in the deep sea trench
- Morphology of the oceanic crust
  (Aseismic ridges and or Midocean ridges)





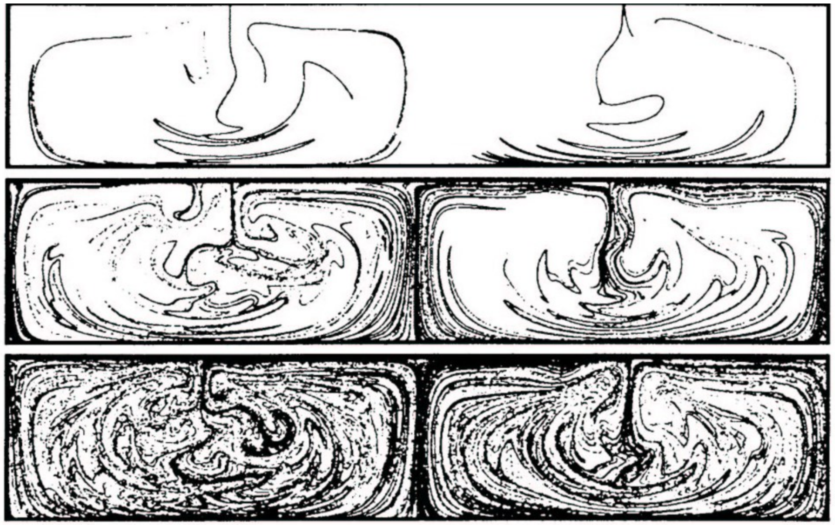
http://www.le.ac.uk/geology/art/gl209/lecture6/lecture6.html

Where and how subducted plates becomes destroyed and reworked in the mantle?

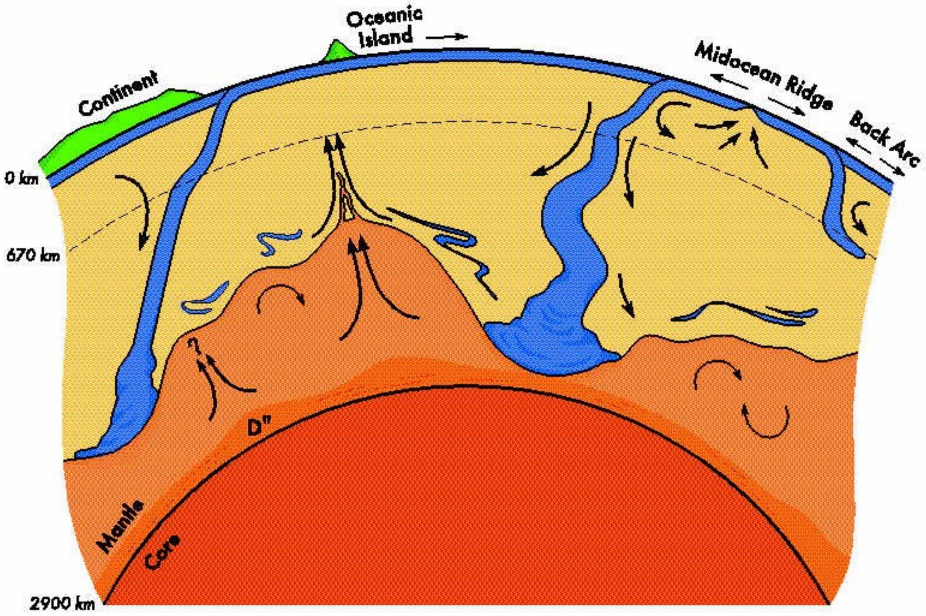
➔Completely mixed into the asthenospheric mantle?

➔Partially reworked and formation of mantle reservoirs?

➔Enrichment near the mantle-core boundary? (Mantle reservoirs)

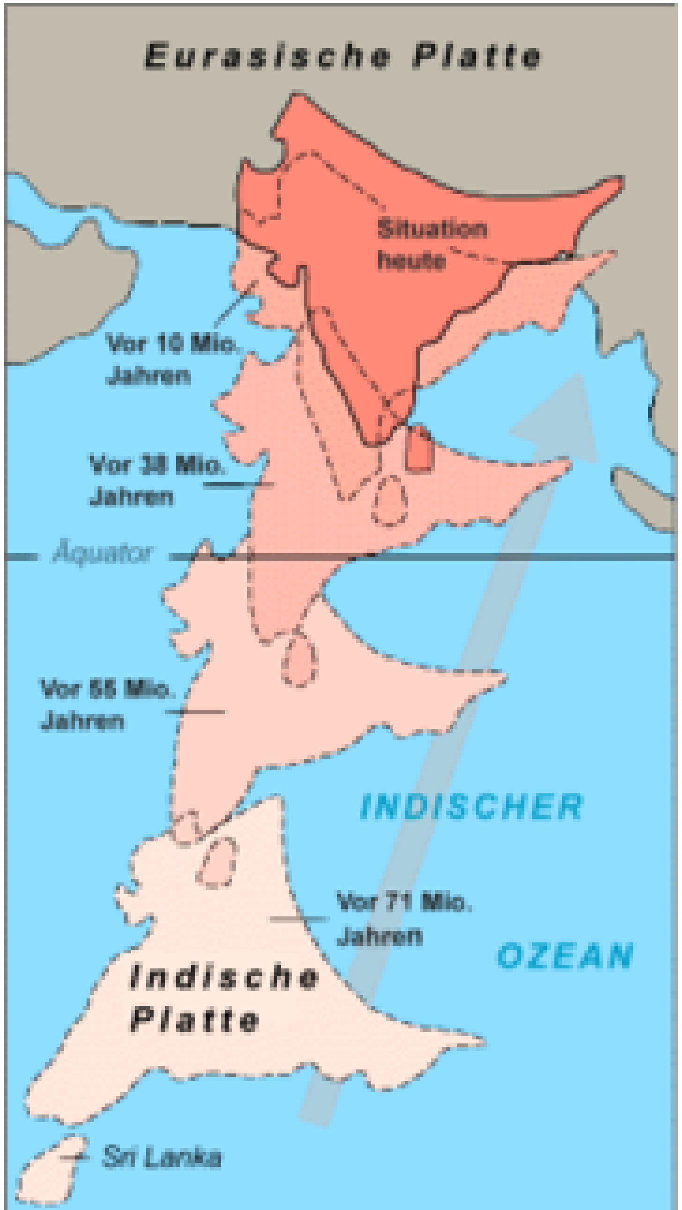


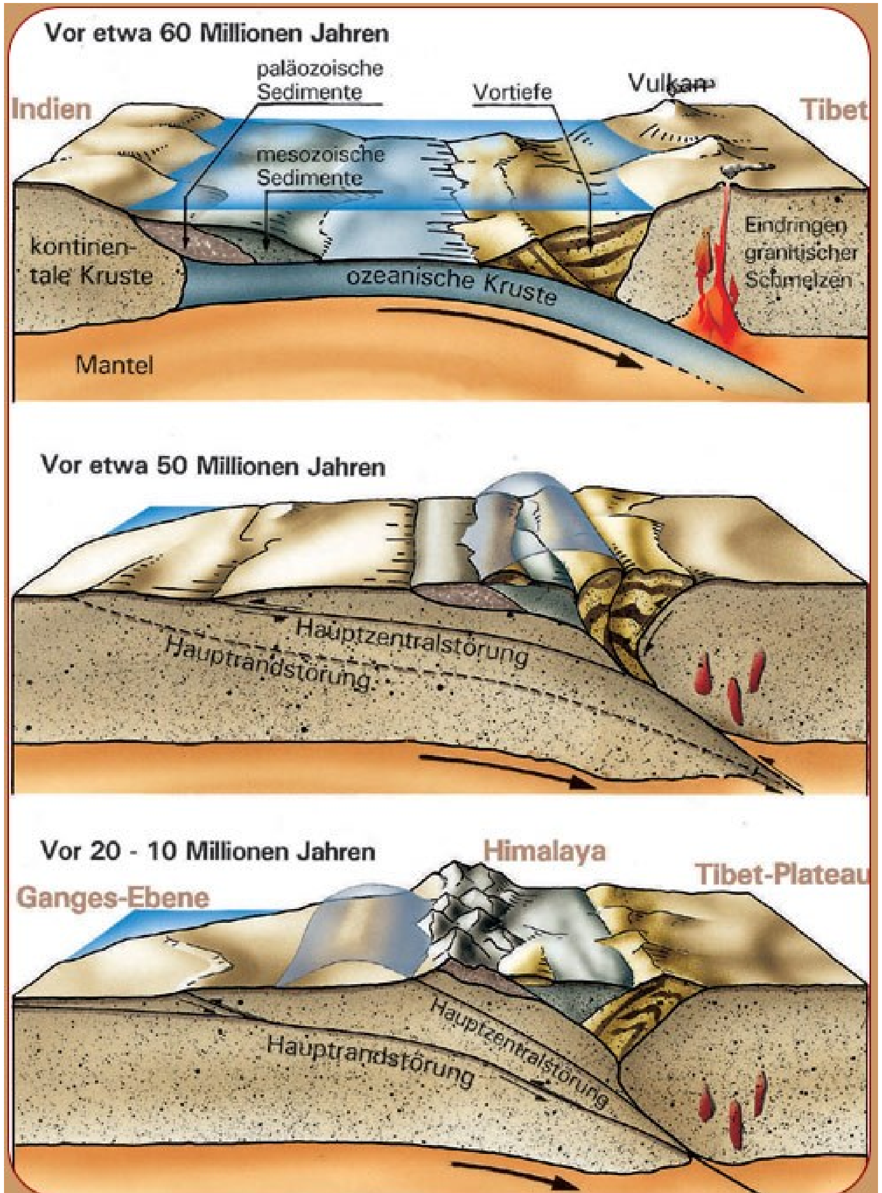
Hunt & Kellogg, JGR (2001)



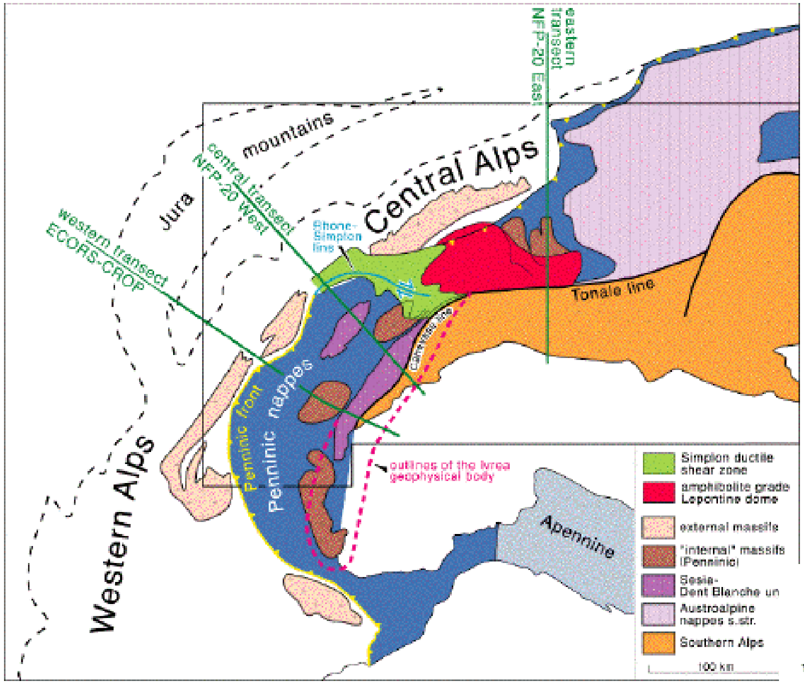
Kellogg, Hager & van der Hilst, Science (1999)

1.2.2 Continent-Continent collision: Himalaya formation due to collision of the Indian and Eurasian plates



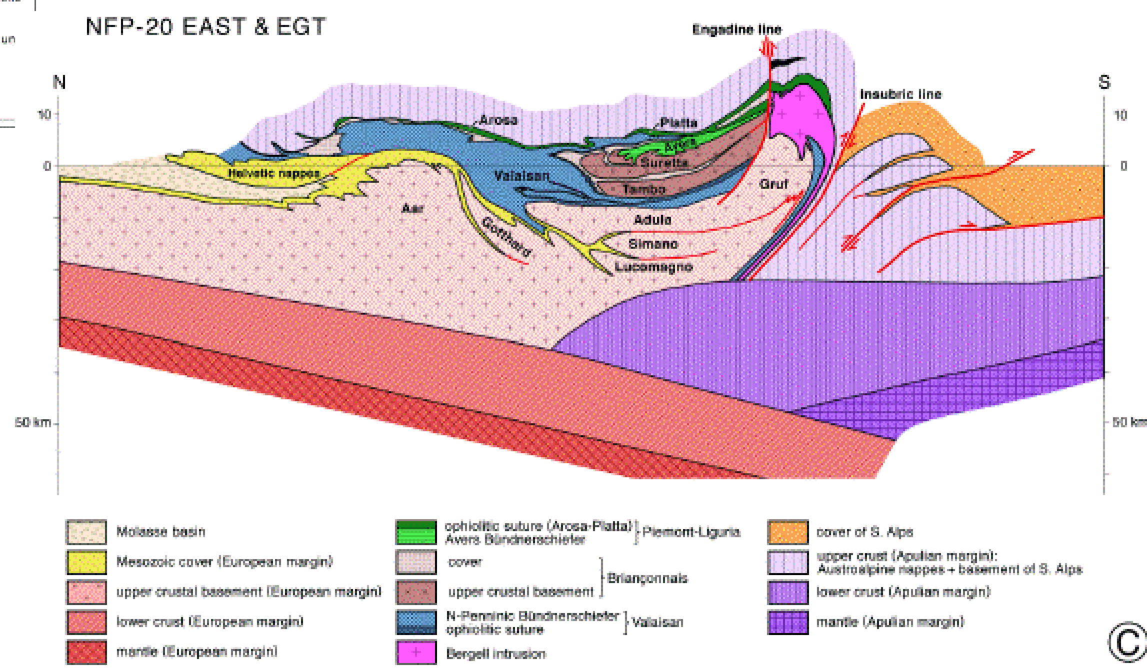


Structure of the European Alps



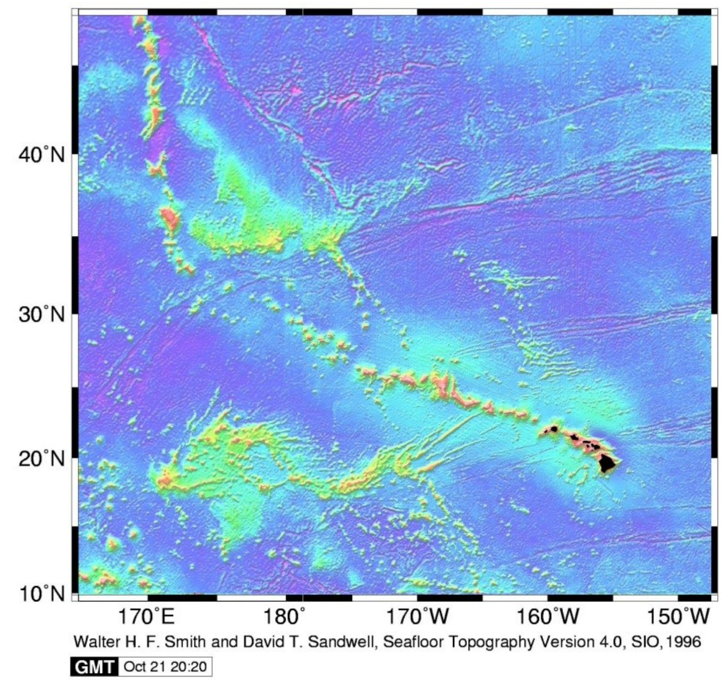
Sketch map of the Alps, indicating locations of the three geophysical-geological transects depicted in the Figure below (Schmid and Kissling 2000)

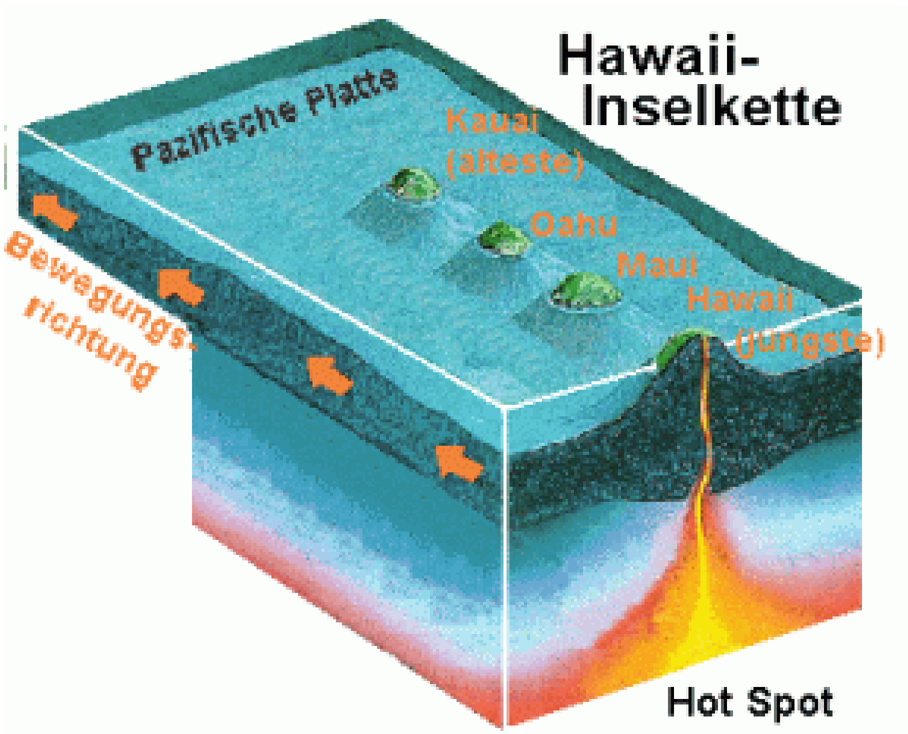
Three schematic geophysical-geological cross sections through the central Alps (The easternmost green profile is shown).

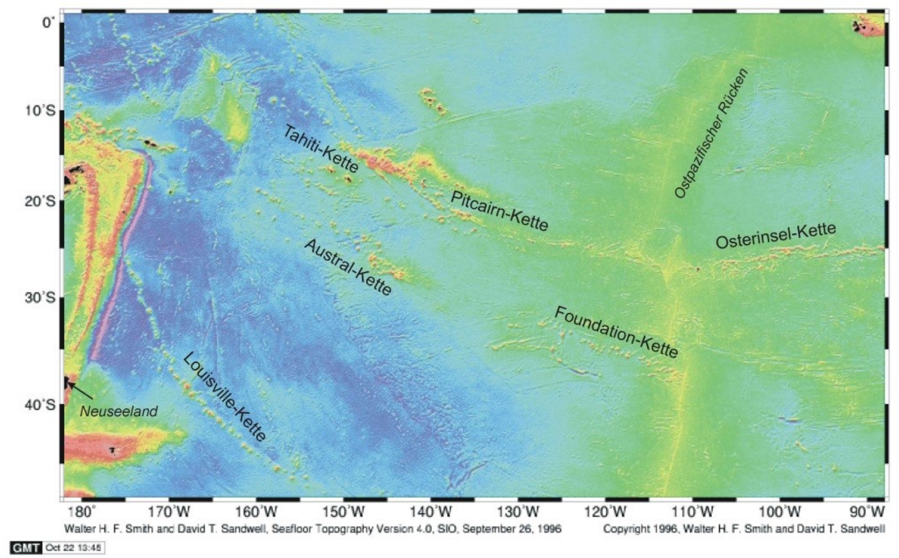


1.4 Mantle Plumes (Hotspot Volcanisms)

Since the volcanic activity above a hot spot remains relatively stationary, the relative movements of oceanic plates let to the formation of island chains, so called hot spot tracks, like at Hawai.

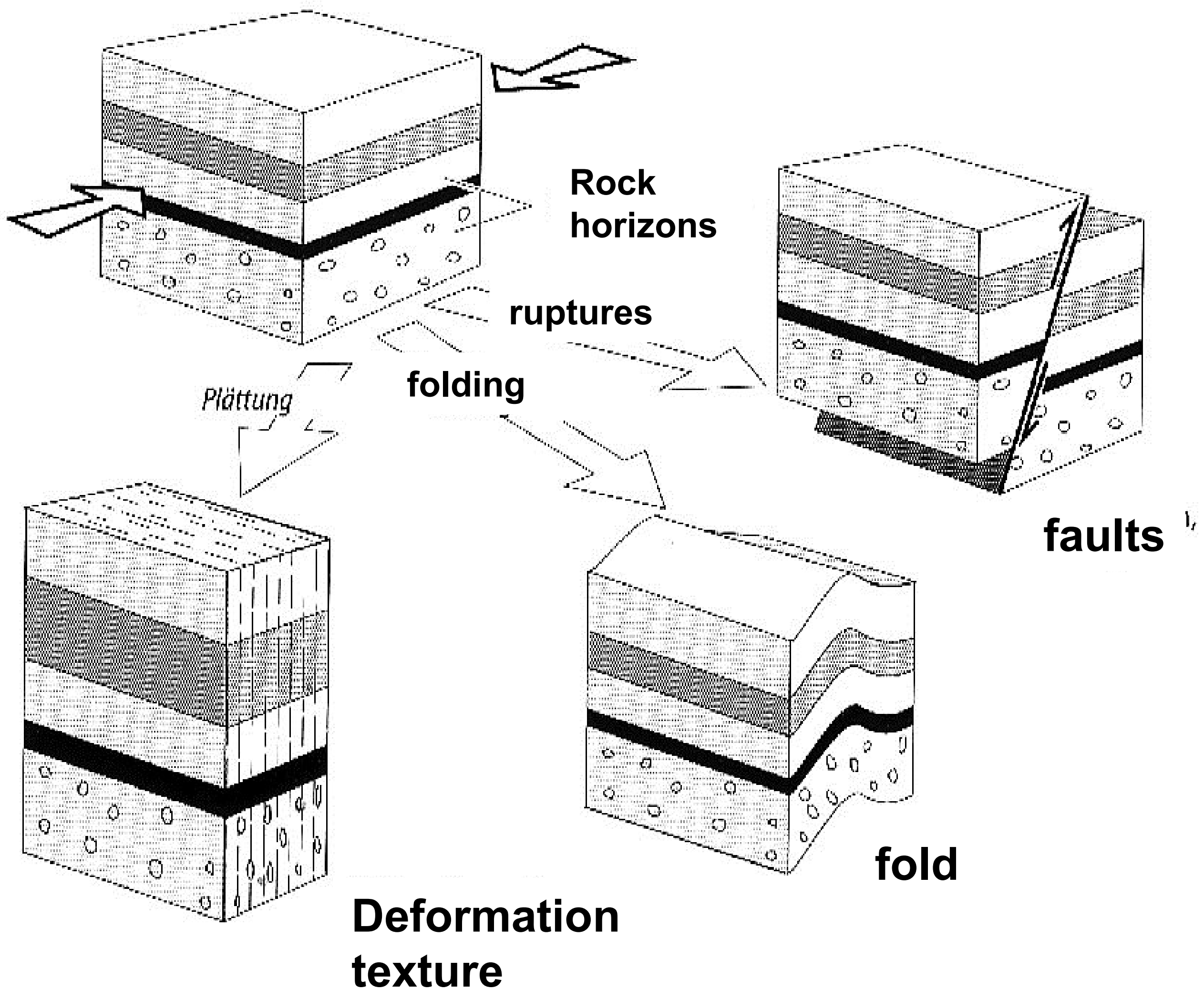






Reconstruction of the large Continent Pangäa about 250 Myr ago

1. Geological structures and tectonic features

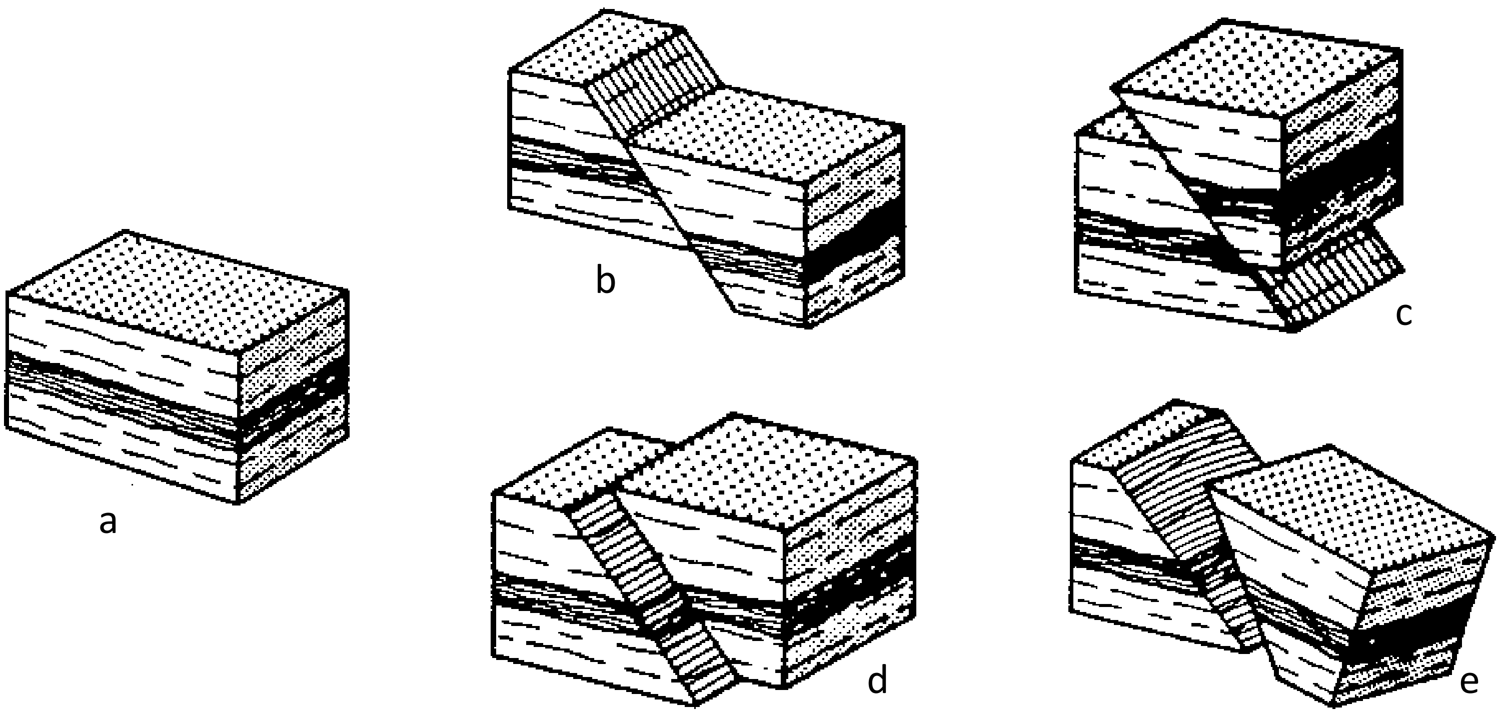


Powell, 1995

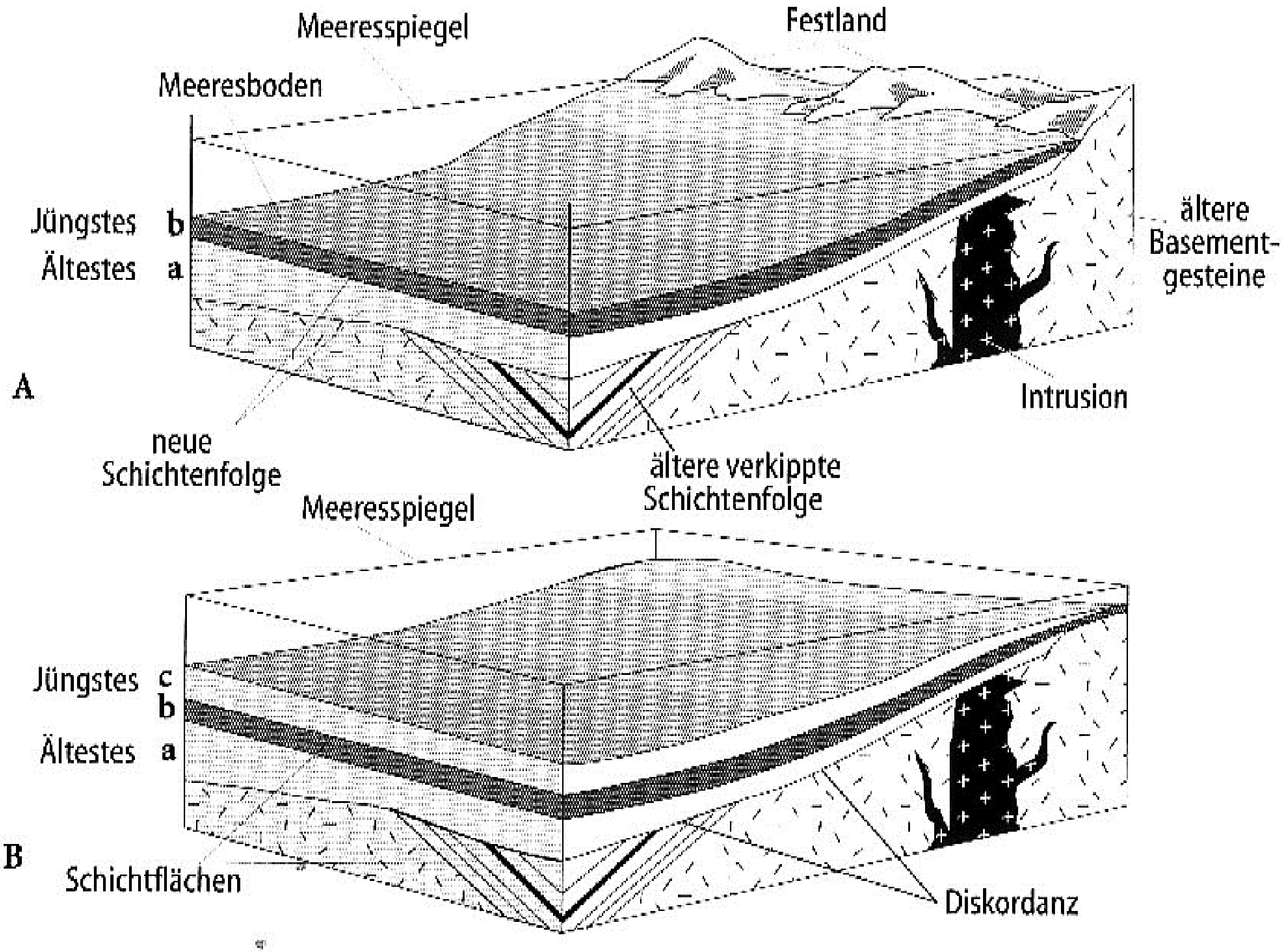
Fault systems

Tektonic features and different realtive motions of the fracture system.

Fault systems:
- Slamp fault (b)
- Thrust fault (c)
- Strike slip fault (d)
- Gyration (e)

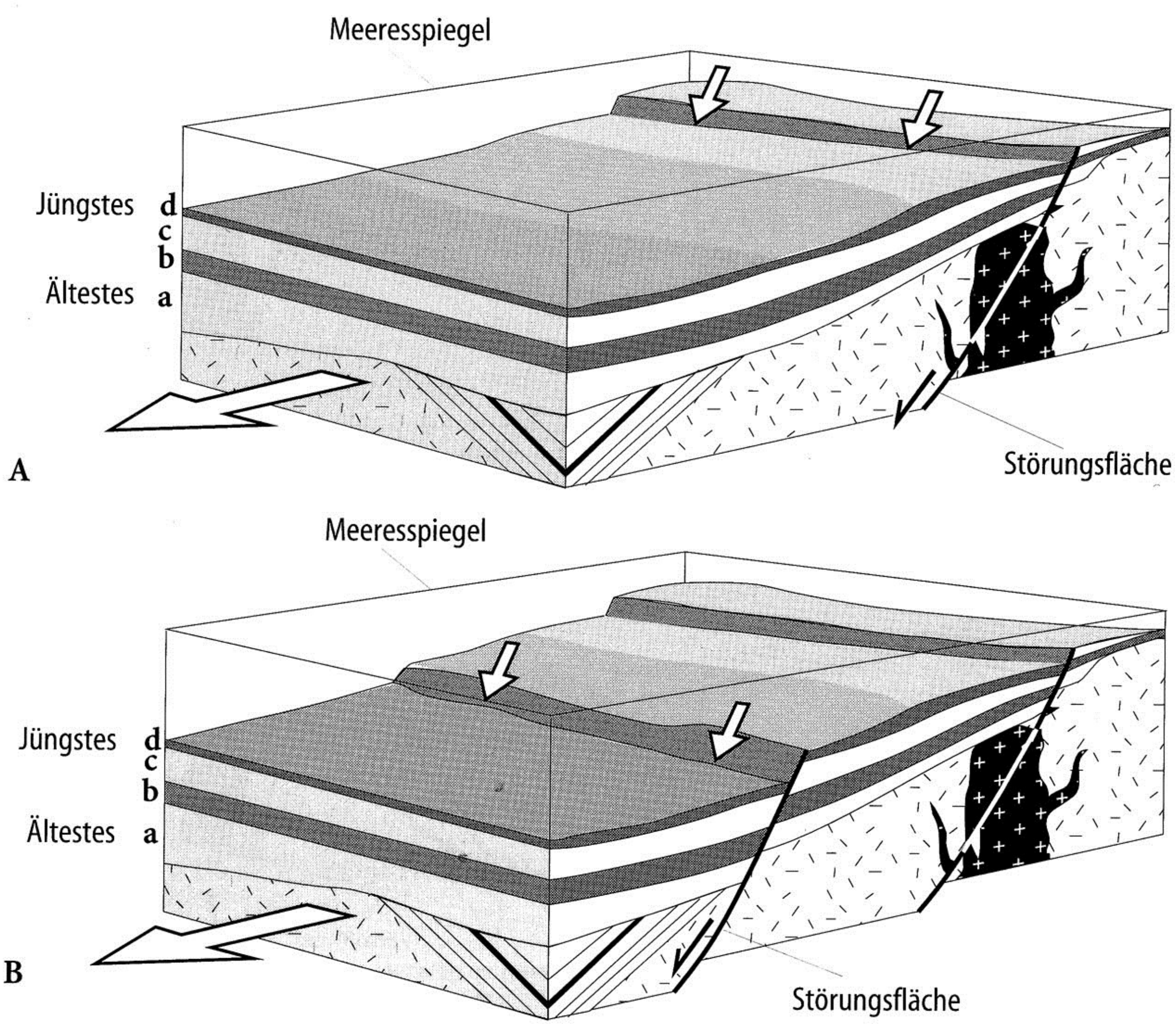


Geological units with discordances



Powell, 1995

Rotation



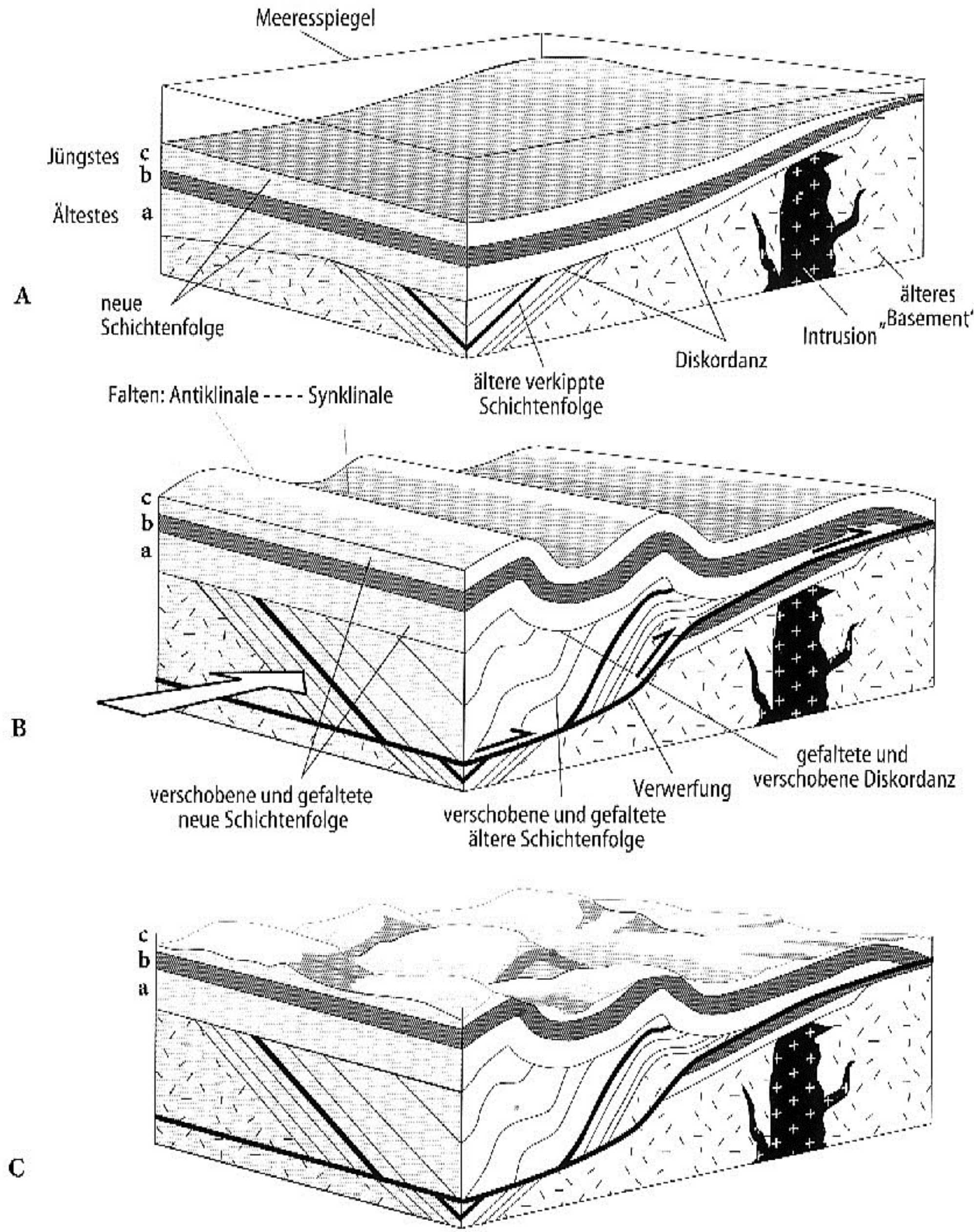
Abschiebungen

Powell, 1995

Compression

Faults,
over thrusting

Diskordance with
folding!



Powell, 1995