Natur - Erdwissenschaften

Tatort Plattengrenze

Dozierende

Renée Heilbronner

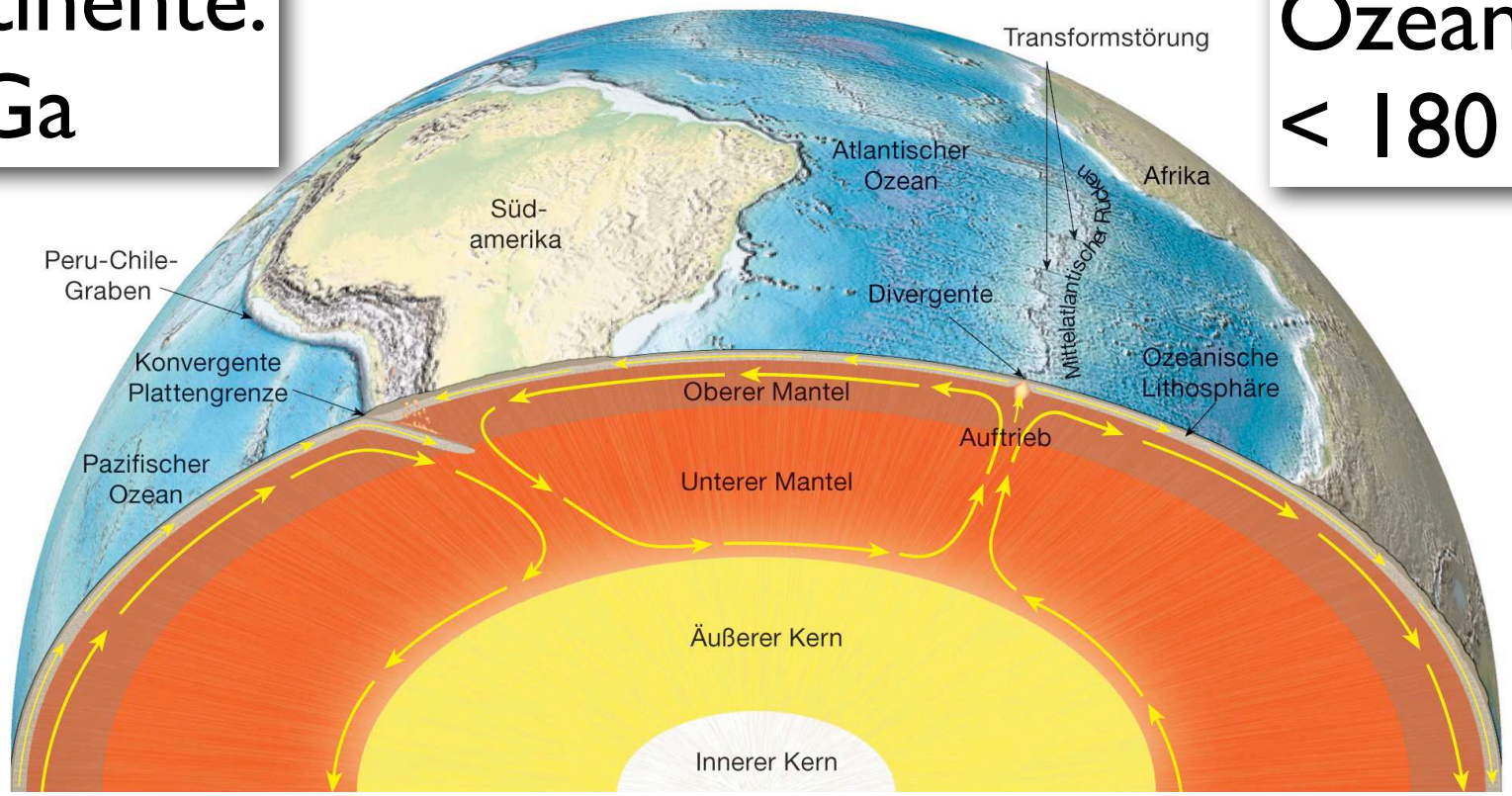
5. Nov. 12. Nov. 19. Nov. 26. Nov.

was bisher geschah ....

Mittelozeanischer Rücken produzieren ausschliesslich ozeanische Lithosphäre

Kontinente:
4.5 Ga

Ozeane :
< 180 Ma



Tatort : Konstruktive Plattengrenze

Produktion von Lithosphäre

Gesamtlänge der Ozeanische Rücken:
70'000 km (= $70 \cdot 10^6$ m)
durchschnittliche spreading rate:
7 cm / Jahr (= 0.07 m)
Produzierte Fläche pro Jahr:
$70 \cdot 10^6 \cdot 0.07 \approx 5 \cdot 10^6$ m^2 (= 5 km^2)

Gesamtoberfläche der Erde ($S = 4\pi r^2$):
$4 \cdot 3.14 \cdot (6370 \text{ km})^2 = 4 \cdot 3.14 \cdot 6.37^2 \cdot 10^{12}$ m^2
$\approx 500 \cdot 10^{12}$ m^2 (= 500 Mio. km^2)

Produktion von Lithosphäre

im Verhältnis: $\frac{5 \cdot 10^6\ m^2}{500 \cdot 10^{12}\ m^2} \approx 10^{-8}$

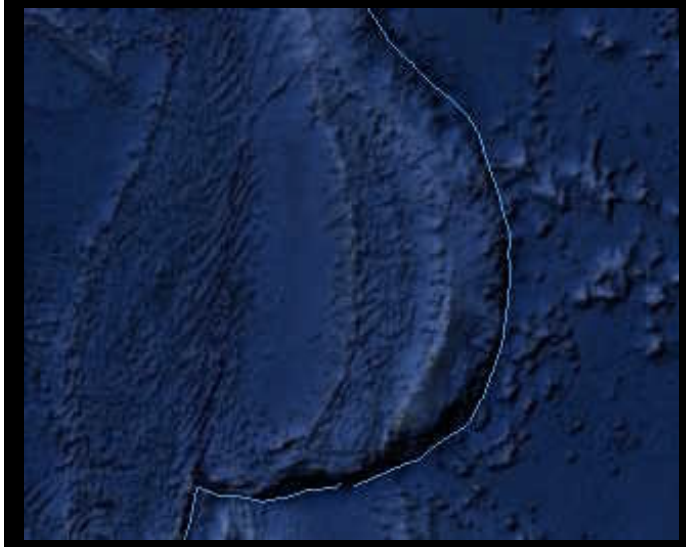
$\Rightarrow$

in 10^8 Jahren (= 10 Ma) wird die Erdoberfläche verdoppelt !!

Da dies nicht geschieht ....
muss die Oberfläche wieder vernichtet werden.

Destruktive Plattengrenzen

3 Typen:



Ozean - Ozean

Ozean - Kontinent

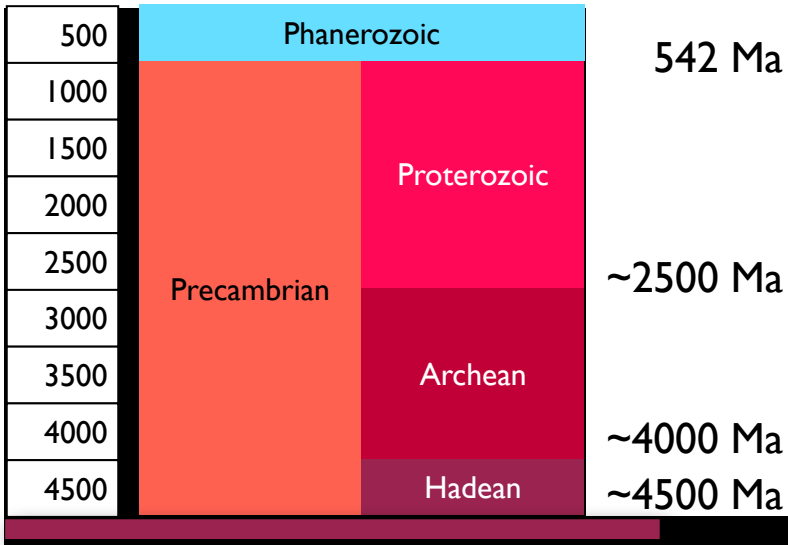
Kontinent - Kontinent

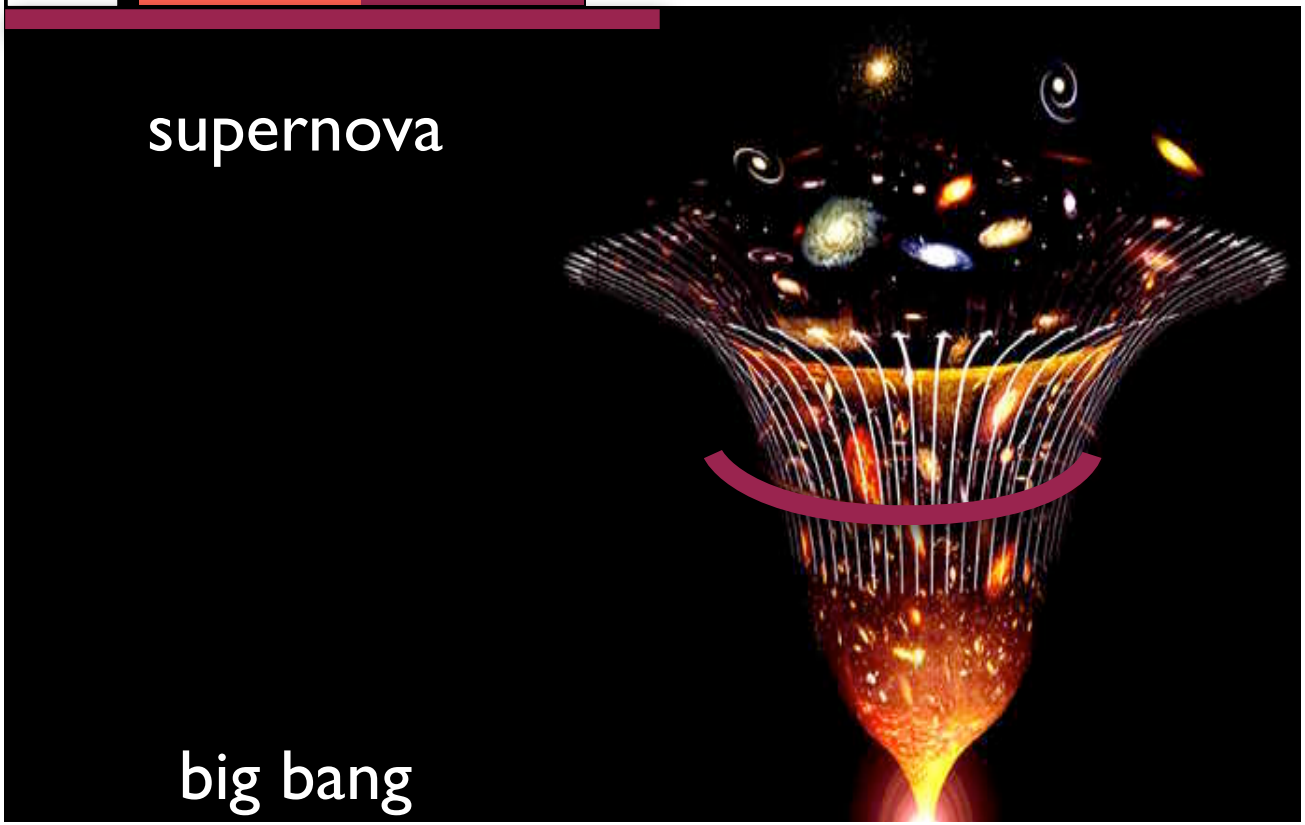
... und woher kommt die kontinentale Kruste ?!

Die Anfänge der Geodynamik

Entstehung ...

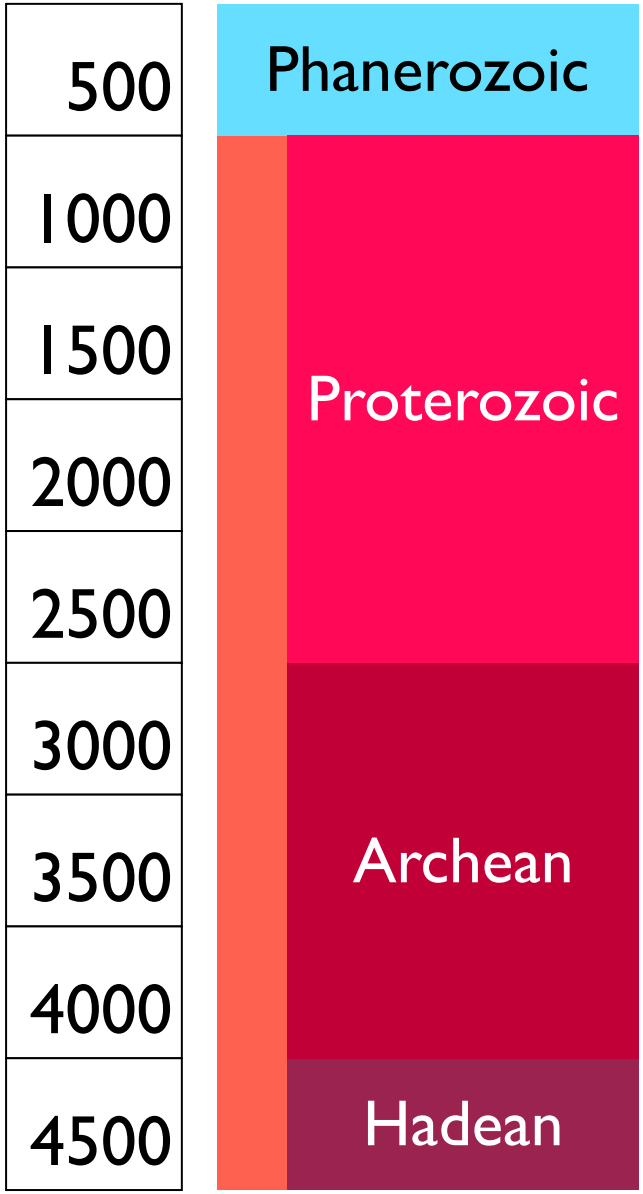
... der Erde
~ 4.5 Ga

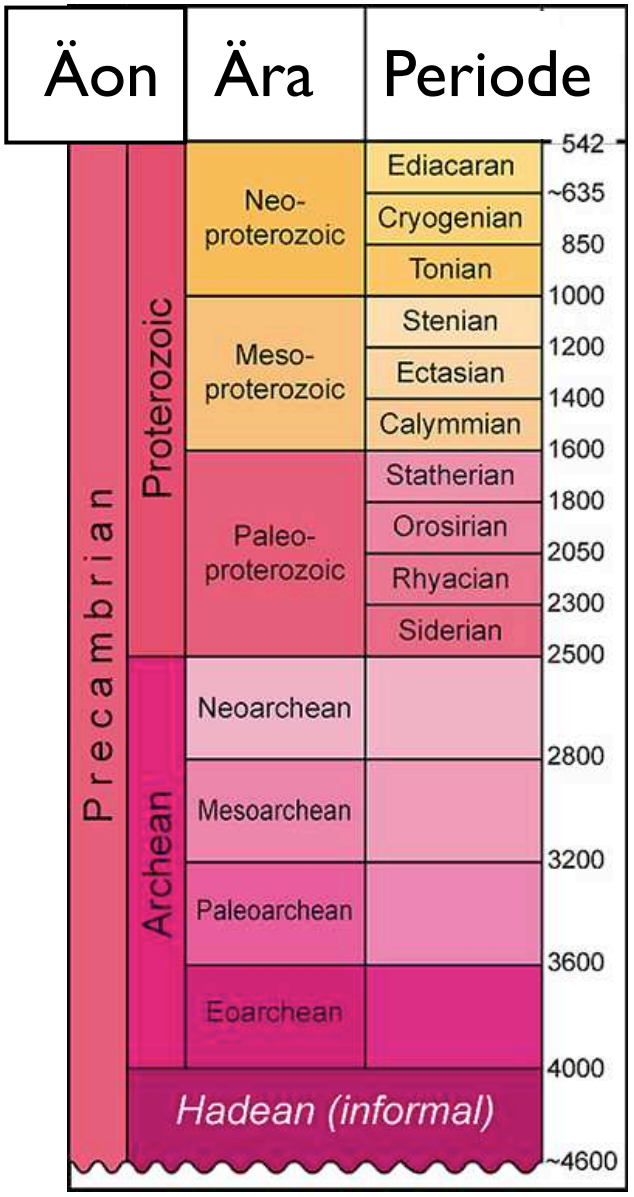




... des Universums
~13.7 Ga

Präkambrium





Hadaikum ~4.5 bis ~4.0 Ga

Hadean

Magma - Ozean

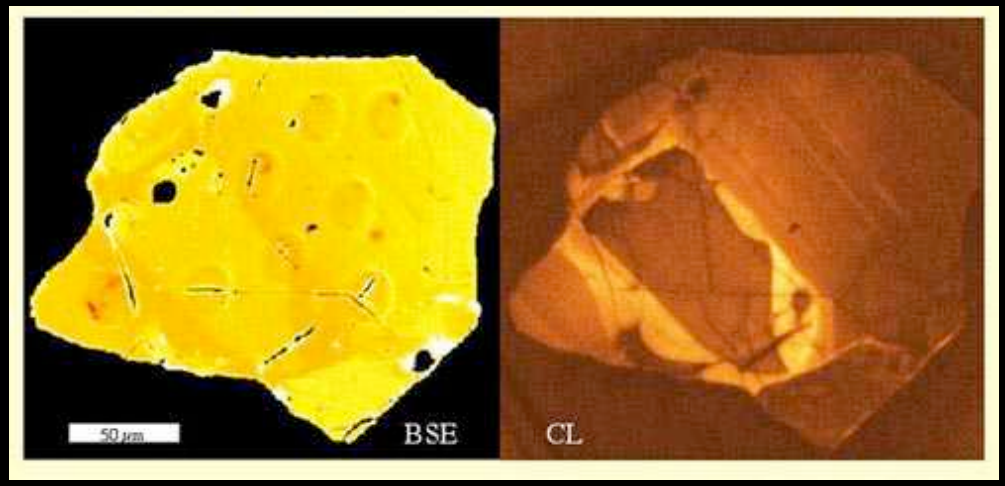
Oldest rocks

Lunar rocks (4.57 Ga)

Acasta gneiss (3.96 Ga)
NW Territories, Canada

Oldest minerals

Zirkon in Sandkorn, West Australien (4.2 Ga)

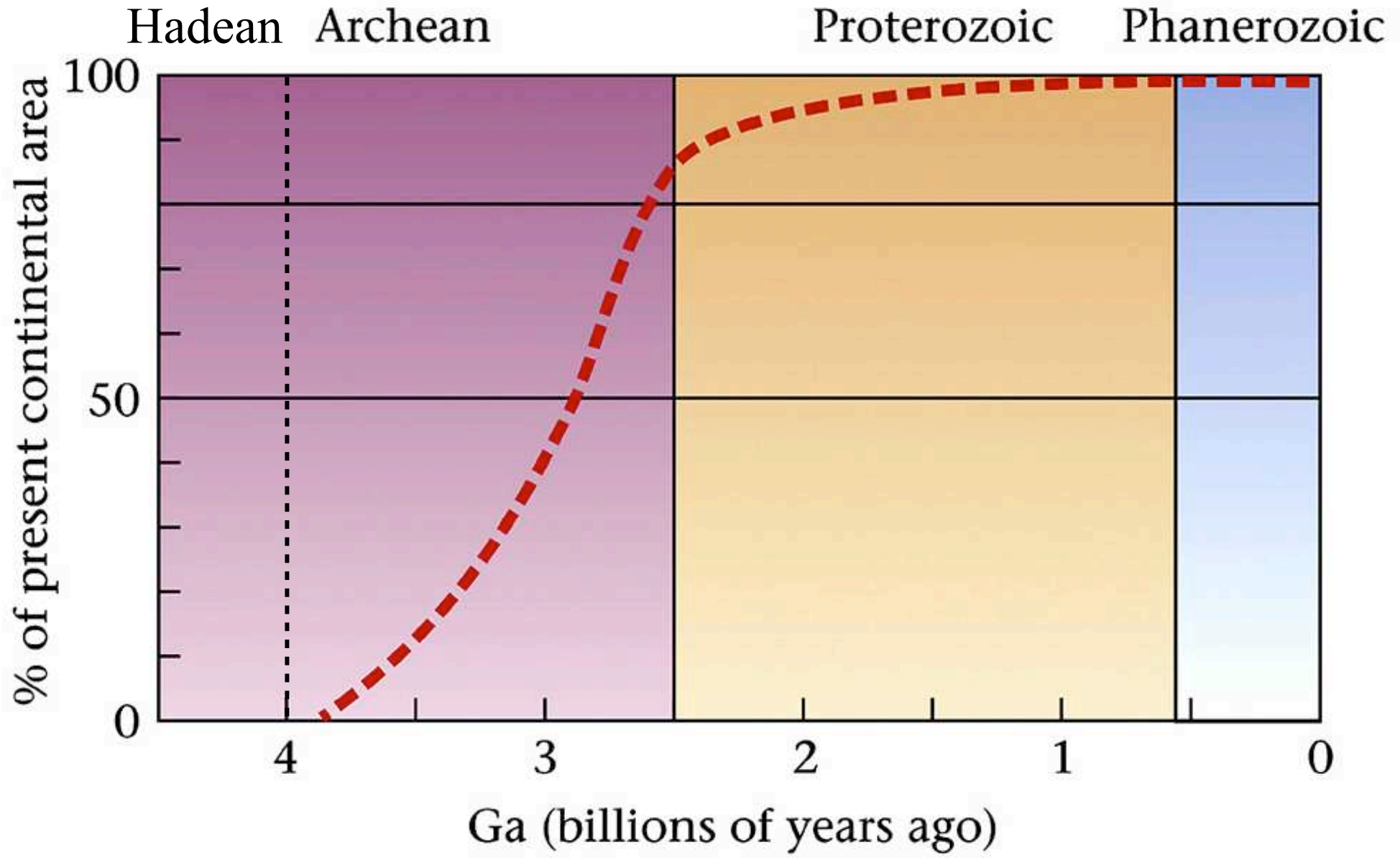


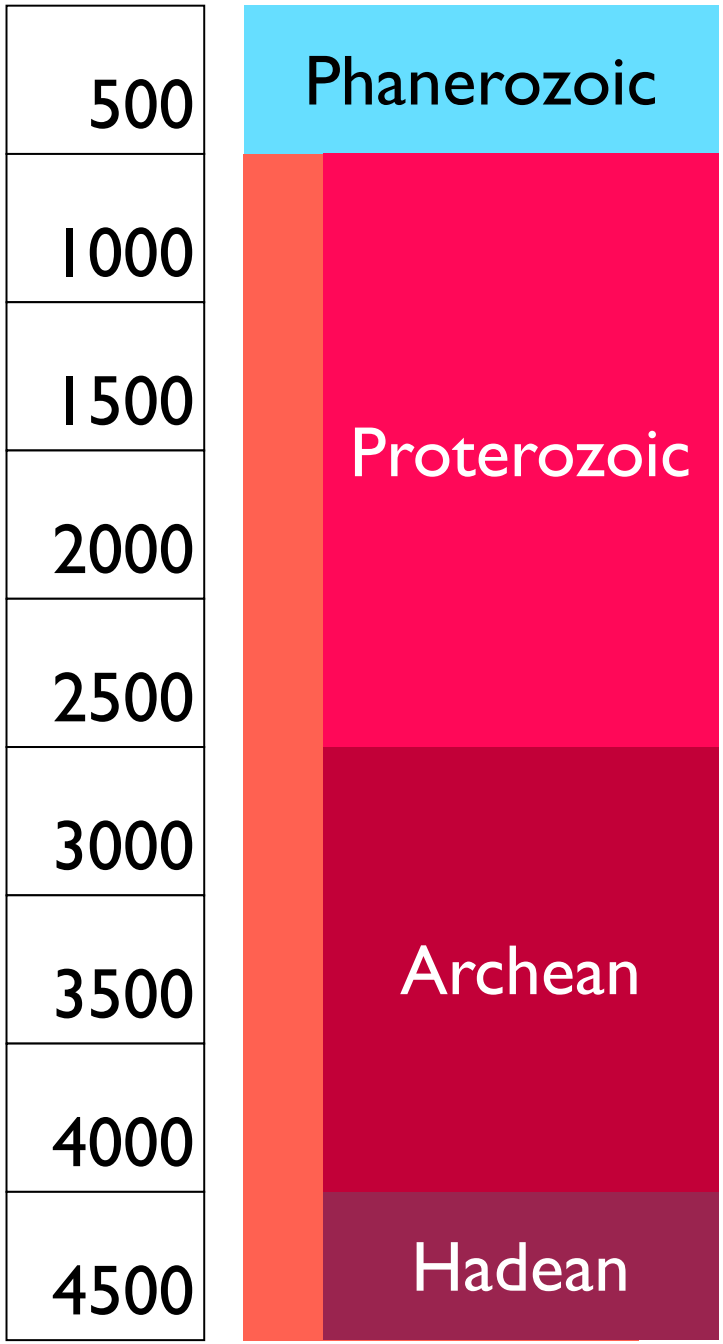
Alter des Minerals = Alter magmatisches Ereignis

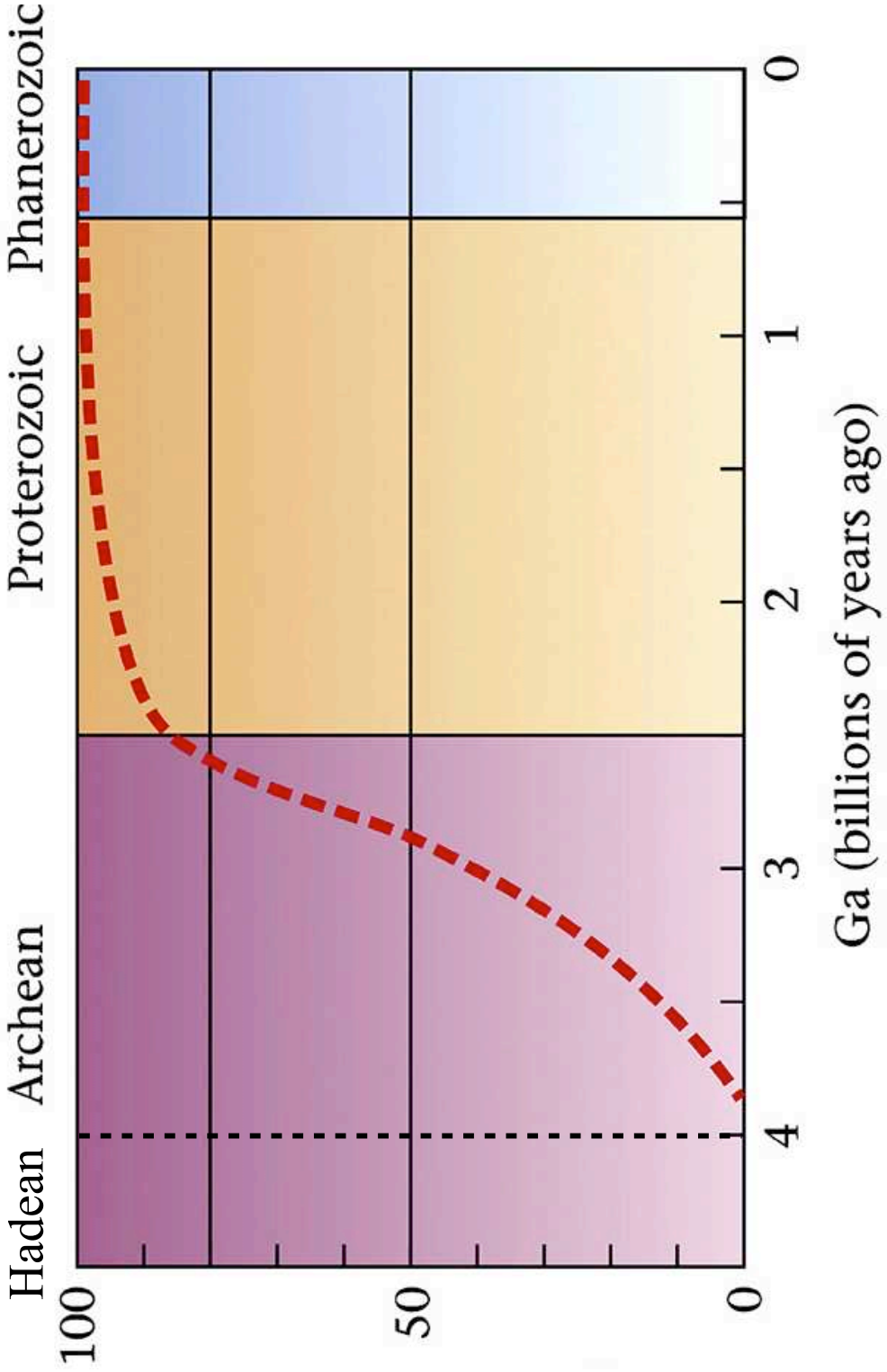
Alter des Sedimentgesteins < Alter Mineral

Deformation ist jünger als das deformierte Gestein

Archaikum: Entwicklung der Kontinente




500
1000
1500
2000
2500
3000
3500
4000
4500
Phanerozoic
Proterozoic
Archean
Hadean


Phanerozoic
Proterozoic
Archean
Hadean
100
50
0
4
3
2
1
0
Ga (billions of years ago)

Archaikum ~4.0 bis ~2.5 Ga

Archaische Terrane (Archean Terranes)

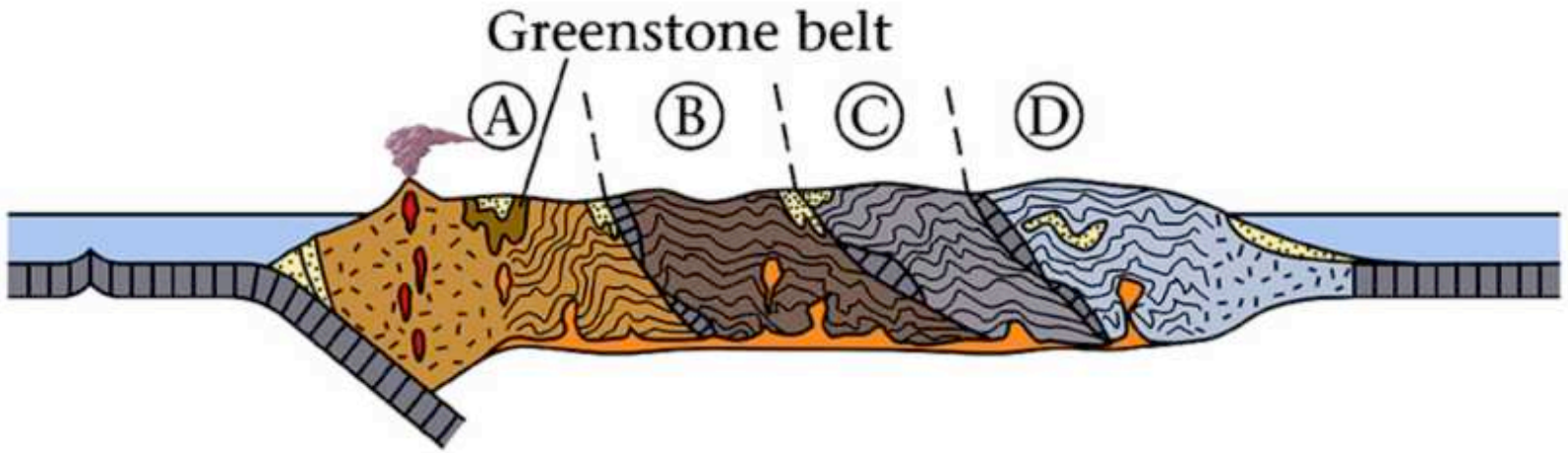
1- high grade gneissic regions (hochmetamorph)
2- greenstone belts (niedermetamorph)
3- Stark deformiert und verfaltet
4- Kontakt zwischen greenstone belts und gneissic regions ist komplex

Archaikum ~4.0 bis ~2.5 Ga

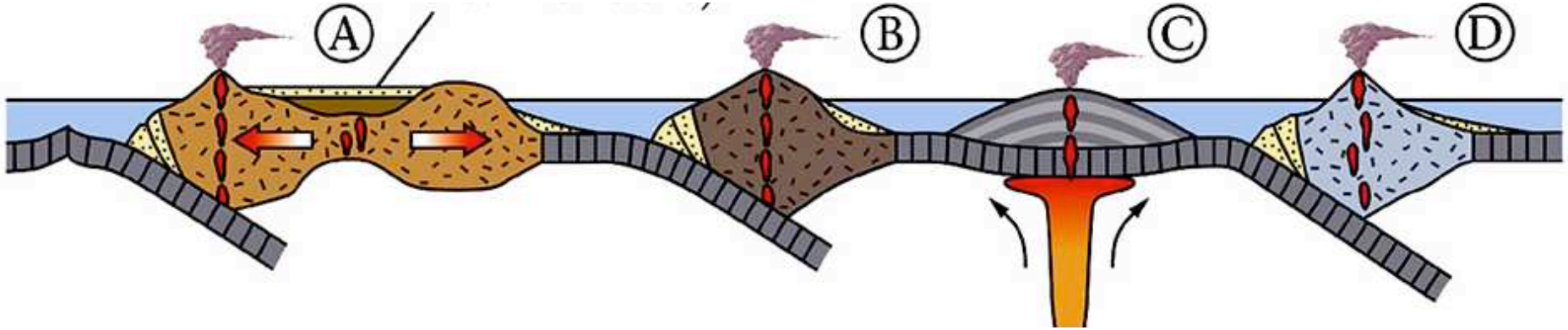
High grade gneissic regions (hochmetamorph)

Quarz-Feldspat Gneiss
Meta-Quarzite
Vulkanisches Meta-Sedimente
Eisenführende Formationen
Karbonate

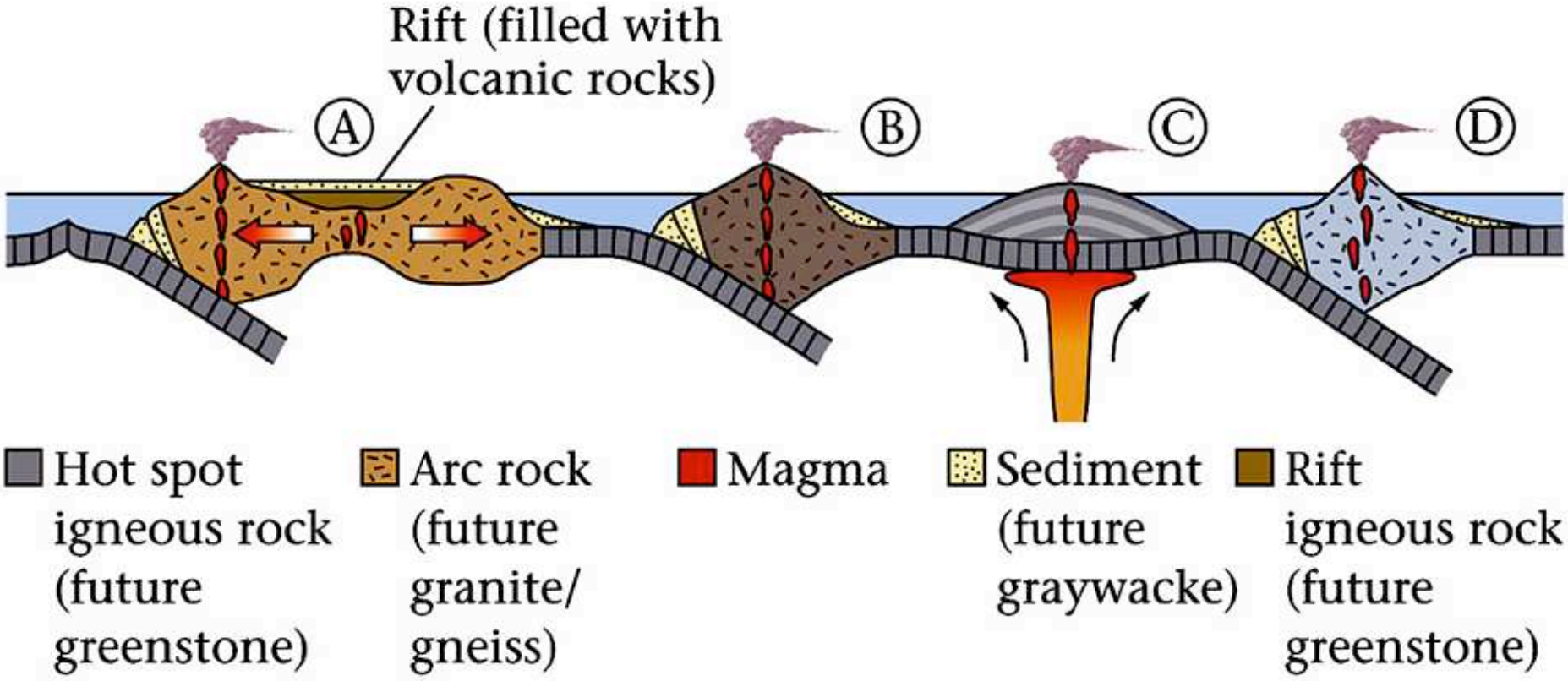
Plattentektonik im Archaikum ?



Plattentektonische Interpretation

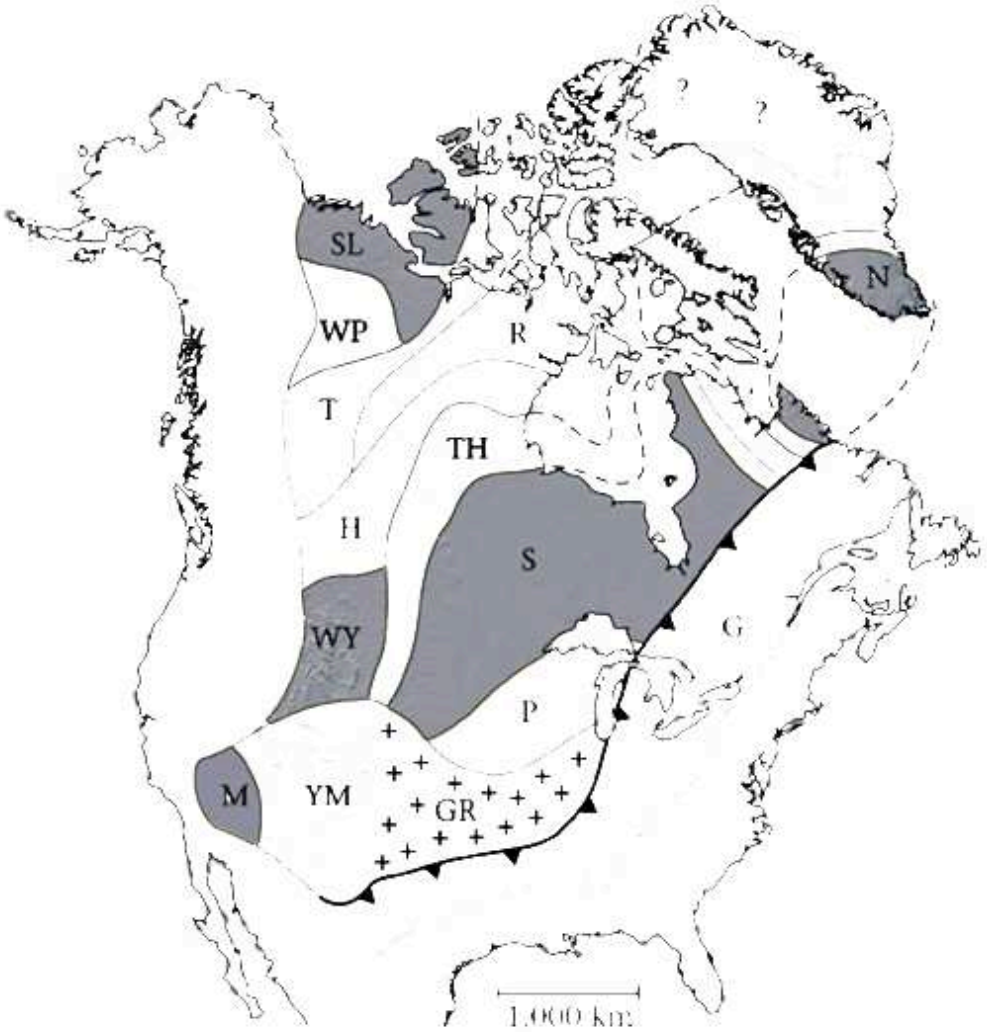


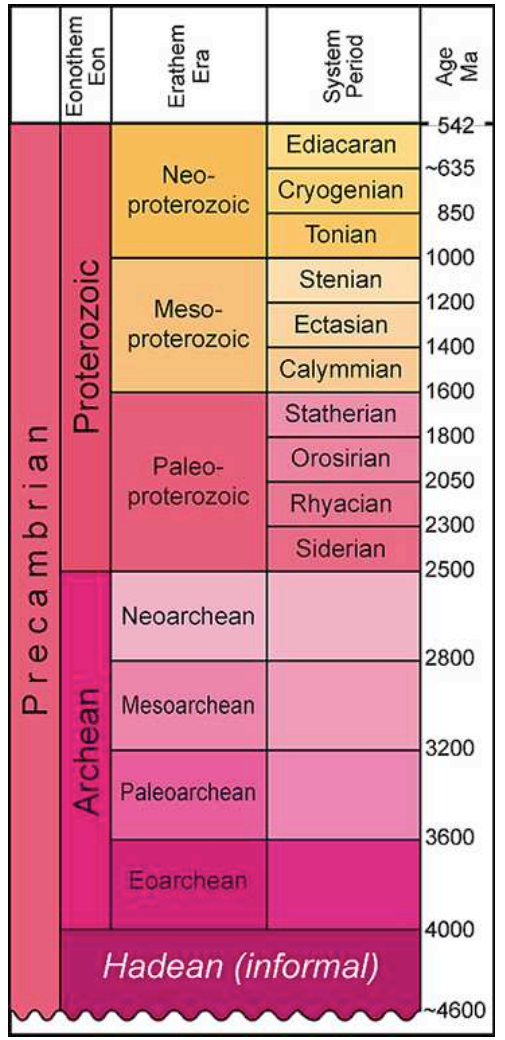
Plattentektonik im Archaikum ?



⇒ schnelle und kleine Platten

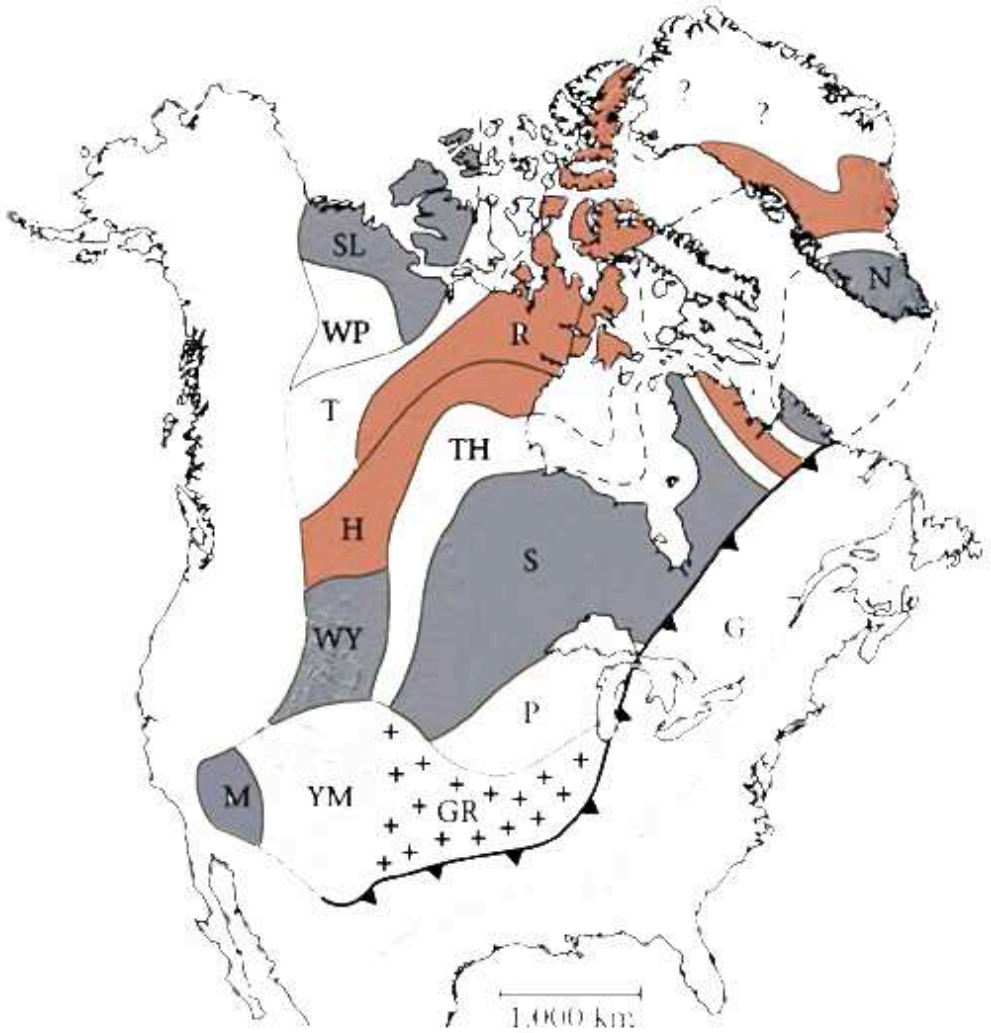
Archaische Krustenanteile

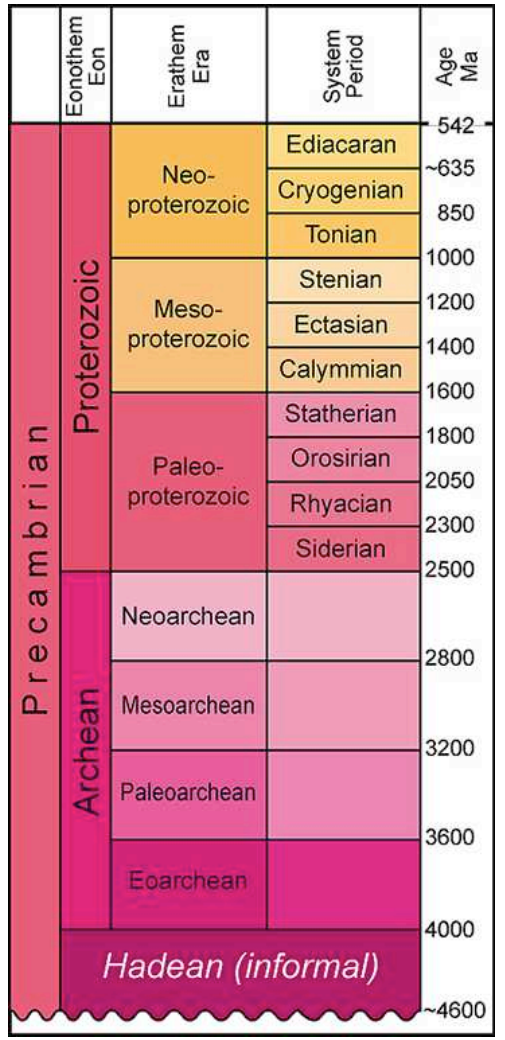




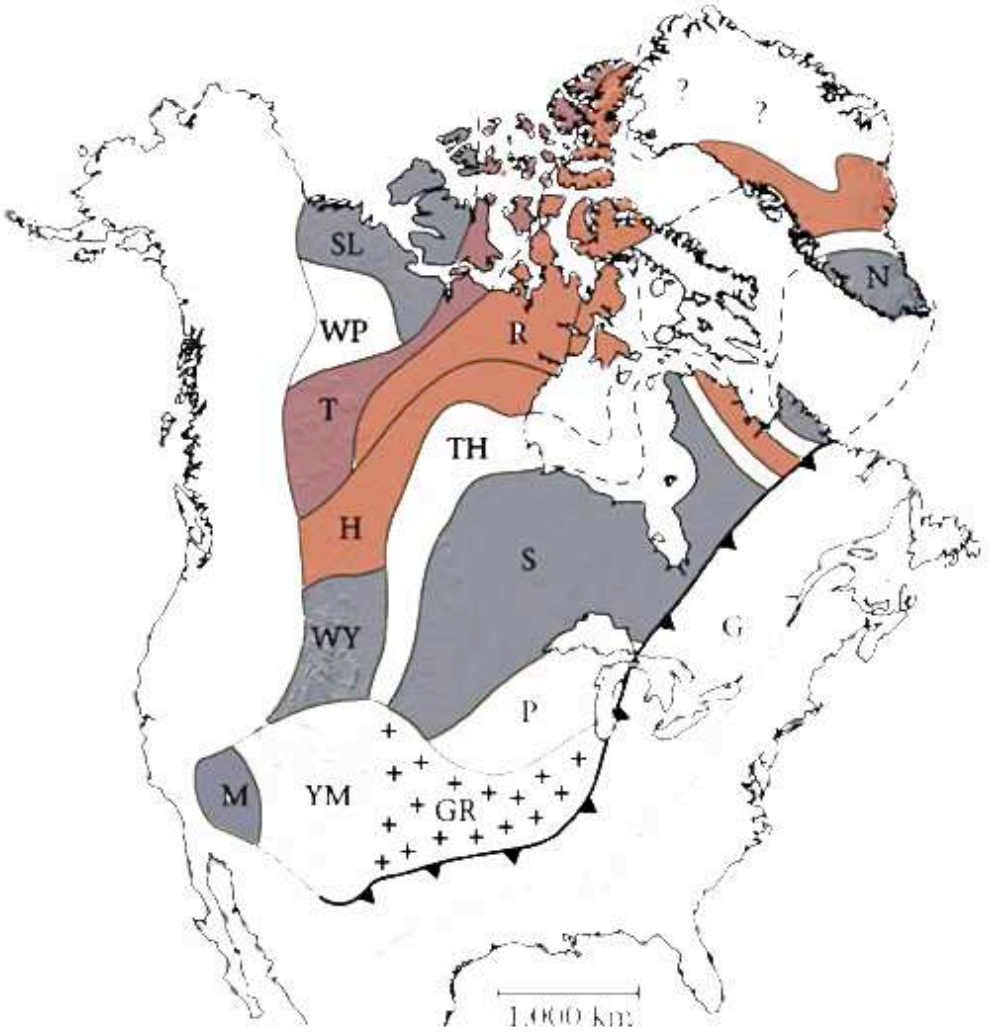
Archaikum, metamorph überprägt

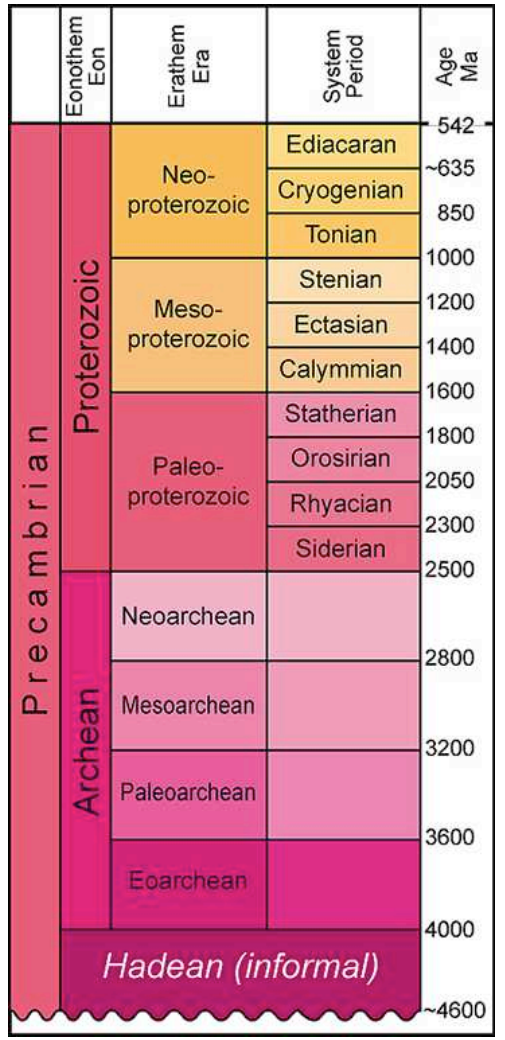
(im Proterozoikum)





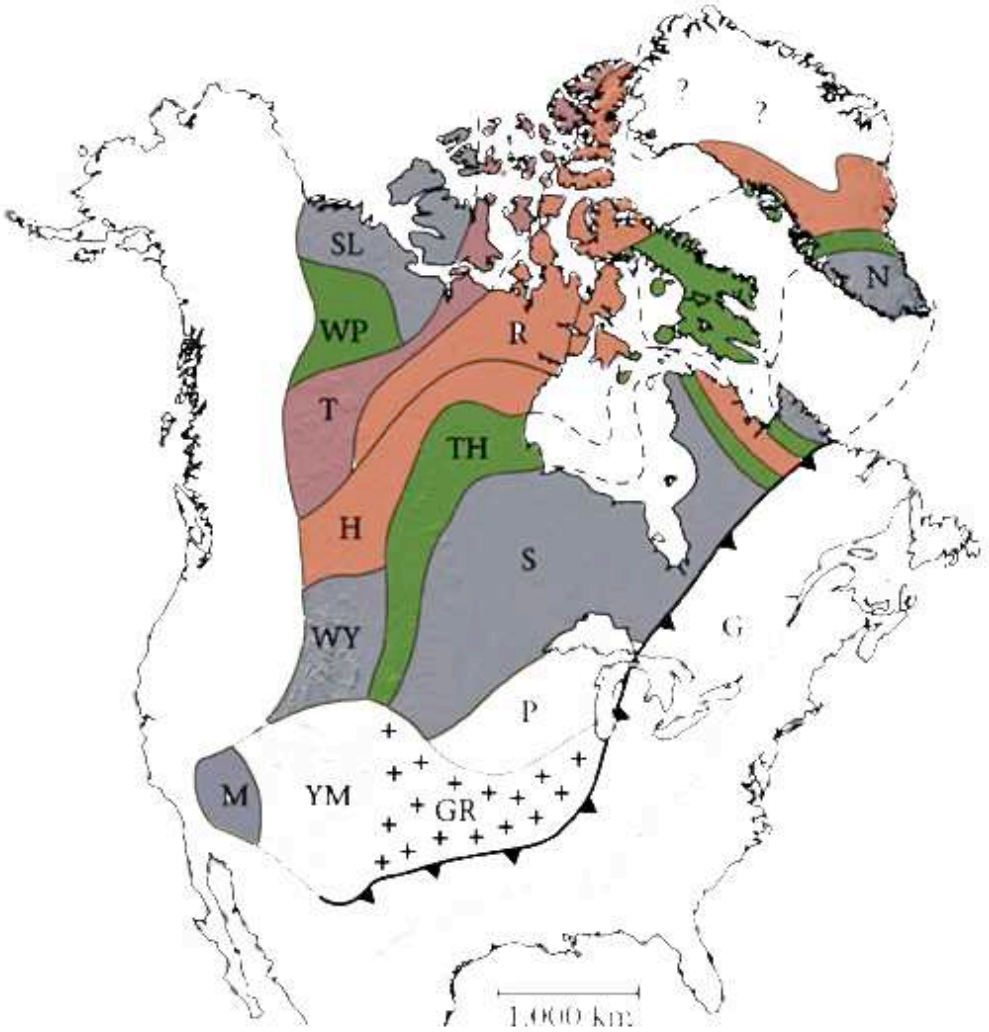
Proterozoikum 1.9 Ga

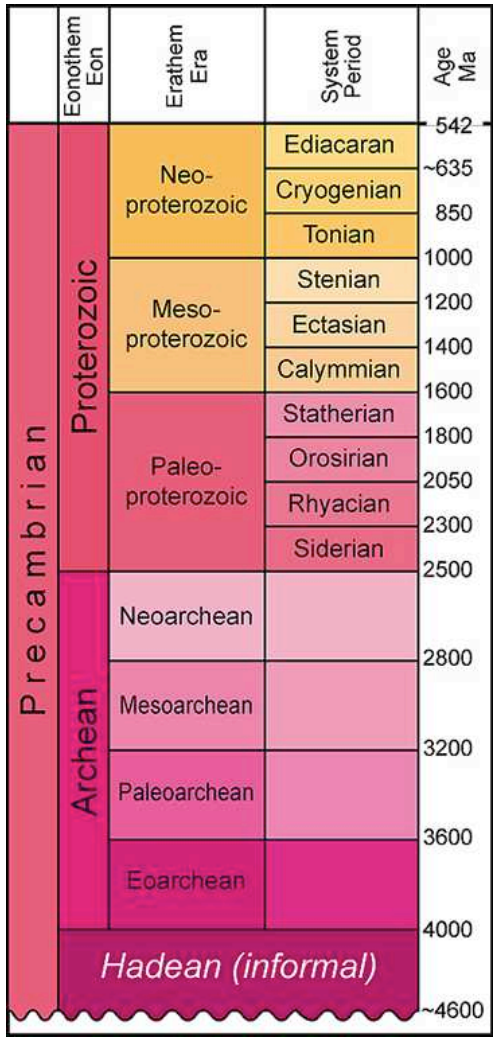




Kontinentale Kollision

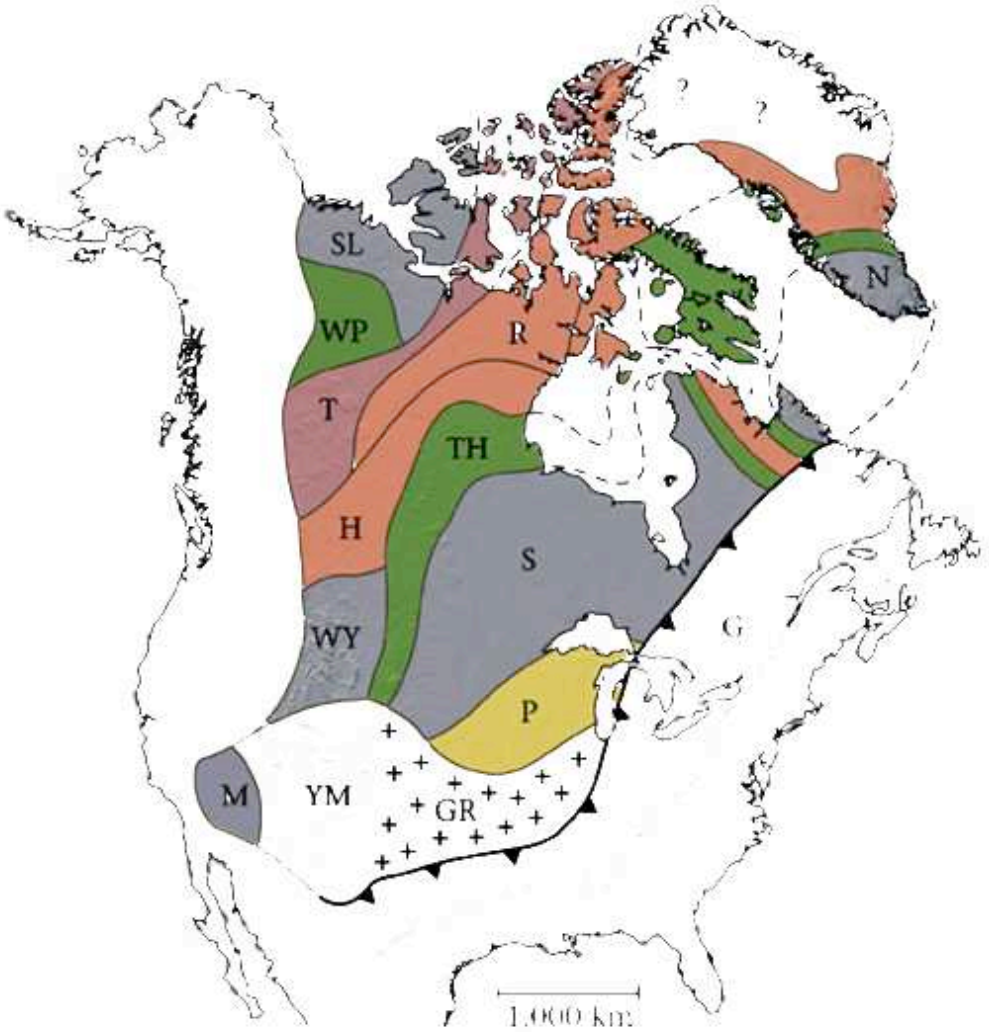
Proterozoikum 1.8 Ga

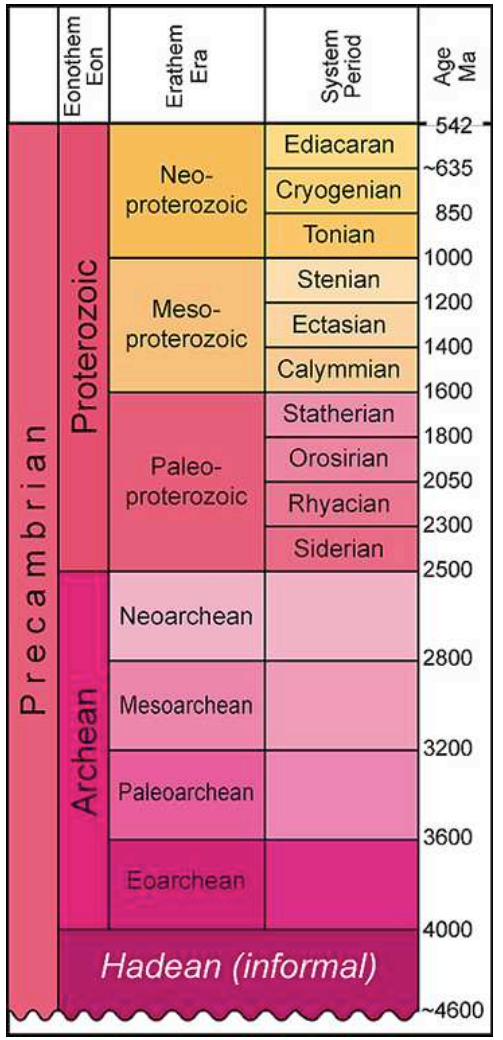




Kontinentale Kollision

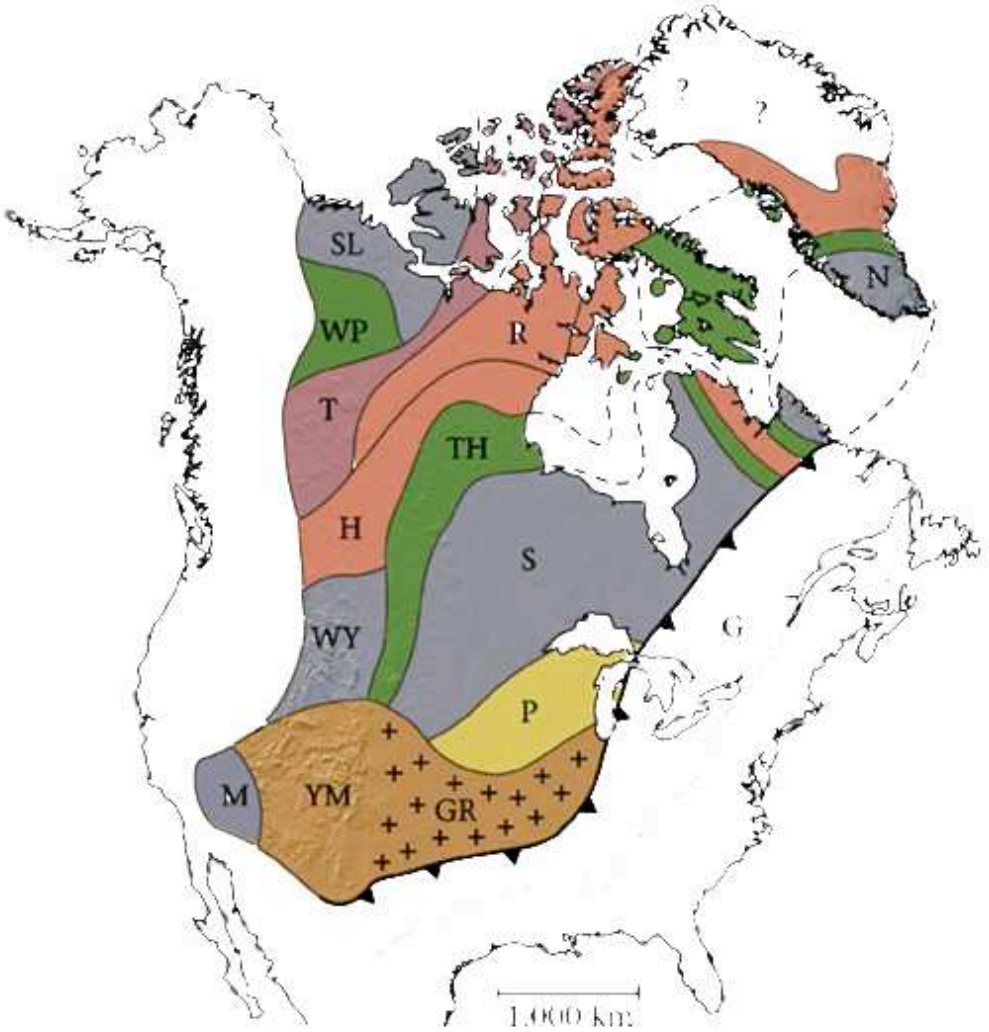
Proterozoikum 1.8 Ga

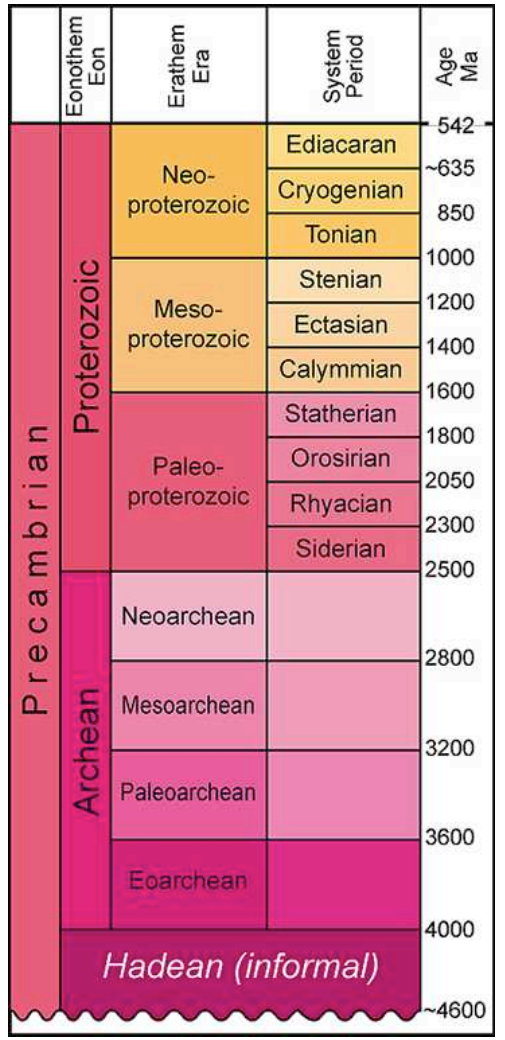




Akkretion von Kruste

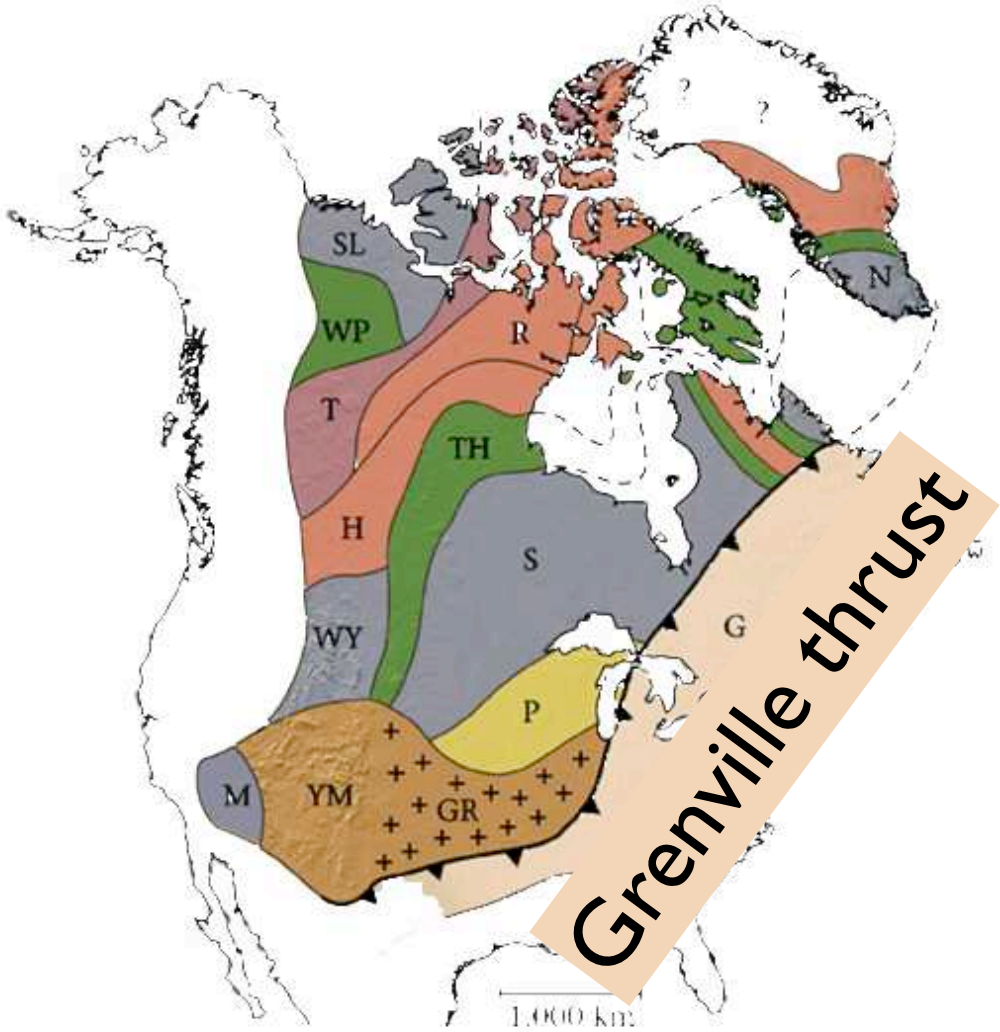
Proterozoikum 1.3 -1.7

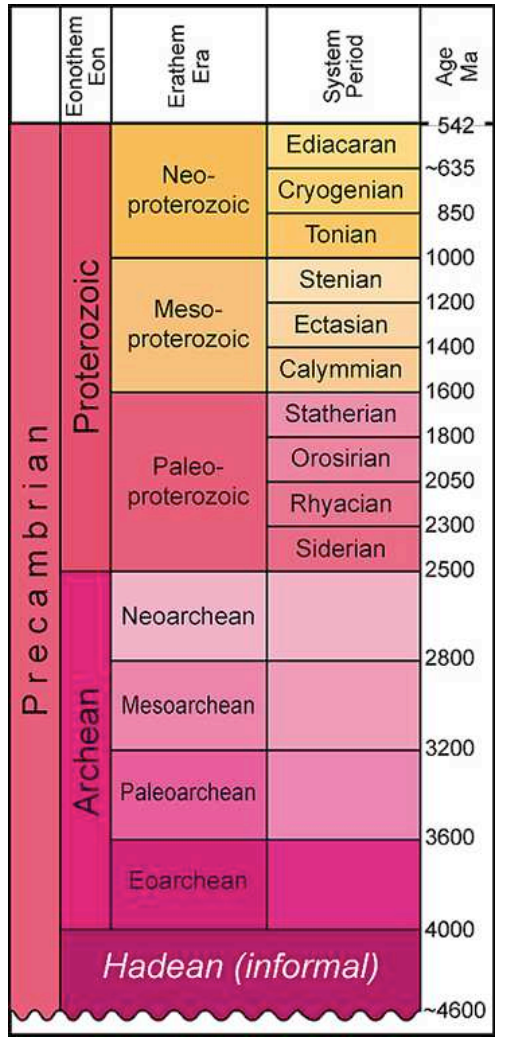




Akkretion von Kruste

Proterozoikum 1.1 Ga

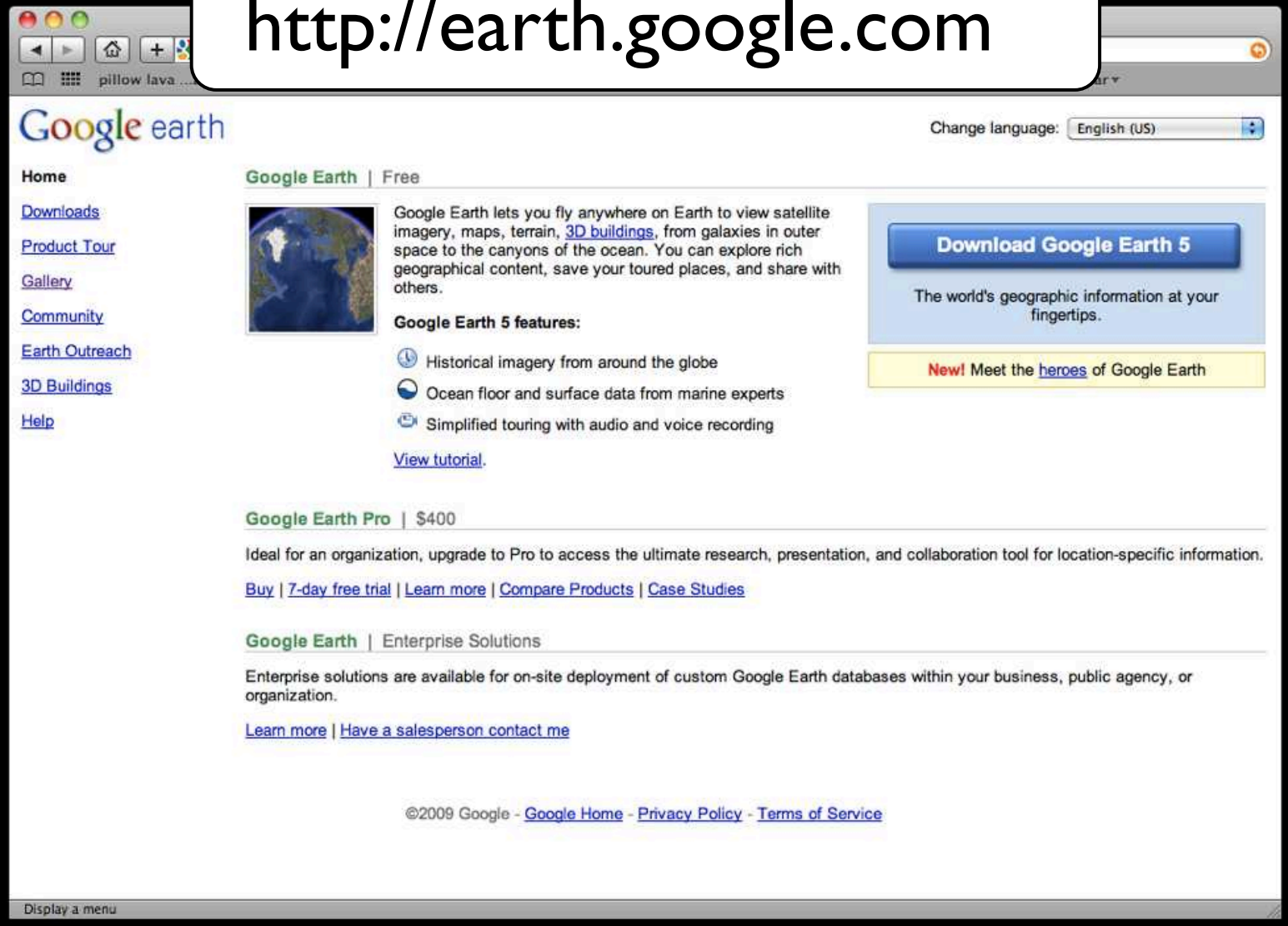




Kontinentale Kollision

Let's google !

http://earth.google.com



Kanadischer Schild: Archaikum

Precambrian (Archean) of the Canadian shield

Grönland, Archaikum

Qeqertarsuatsiaat (Fiskenaesset)

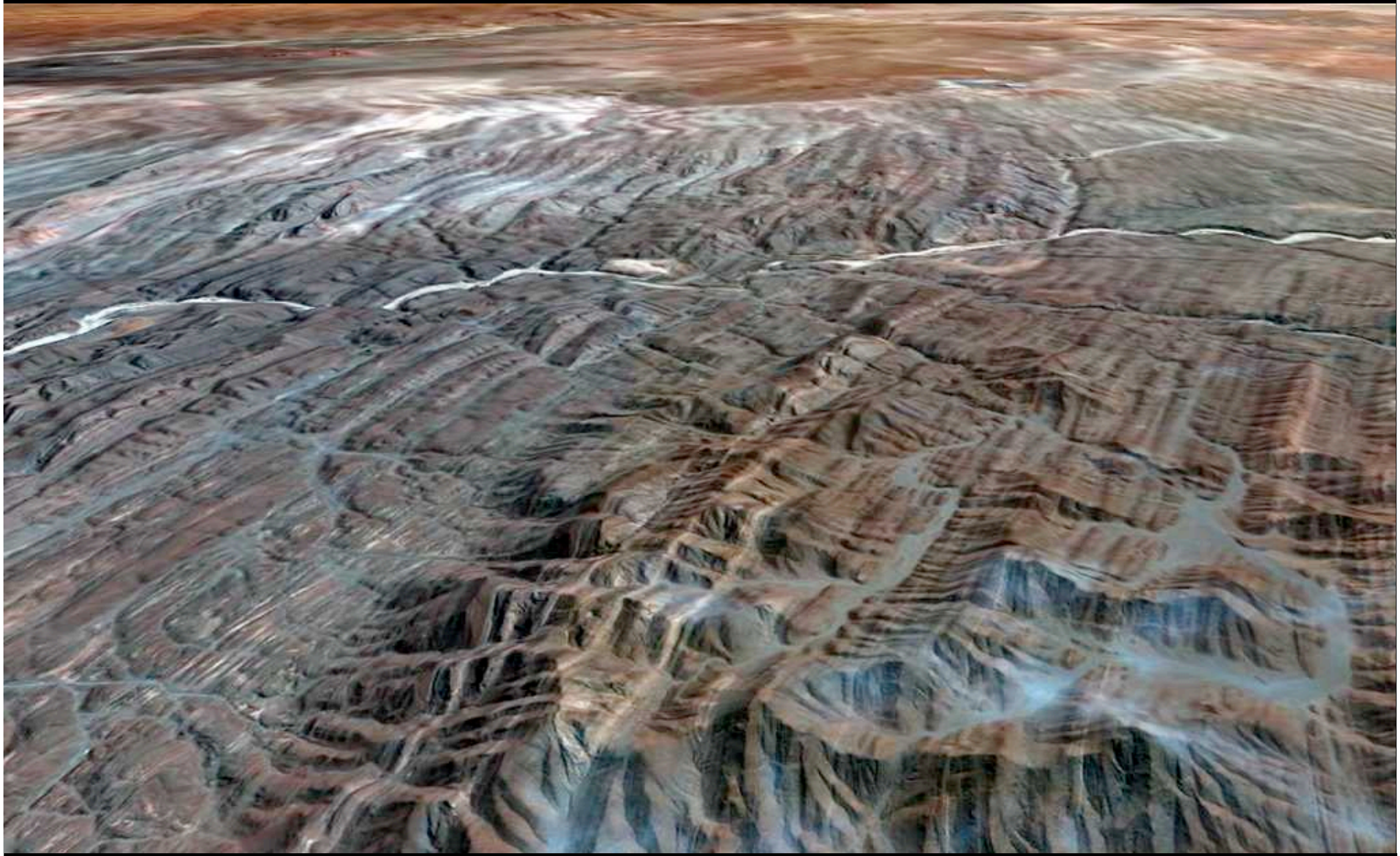
Ugab, Namibia: Proterozoikum

Proterozoische, verfaltete, steilgestellte Sedimente

Ugab, Namibia google Earth

Proterozoische, verfaltete, steilgestellte Sedimente

Ugab, Namibia



Proterozoische, verfaltete, steilgestellte Sedimente

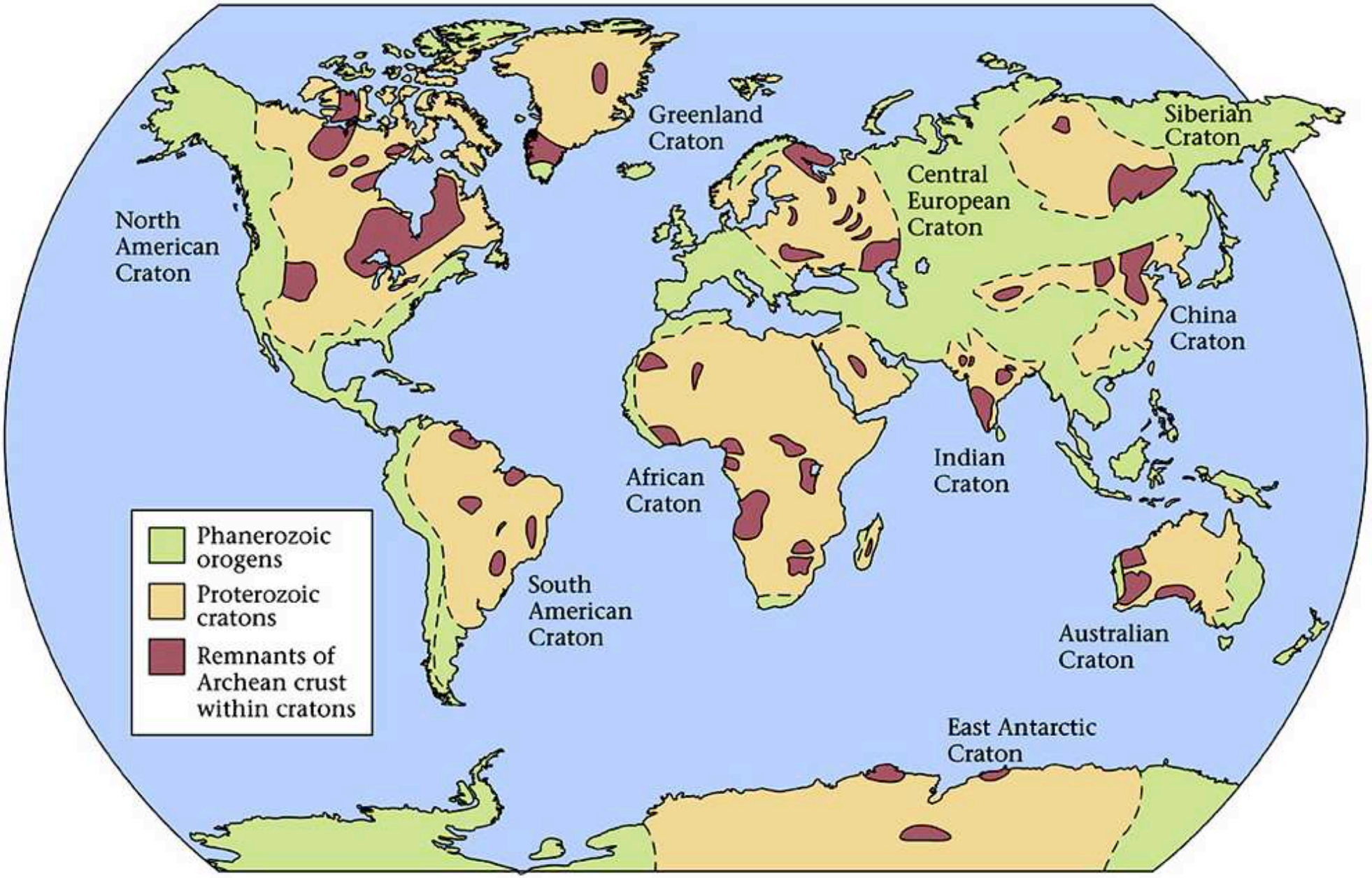
Ugab, Namibia

Proterozoische, verfaltete, steilgestellte Sedimente

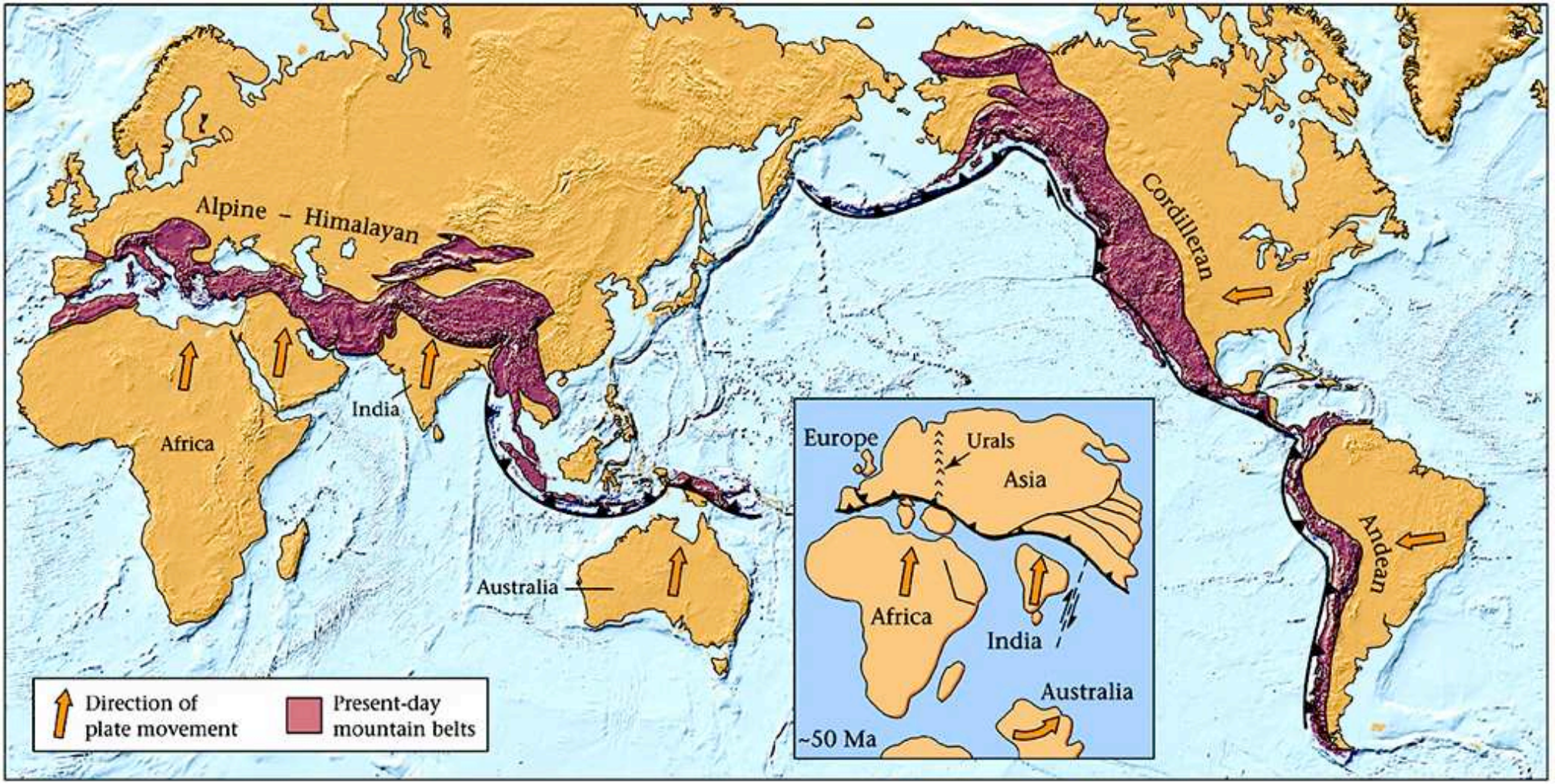
Ugab, Namibia

Proterozoische, verfaltete, steilgestellte Sedimente

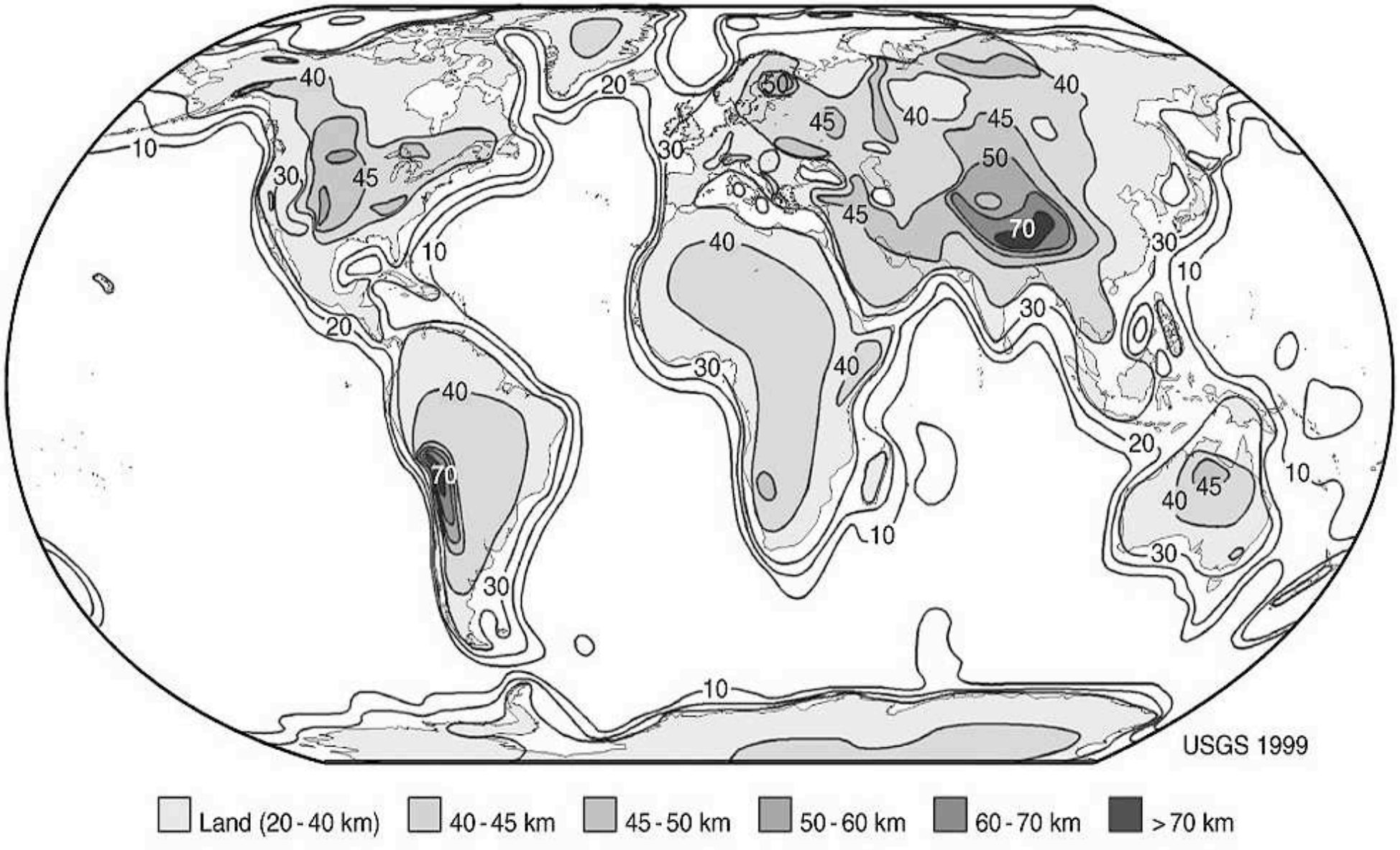
Präkambrische Kruste



Aktive kontinentale Gebirgssysteme



Heute: Dicke der kontinentalen Kruste



Erste Atmosphäre

H_2O

CH_4

NH_3

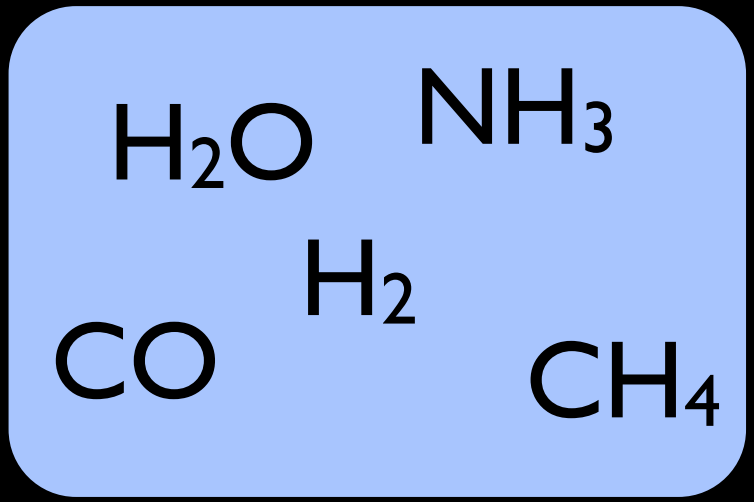
H_2

N_2

CO_2

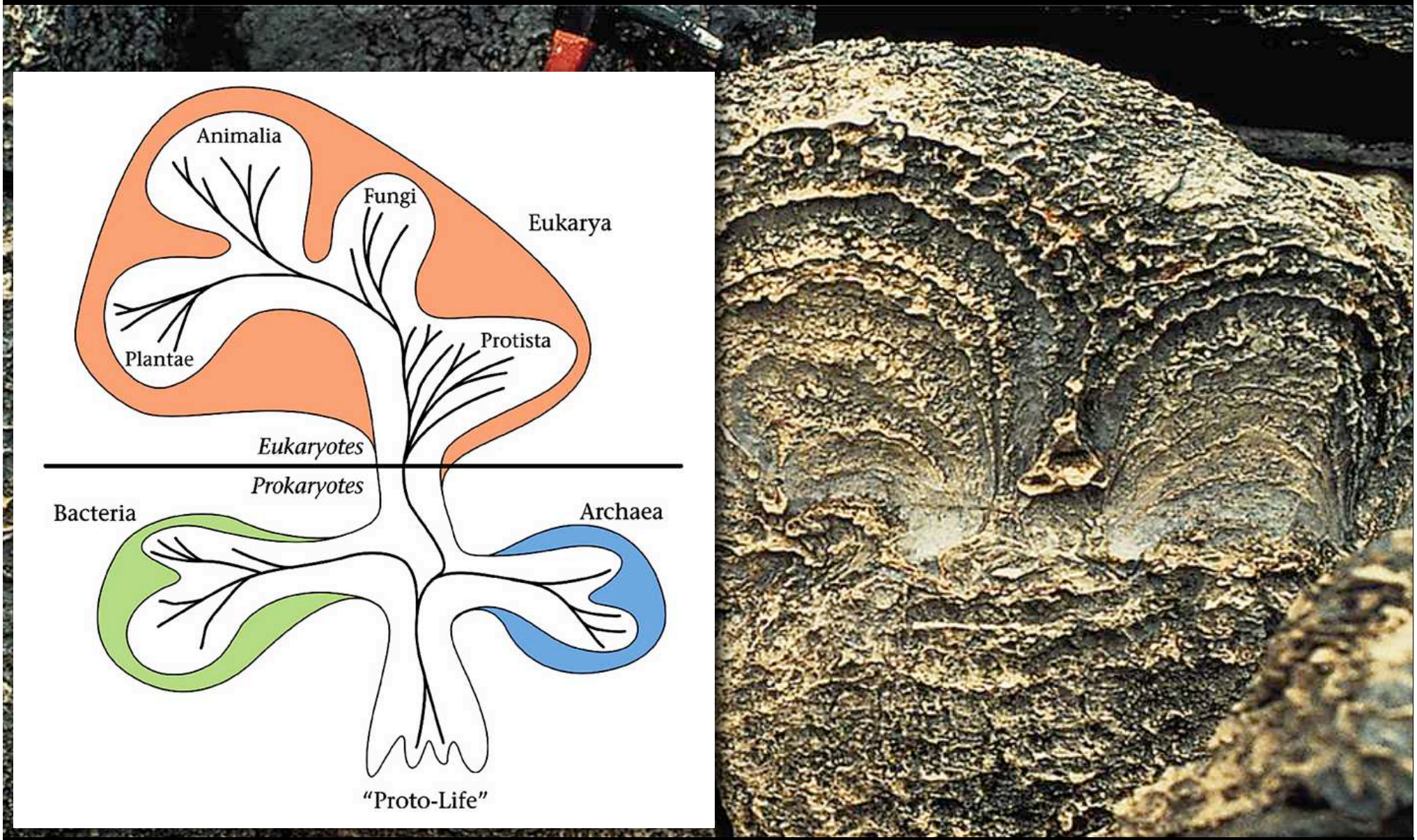
SO_4

"Ursuppe"



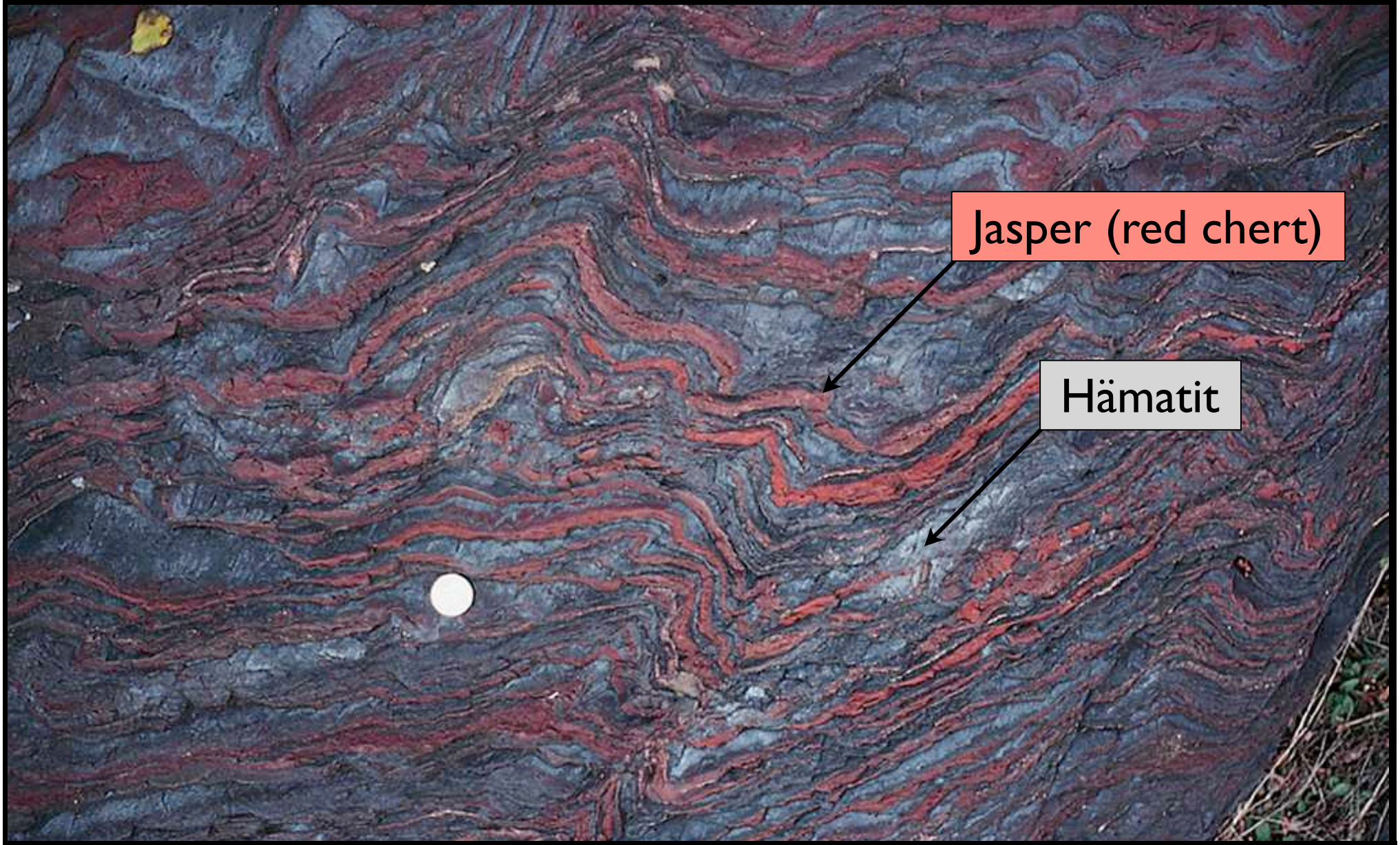
ca. 250 mal dichter als heute

Stromatolithe: Archaikum



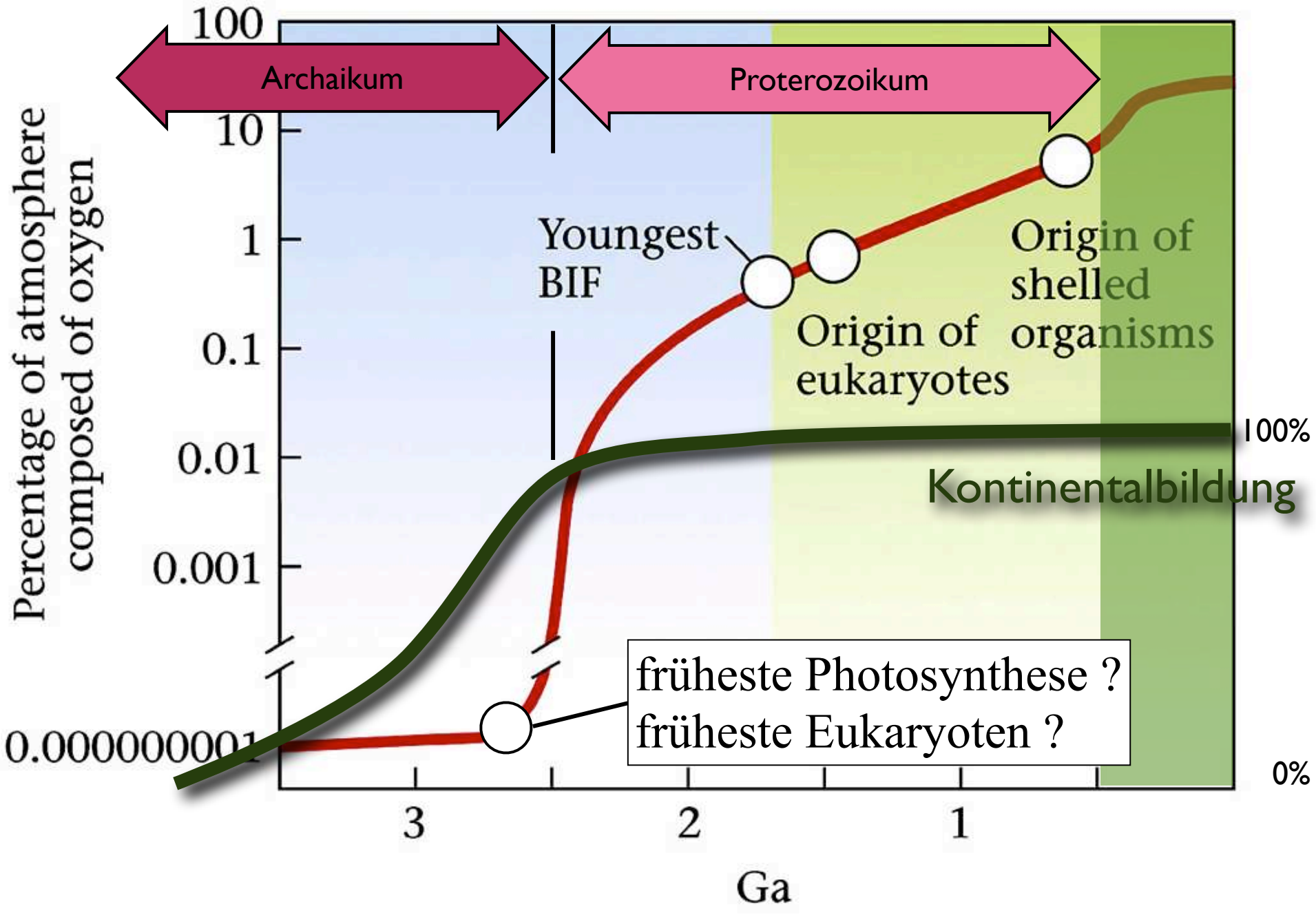
Früheste Lebensform ~3.2 Ga: Cyanobacteria

Banded Iron Formation (BIF)

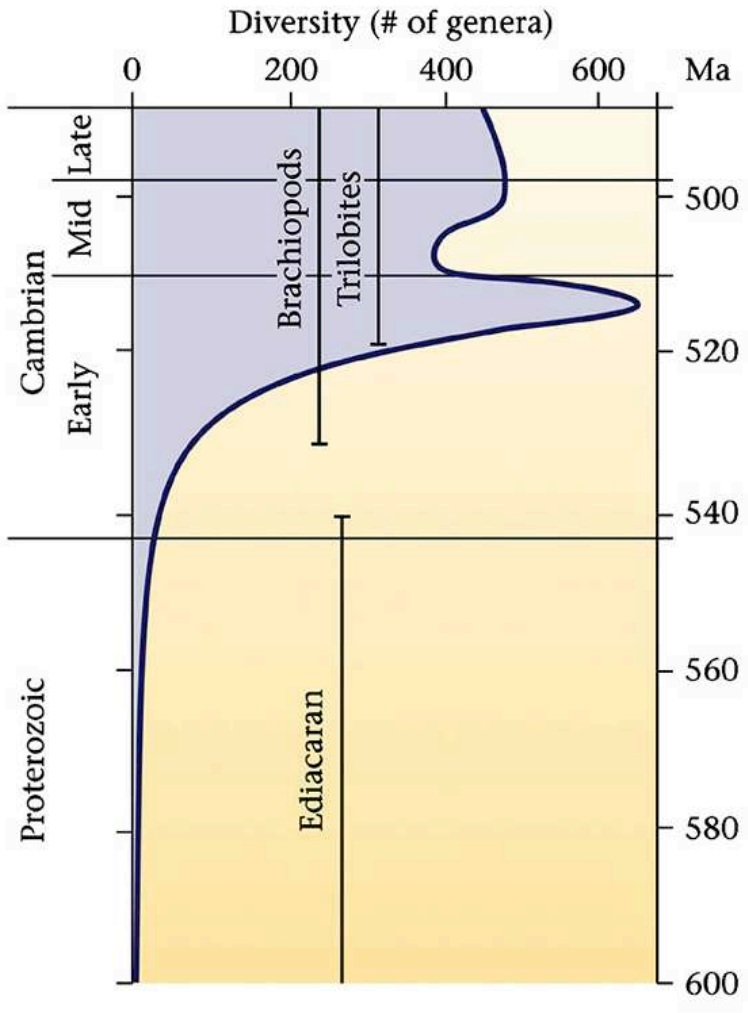


Iron Range, Michigan

Sauerstoffgehalt in der Erdatmosphäre

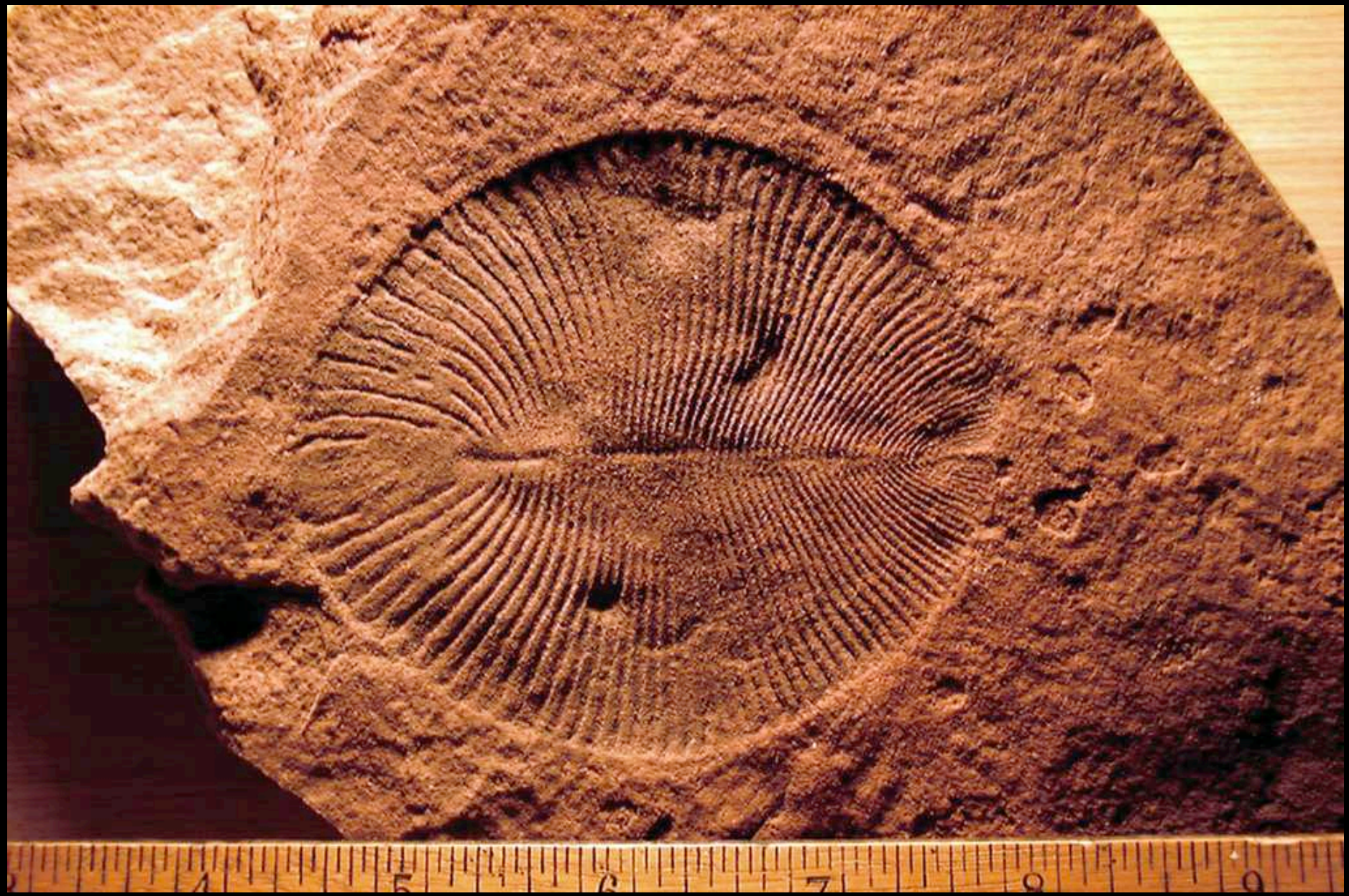


Phanerozoikum



Eonothem Eon	Erathem Era	System Period	Series Epoch	Stage Age	Age Ma	GSSP
Phanerozoic	Paleozoic	Devonian	Upper	Famennian	359.2 ±2.5	
				Frasnian	374.5 ±2.6	
			Middle	Givetian	385.3 ±2.6	
				Eifelian	391.8 ±2.7	
			Lower	Emsian	397.5 ±2.7	
				Pragian	407.0 ±2.8	
				Lochkovian	411.2 ±2.8	
		Silurian	Pridoli		416.0 ±2.8	
			Ludlow	Ludfordian	418.7 ±2.7	
				Gorstian	421.3 ±2.6	
			Wenlock	Homerian	422.9 ±2.5	
				Sheinwoodian	426.2 ±2.4	
			Llandovery	Telychian	428.2 ±2.3	
				Aeronian	436.0 ±1.9	
				Rhuddanian	439.0 ±1.8	
		Ordovician	Upper	Hirnantian	443.7 ±1.5	
				Katian	445.6 ±1.5	
				Sandbian	455.8 ±1.6	
			Middle	Darriwilian	460.9 ±1.6	
				Dapingian	468.1 ±1.6	
			Lower	Floian	471.8 ±1.6	
				Tremadocian	478.6 ±1.7	
		Cambrian	Furongian	*Stage 10*	488.3 ±1.7	
				Stage 9	~ 492 *	
				Paibian	~ 496 *	
			Series 3	Guzhangian	~ 499	
				Drumian	~ 503	
				Stage 5	~ 506.5	
			Series 2	*Stage 4*	~ 510 *	
				Stage 3	~ 515 *	
			Terreneuvian	*Stage 2*	~ 521 *	
				Fortunian	~ 528 *	
					542.0 ±1.0	

Ediacara Fauna: Spät - Proterozoikum

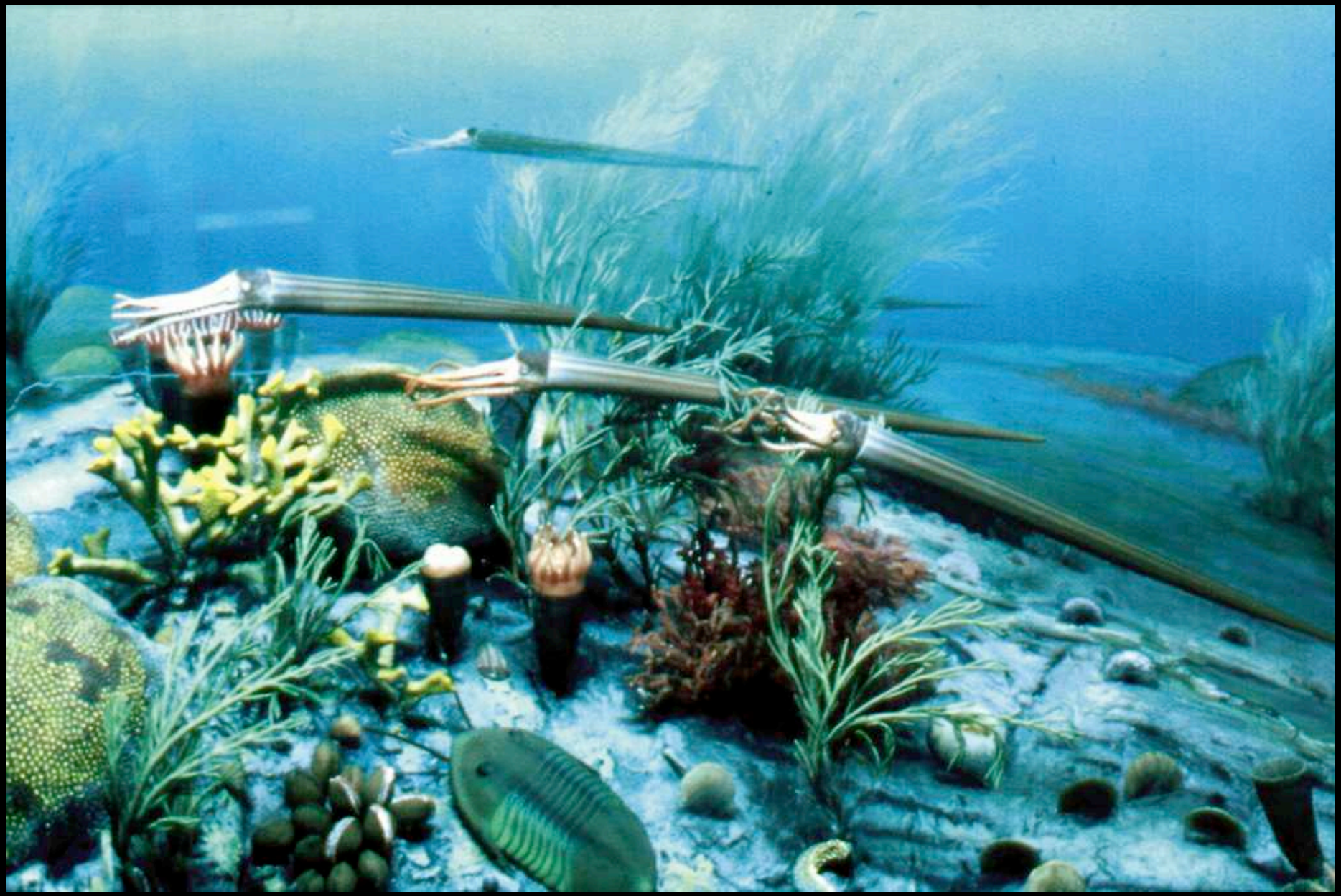


Dickinsonia

Ediacara Fauna: Spät - Proterozoikum

Rekonstruktion: Opabinia

Frühes Paläozoikum

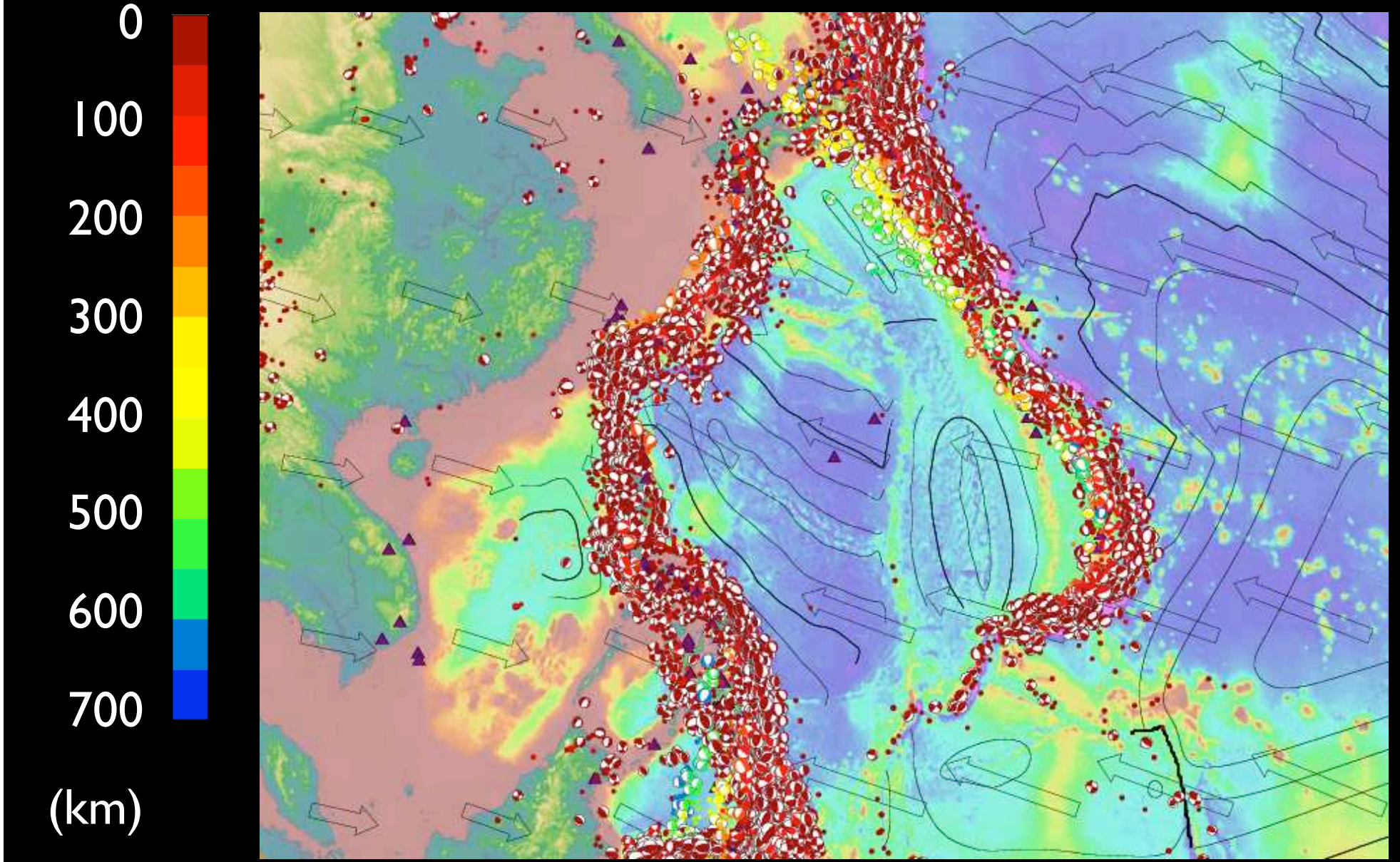


Trilobiten, Nautiliden

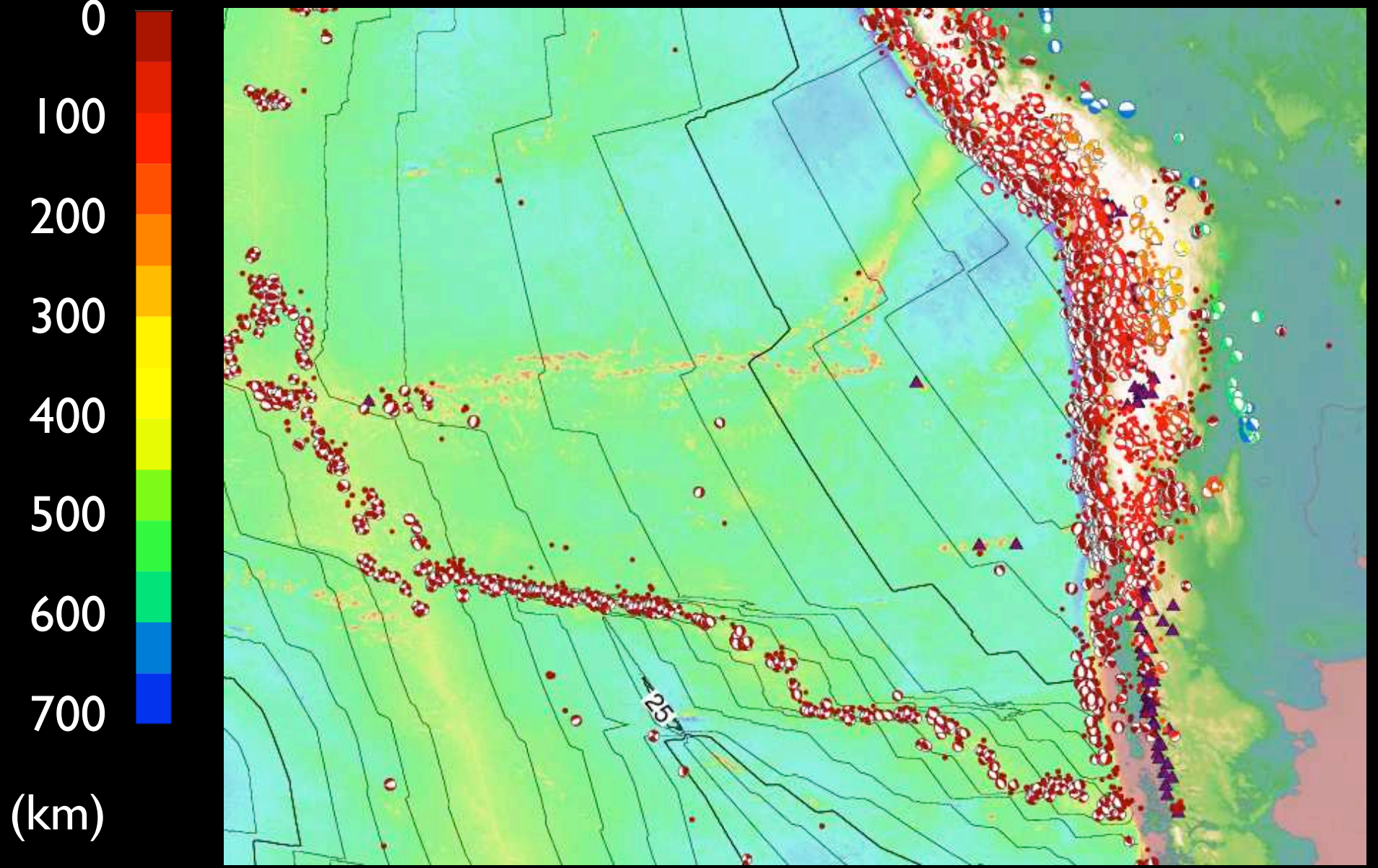
Karbon

Giant dragonfly (wing span ≈ 1m)

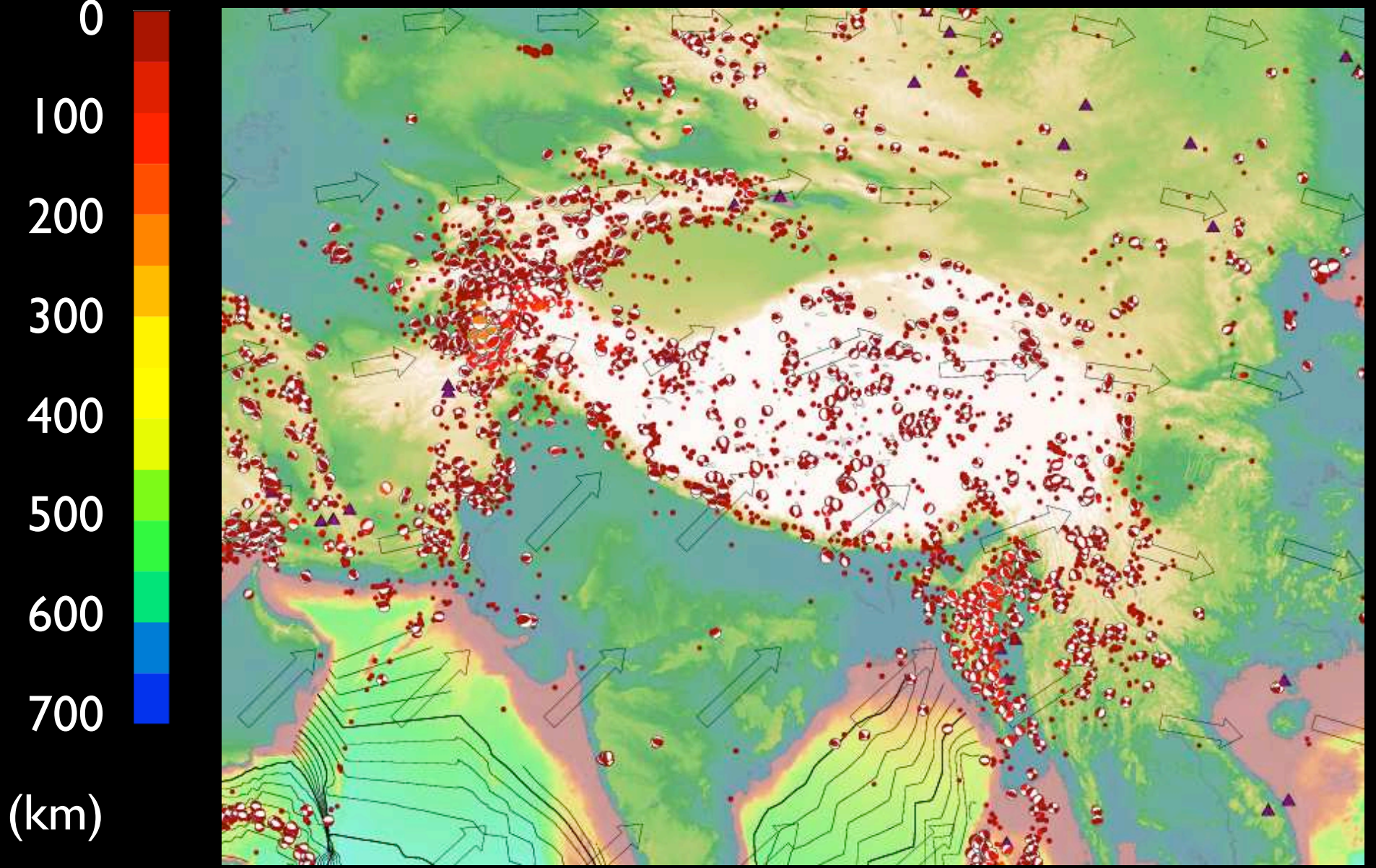
Ozean - Ozean



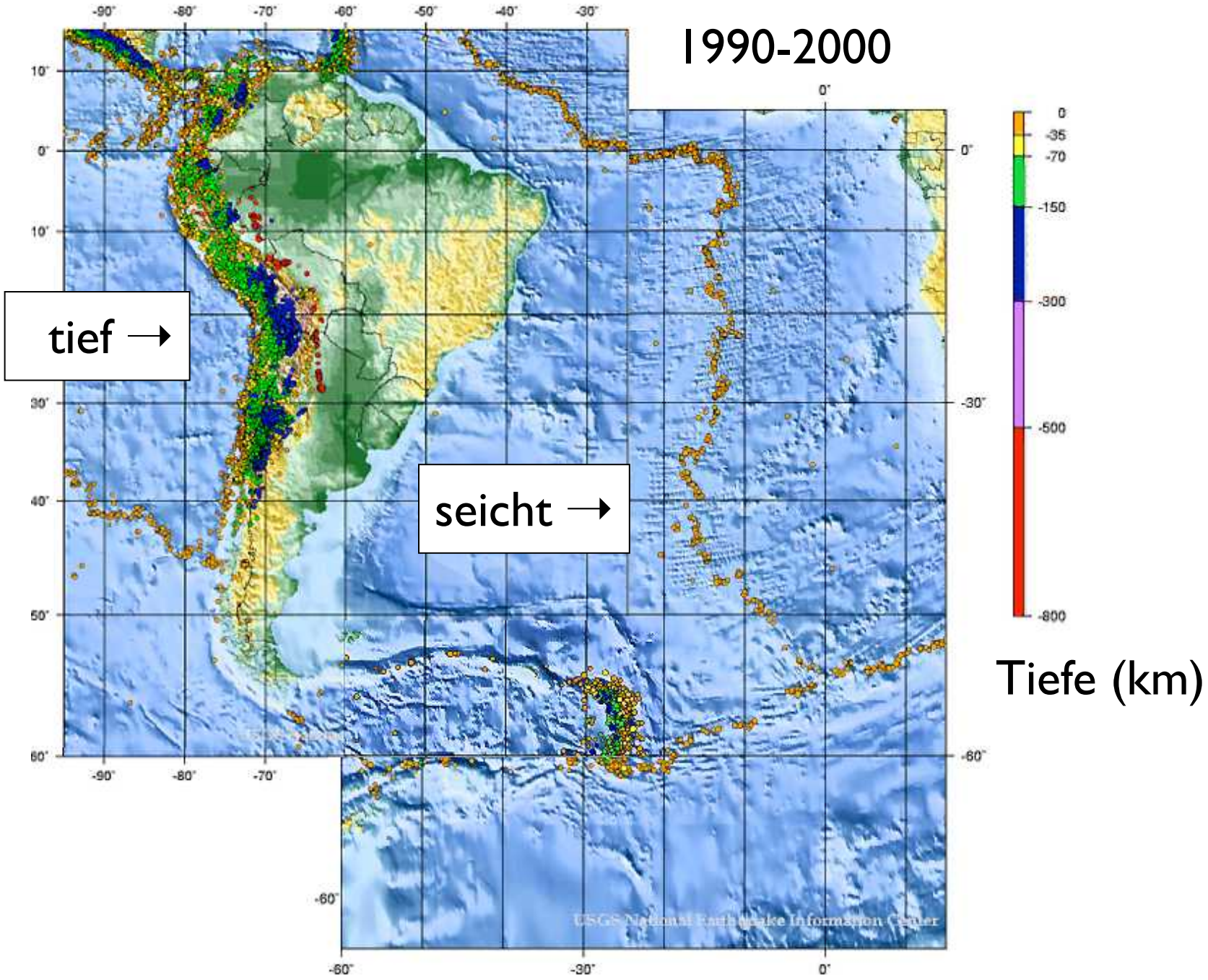
Ozean - Kontinent



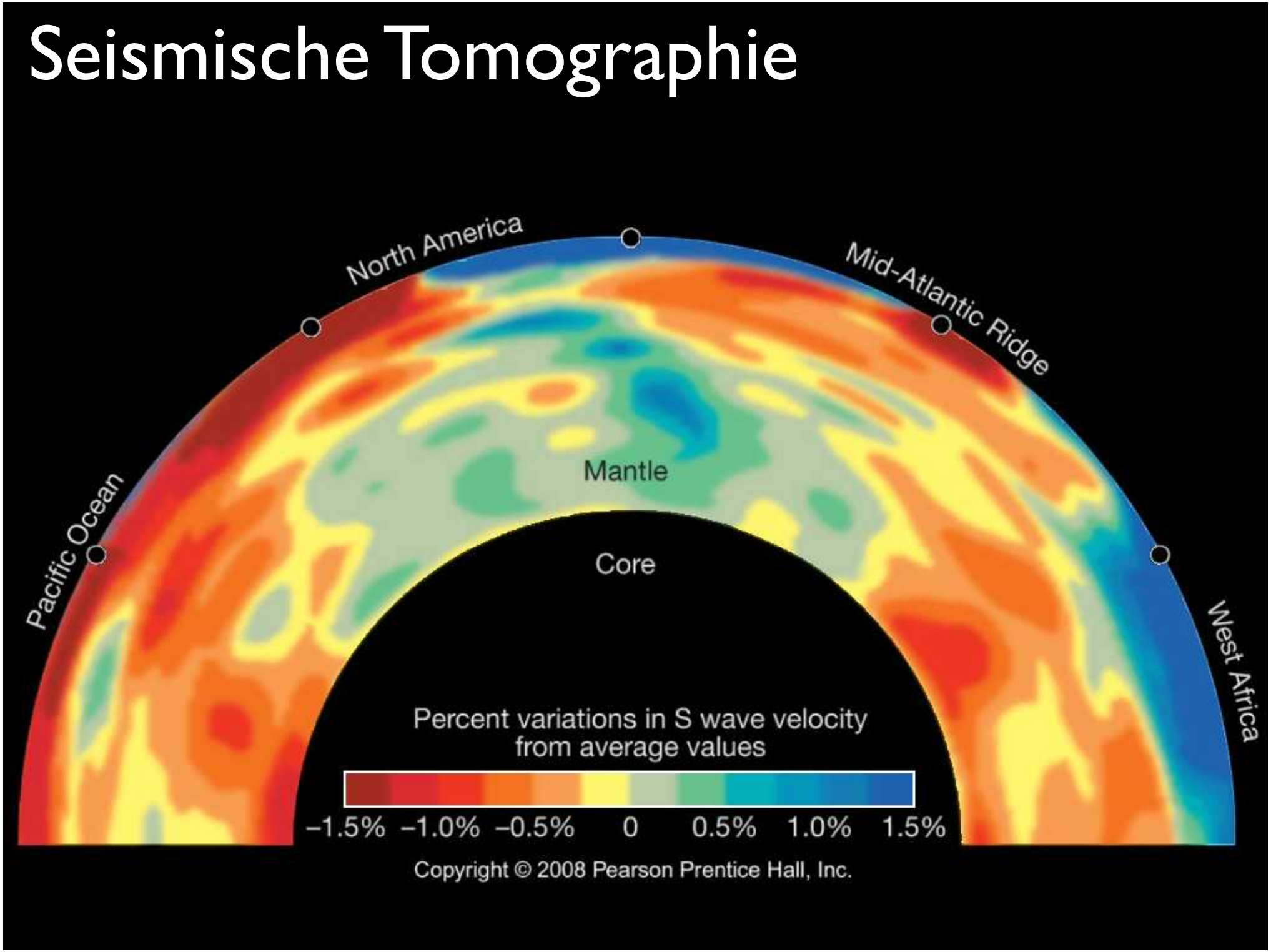
Kontinent - Kontinent

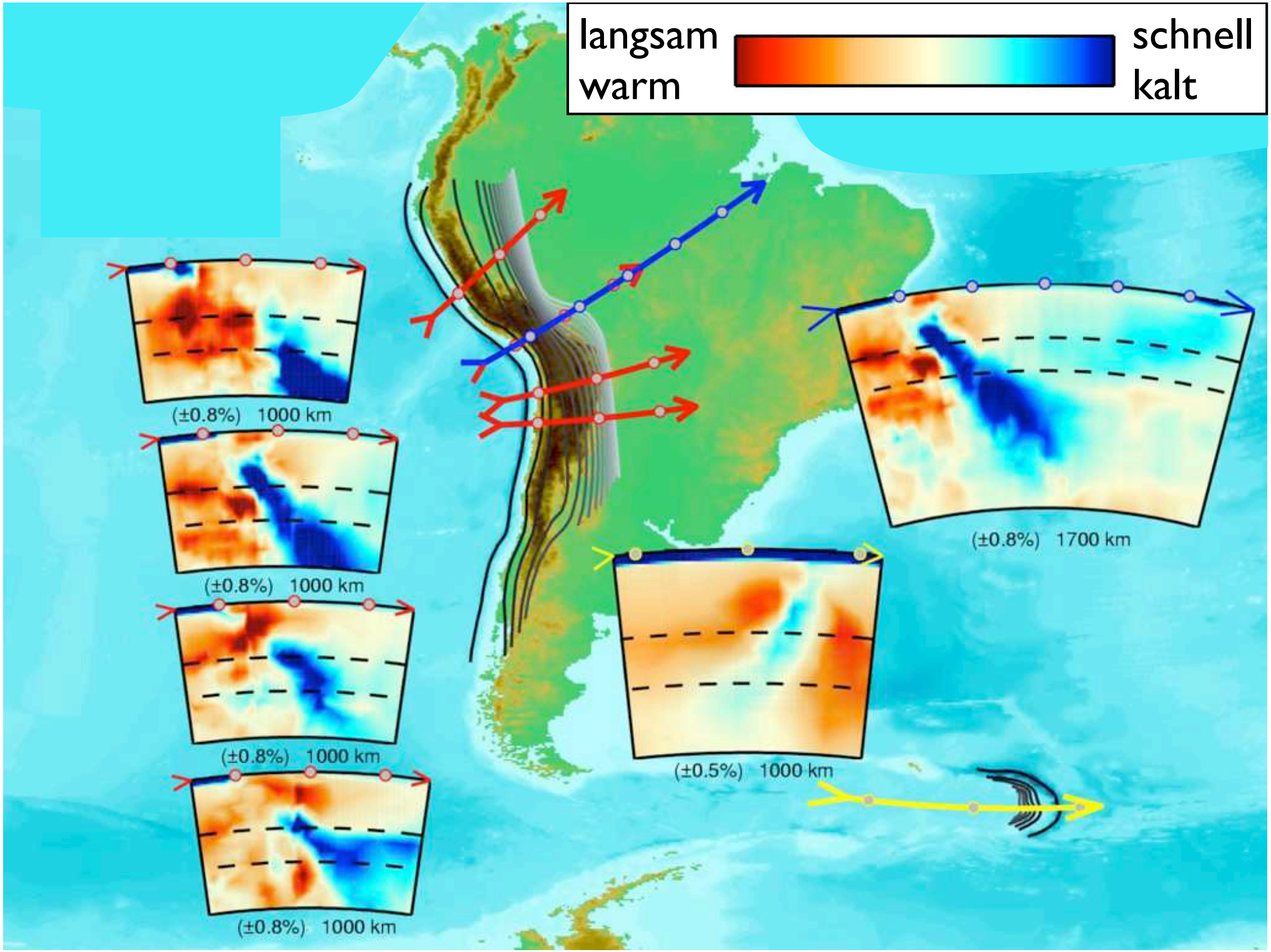


http://earthquake.usgs.gov/regional/world/seismicity/



Seismische Tomographie



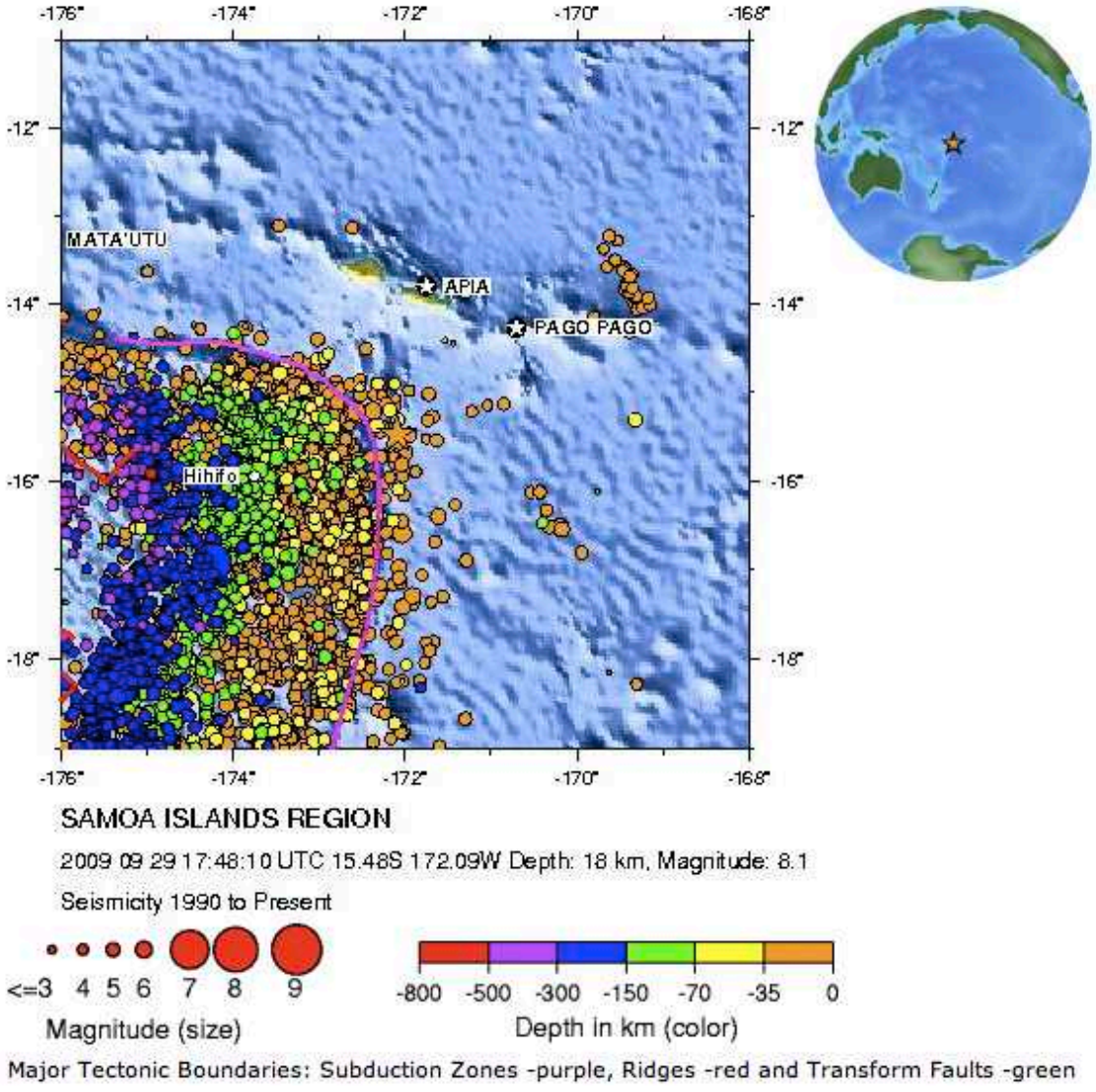

langsam
warm
schnell
kalt
(±0.8%) 1000 km
(±0.8%) 1000 km
(±0.8%) 1000 km
(±0.8%) 1000 km
(±0.5%) 1000 km
(±0.8%) 1700 km

Aktuell: Samoa Island, 29. 9.12009

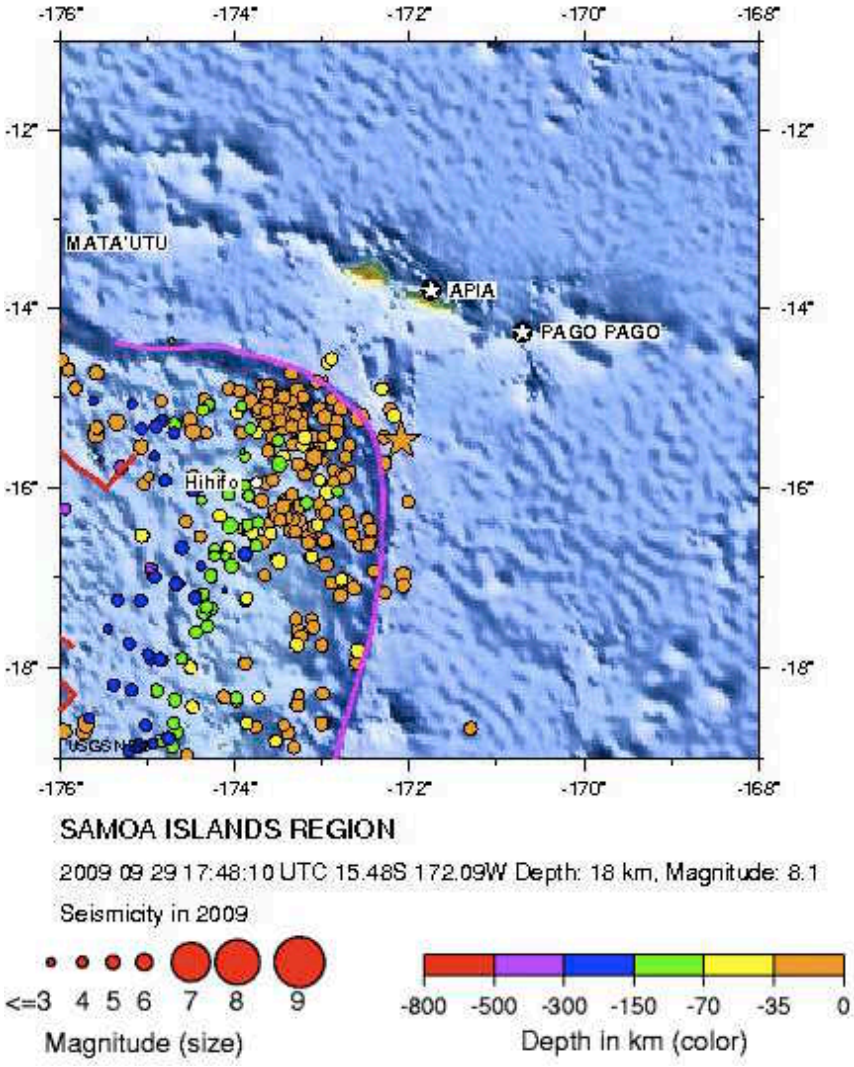
Magnitude 8.1 SAMOA ISLANDS REGION

Tuesday, September 29, 2009 at 17:48:10 UTC

Historic Seismicity



Major Tectonic Boundaries: Subduction Zones -purple, Ridges -red and Transform Faults -green

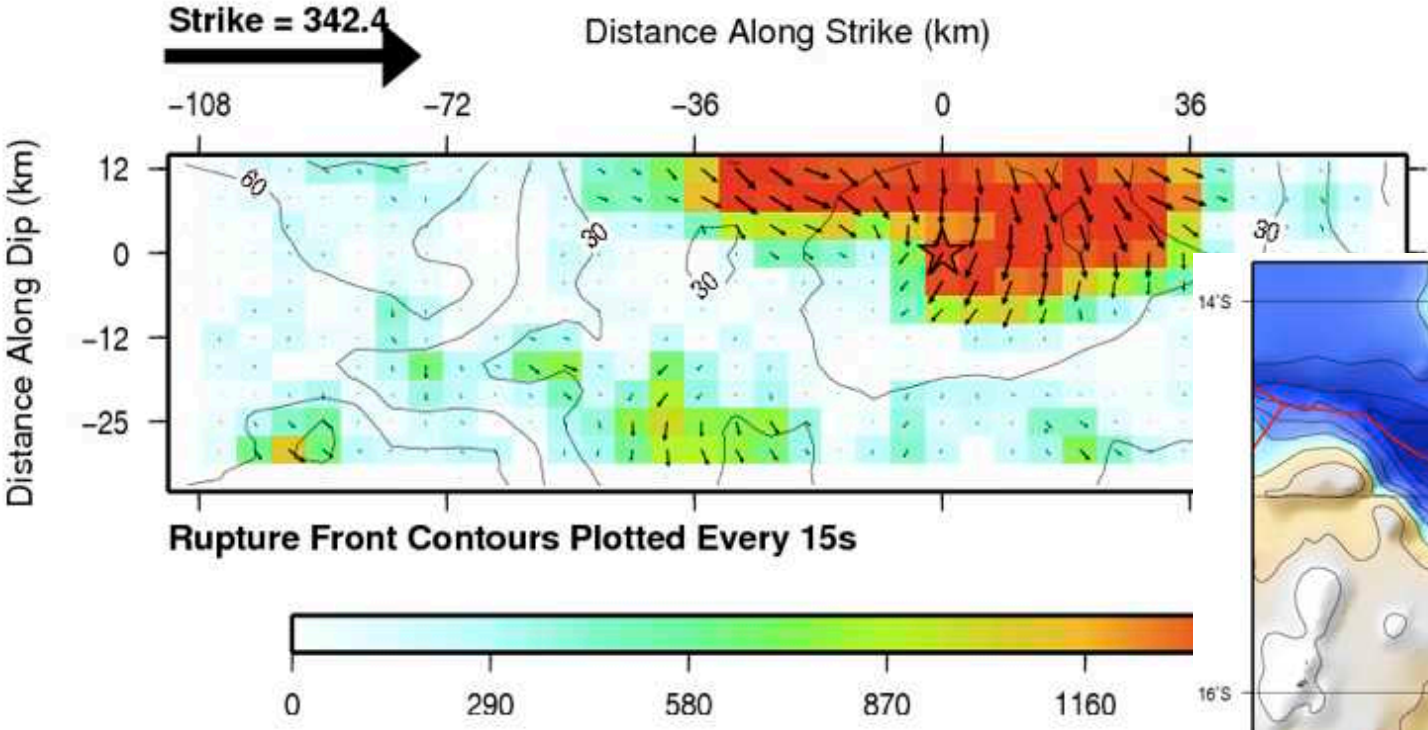


Aktuell: Samoa Island, 29. 9.12009

Result

After comparing the waveform fits based on two planes, we find that the nodal plane (strike=342.5 deg., dip=57.1 deg.) fits the data better. The seismic moment release based upon this plane is 1.63E+028 dyne.cm using a 1D crustal model interpolated from CRUST2.0 (Bassin et al., 2000).

Cross-section of slip distribution



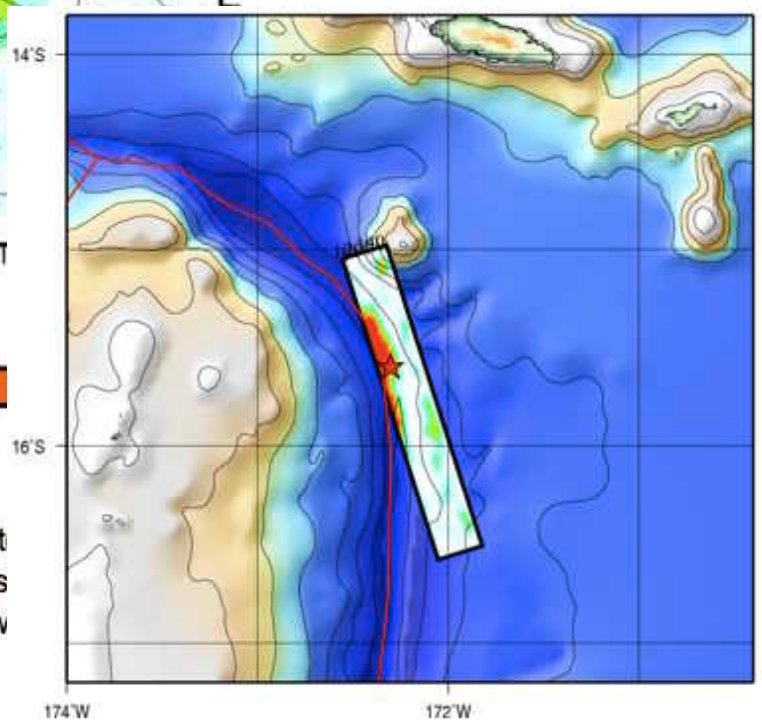
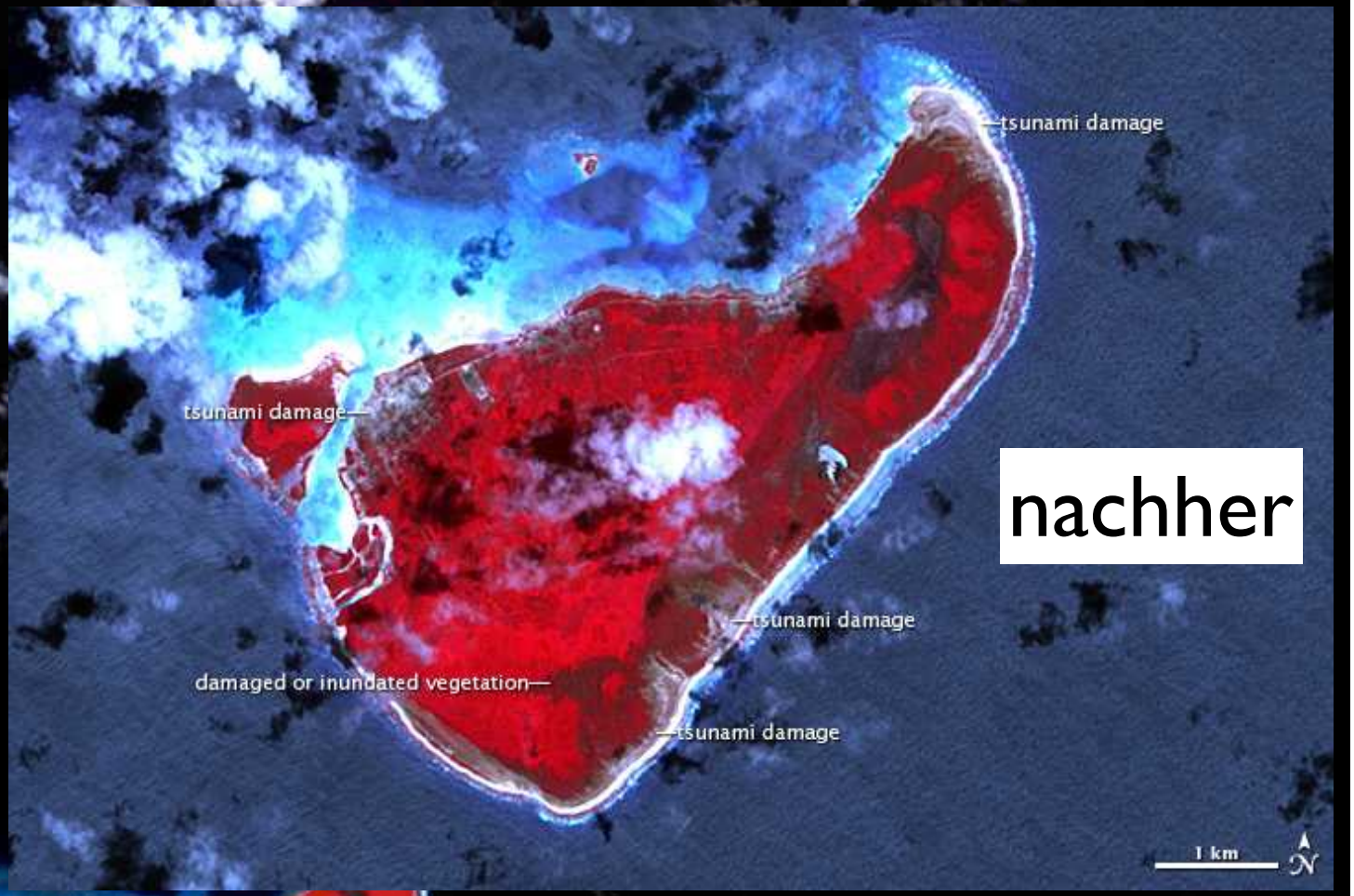
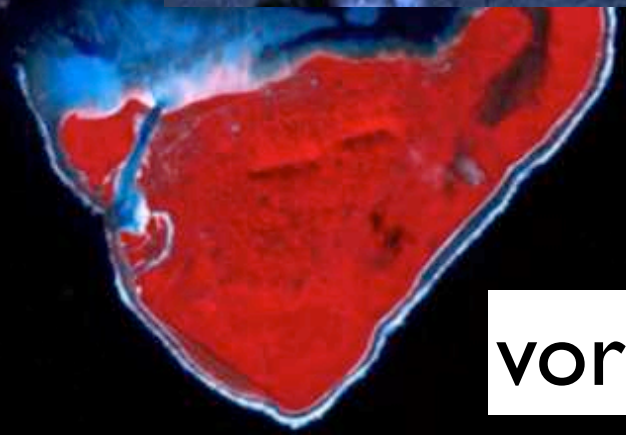


Figure 1. Cross-section of slip distribution. The strike direction of fault plane is indicat
arrow and the hypocenter location is denoted by the red star. The slip amplitude are s
motion direction of the hanging wall relative to the footwall is indicated by white arrow
the rupture initiation time in seconds.

NASA's Earth Observatory: satellite image of tsunami damage on the Tongan island of Niuatoputapu associated with the magnitude 8.0 earthquake of Sept 29th, 2009.

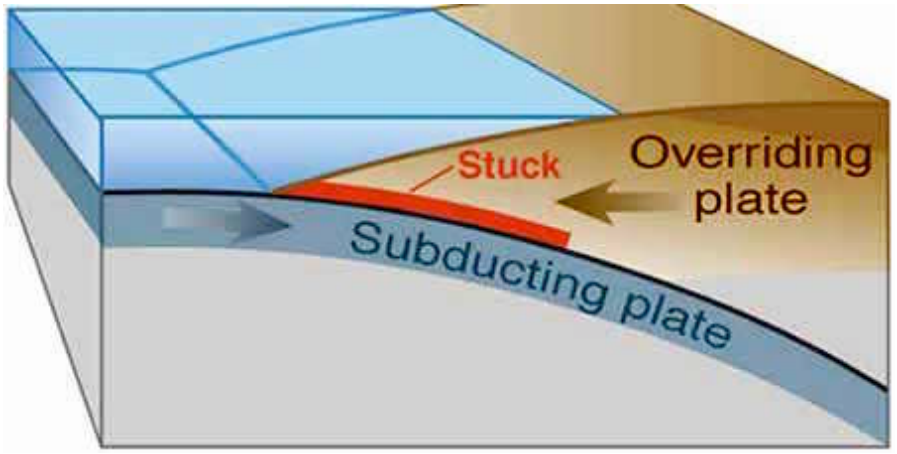


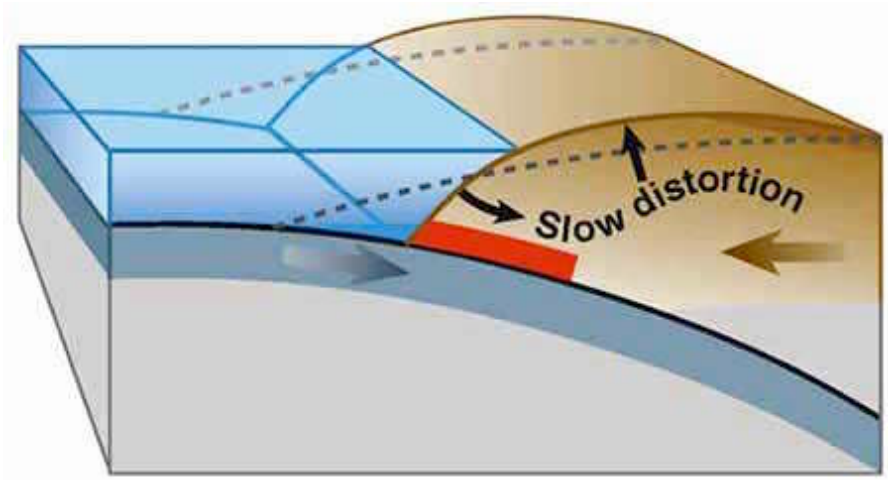
nachher

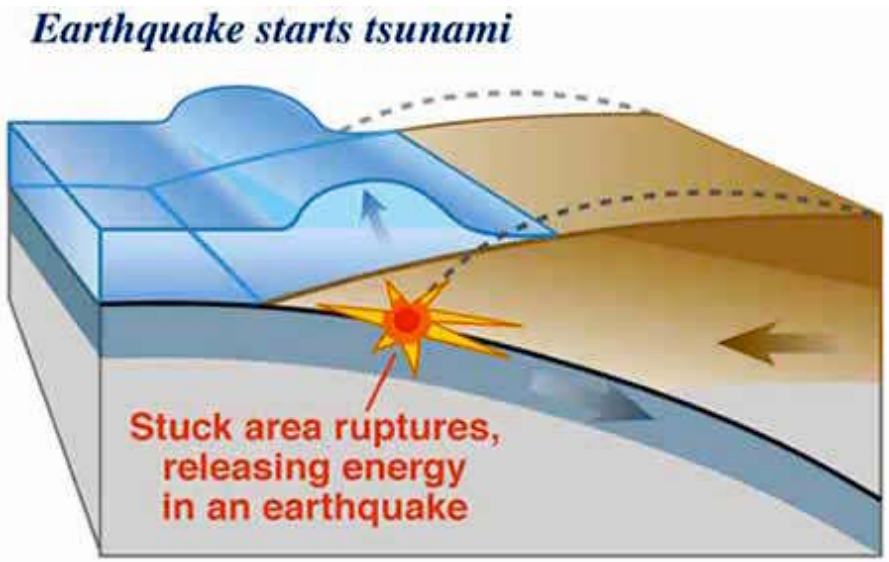


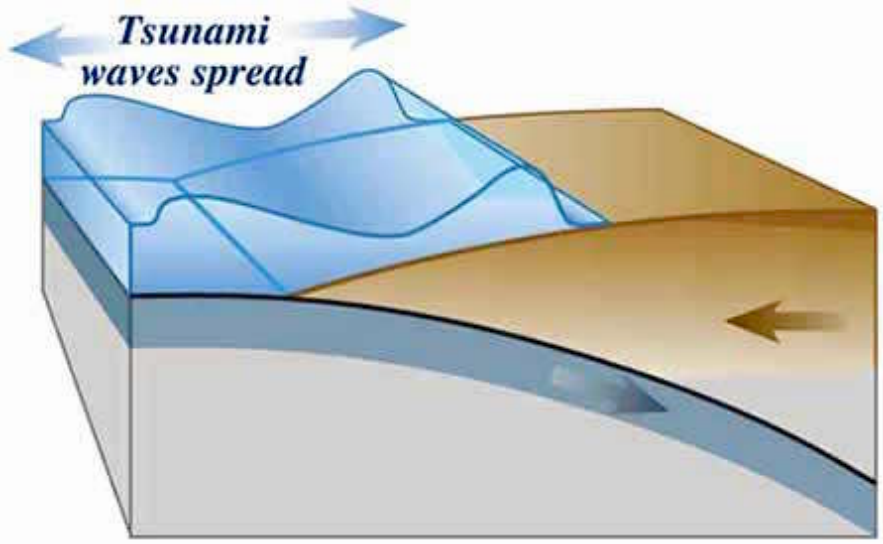
vorher

Tsunami

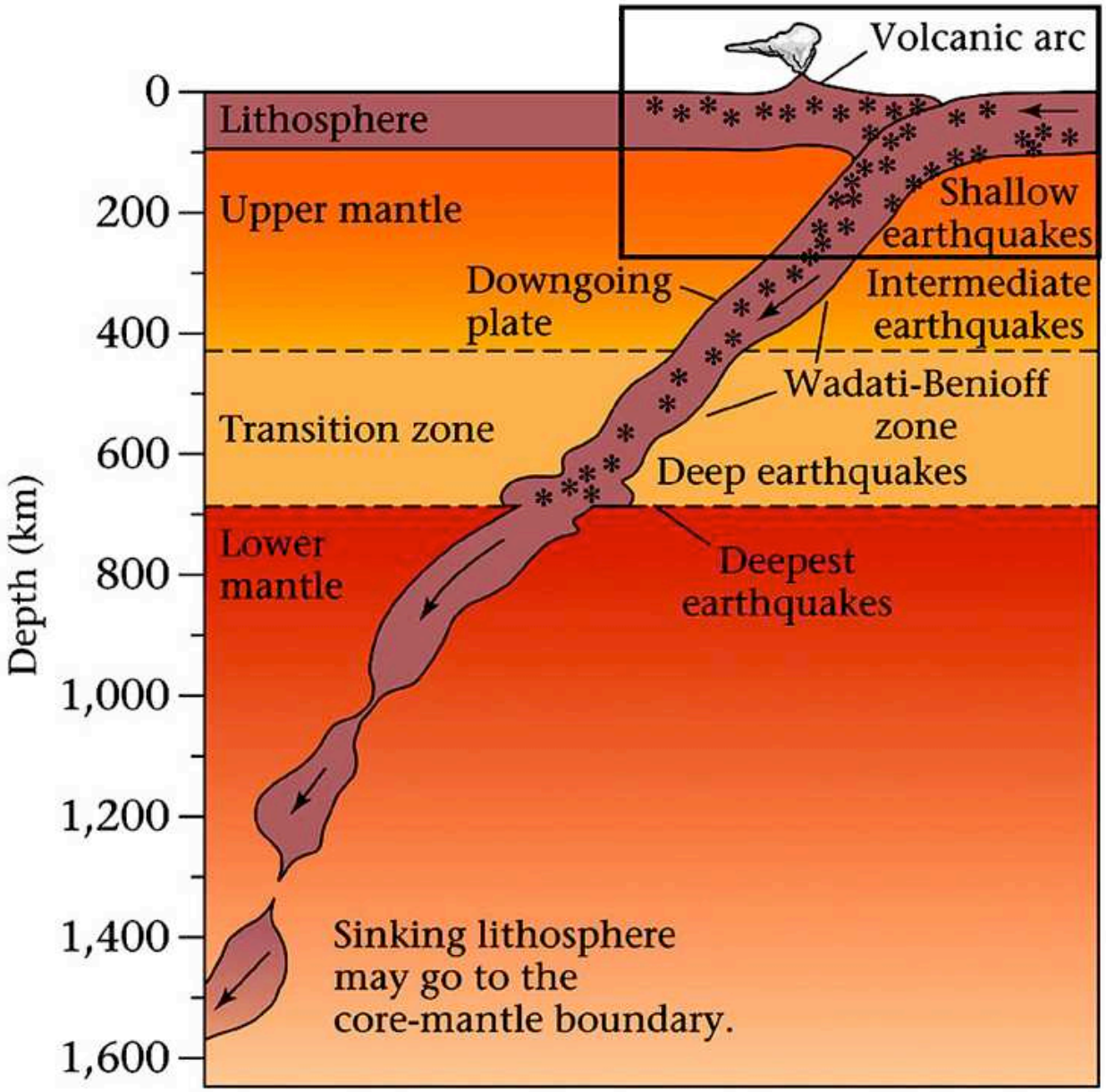

Stuck
Overriding plate
Subducting plate


Slow distortion

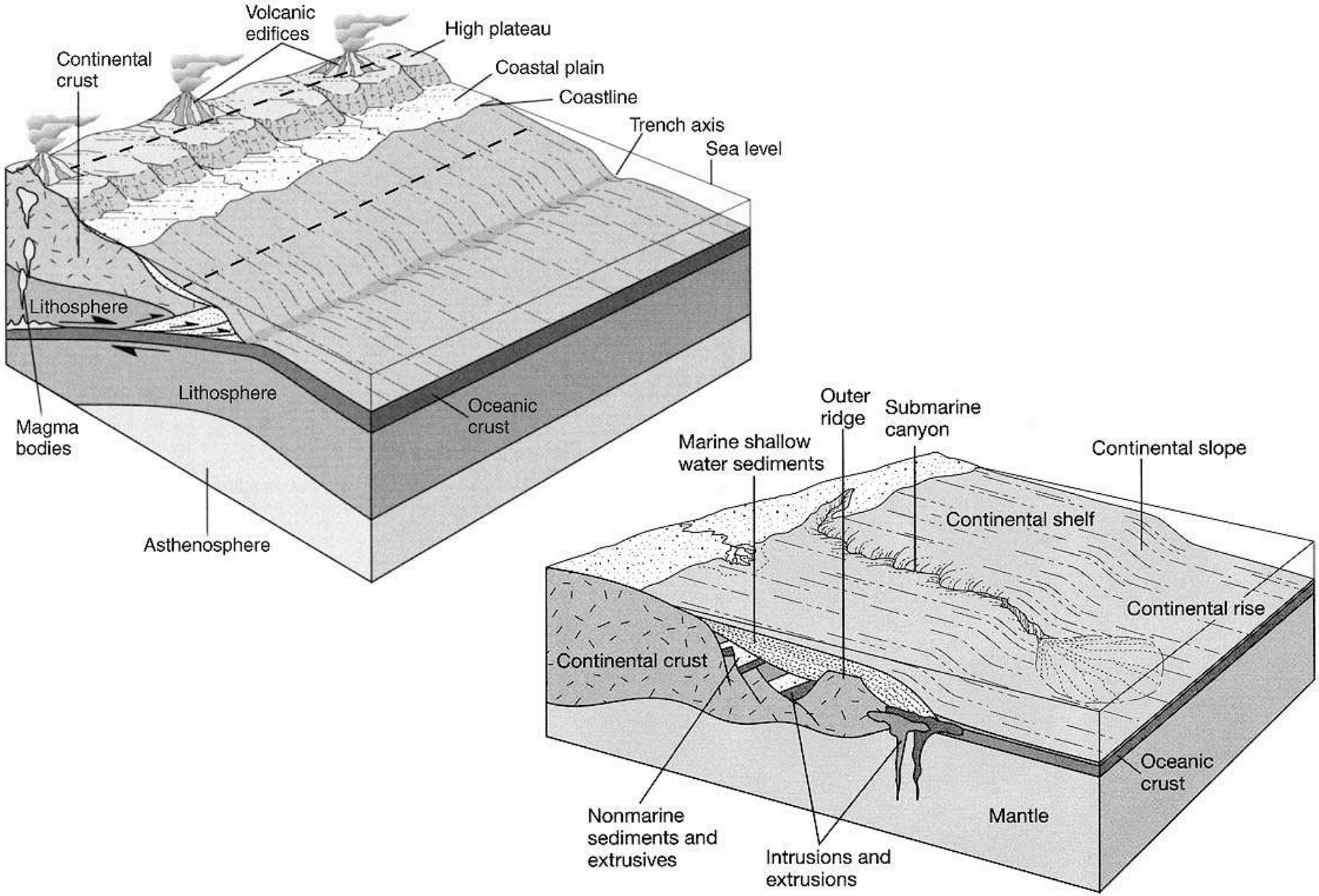

Earthquake starts tsunami
Stuck area ruptures, releasing energy in an earthquake


Tsunami waves spread

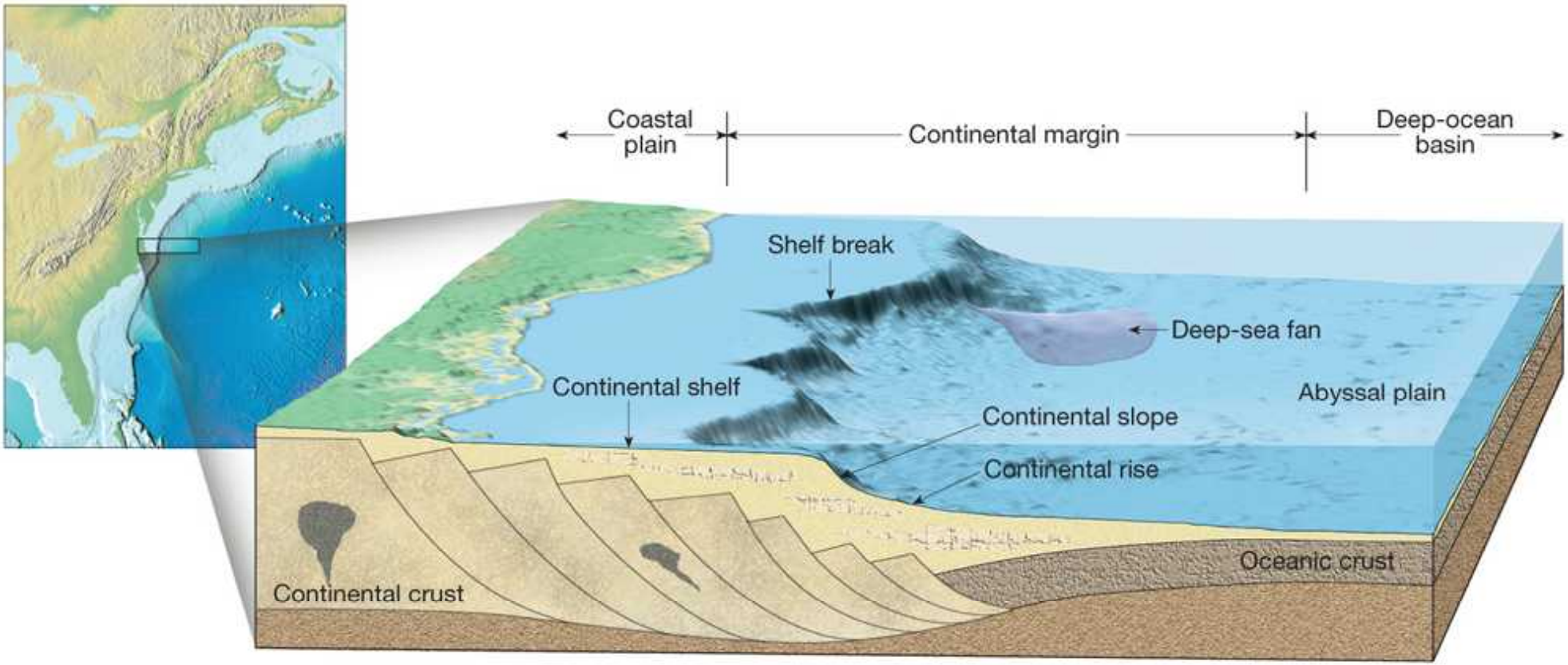
Subduktionszone



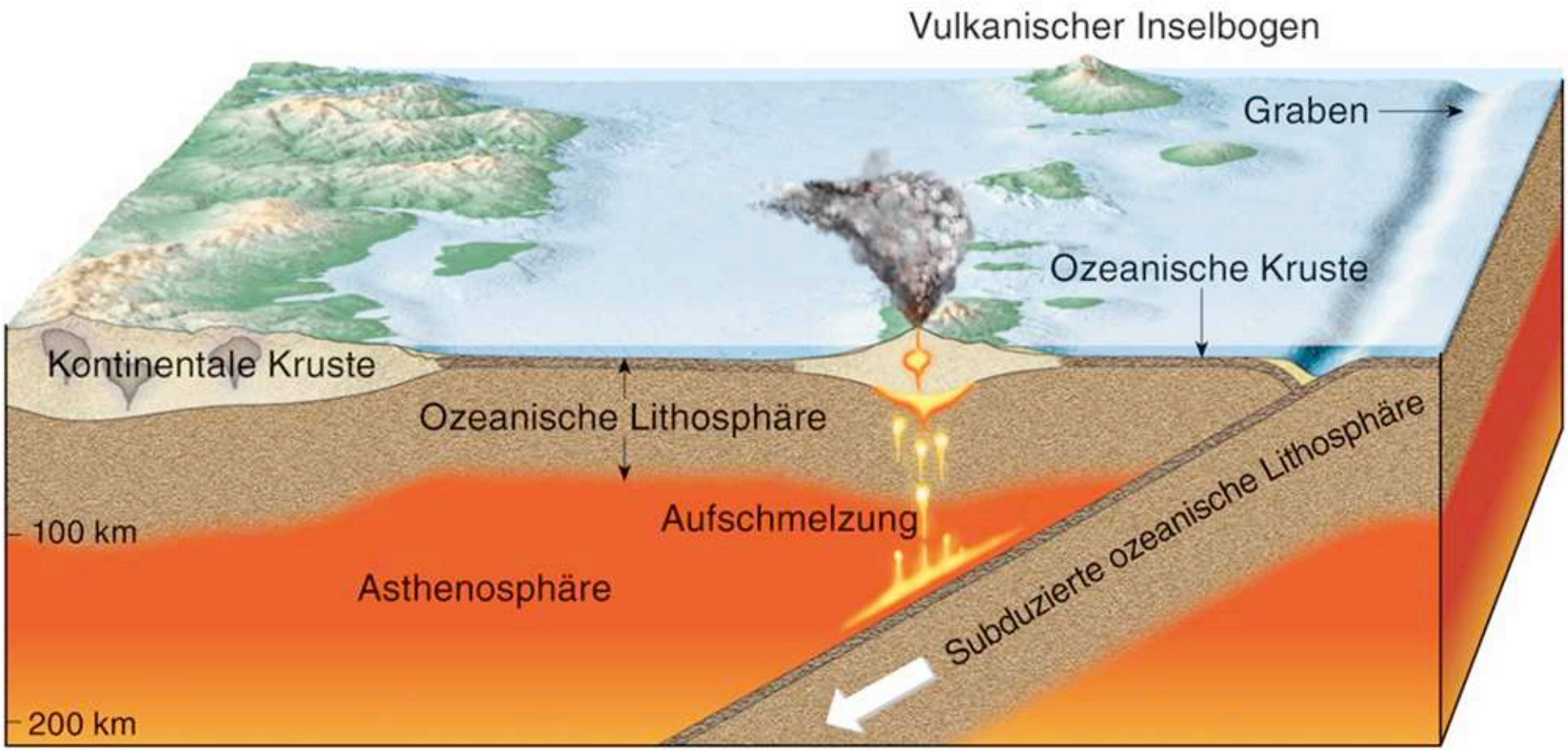
Aktiver vs. passiver Kontinentalrand



Passive continental margin

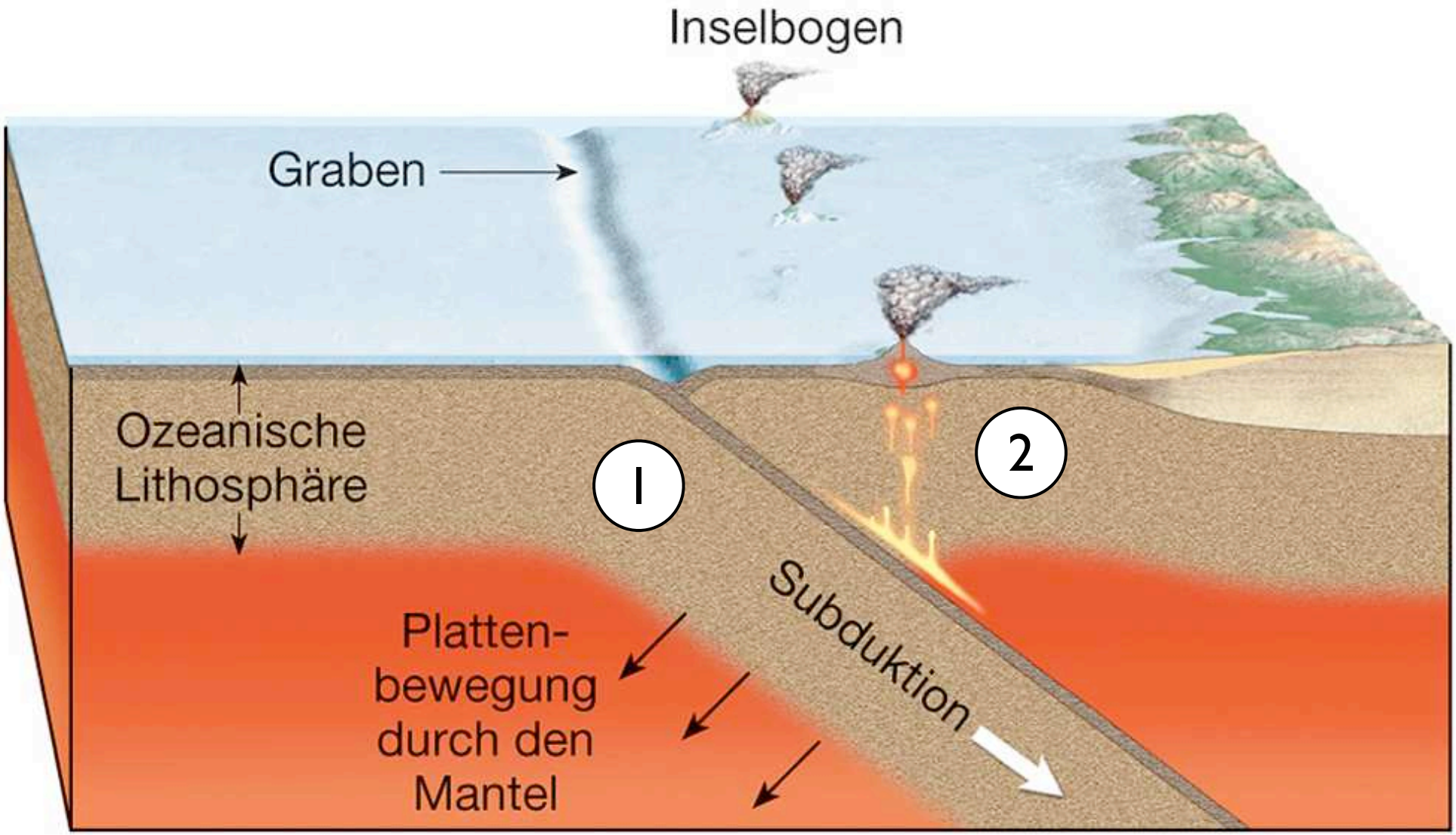


Ozean - Ozean



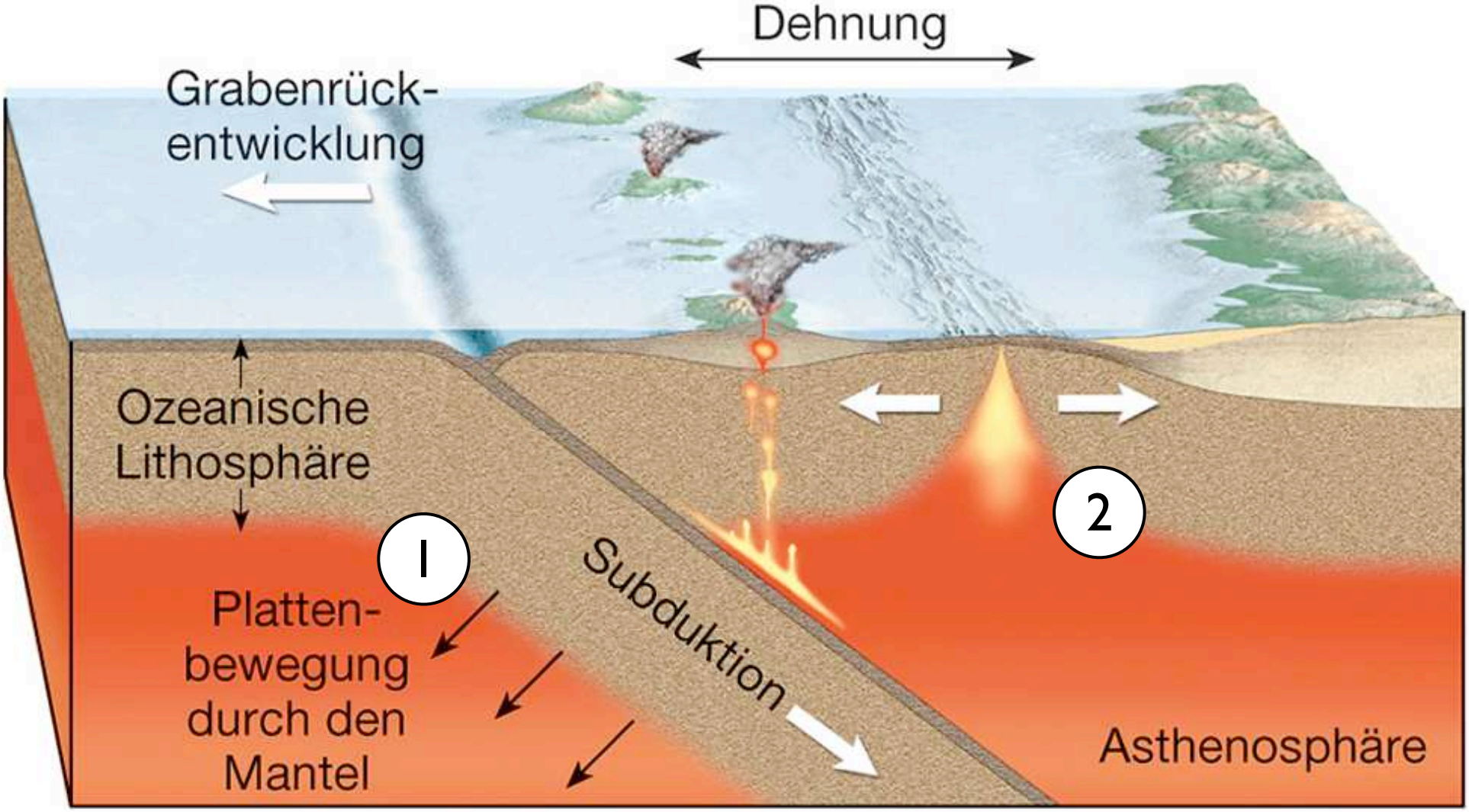
dichtere Platte sinkt hinunter
Vulkanismus am Ozenanboden
Vulkanische Inselbögen: Japan, Aleuten, Tonga

Vulkanischer Inselbogen



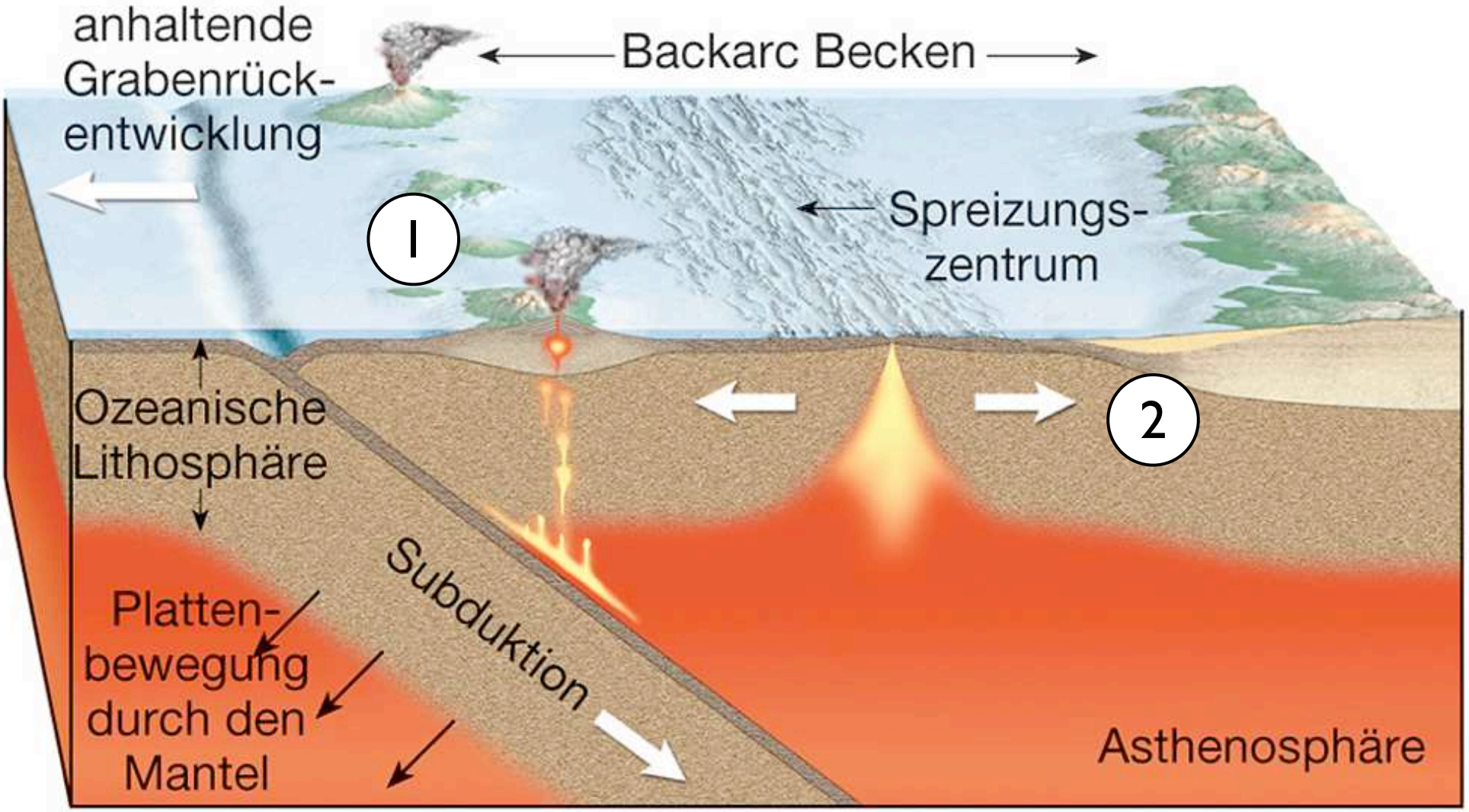
1 Asymmetrie: eine Platte taucht ab (wird subduziert)
2 Wasser führt zur Aufschmelzung und Vulkanismus

Vulkanischer Inselbogen



1 Subduzierte Platte sinkt ab: roll-back
2 Leichtes (heisses) Magma steigt auf, Kruste dehnt sich

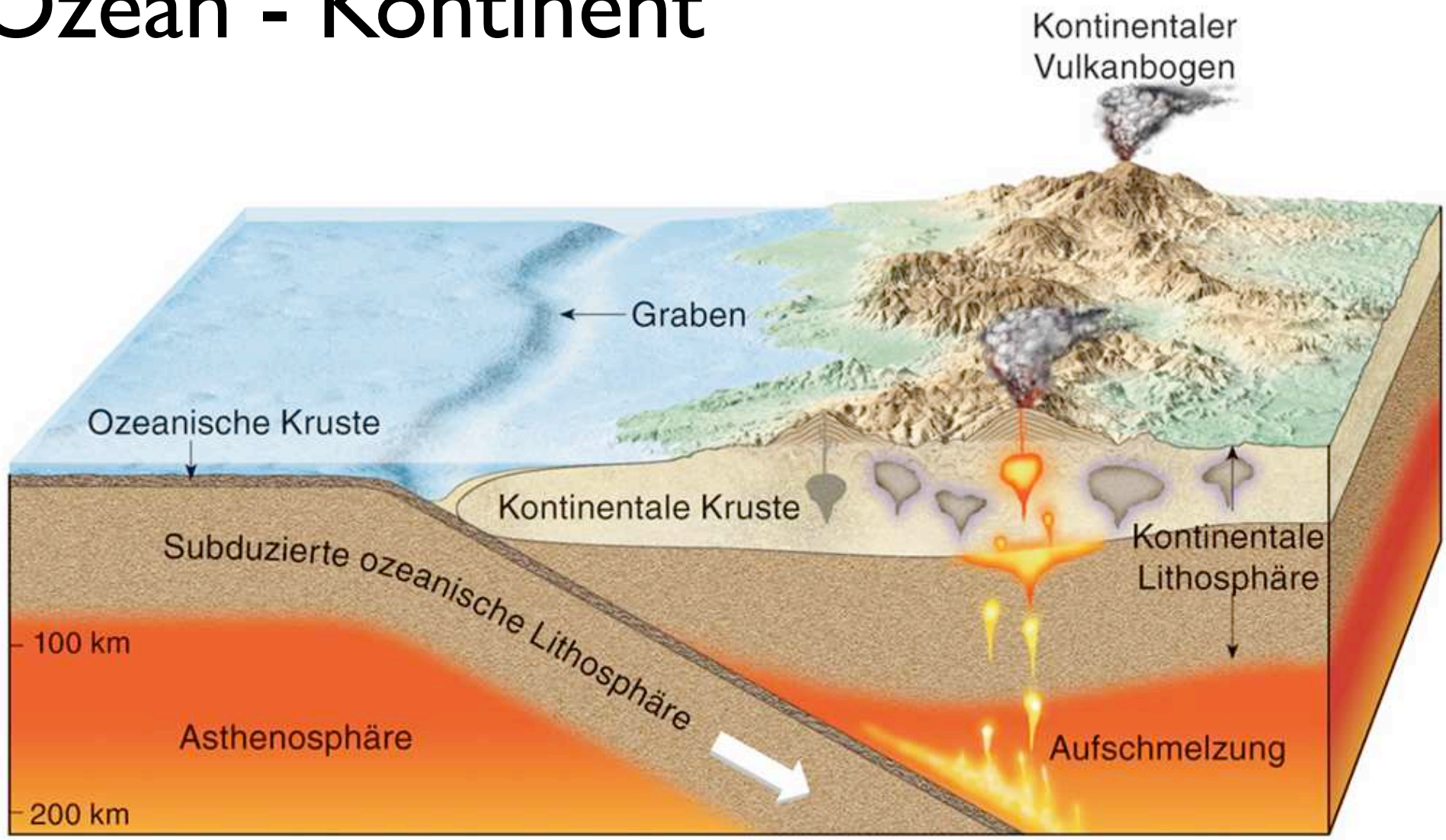
Vulkanischer Inselbogen



1 Vulkanismus führt zu Inseln
2 Ozeanbodenspreizung in obduzierter Platte: back arc spreading

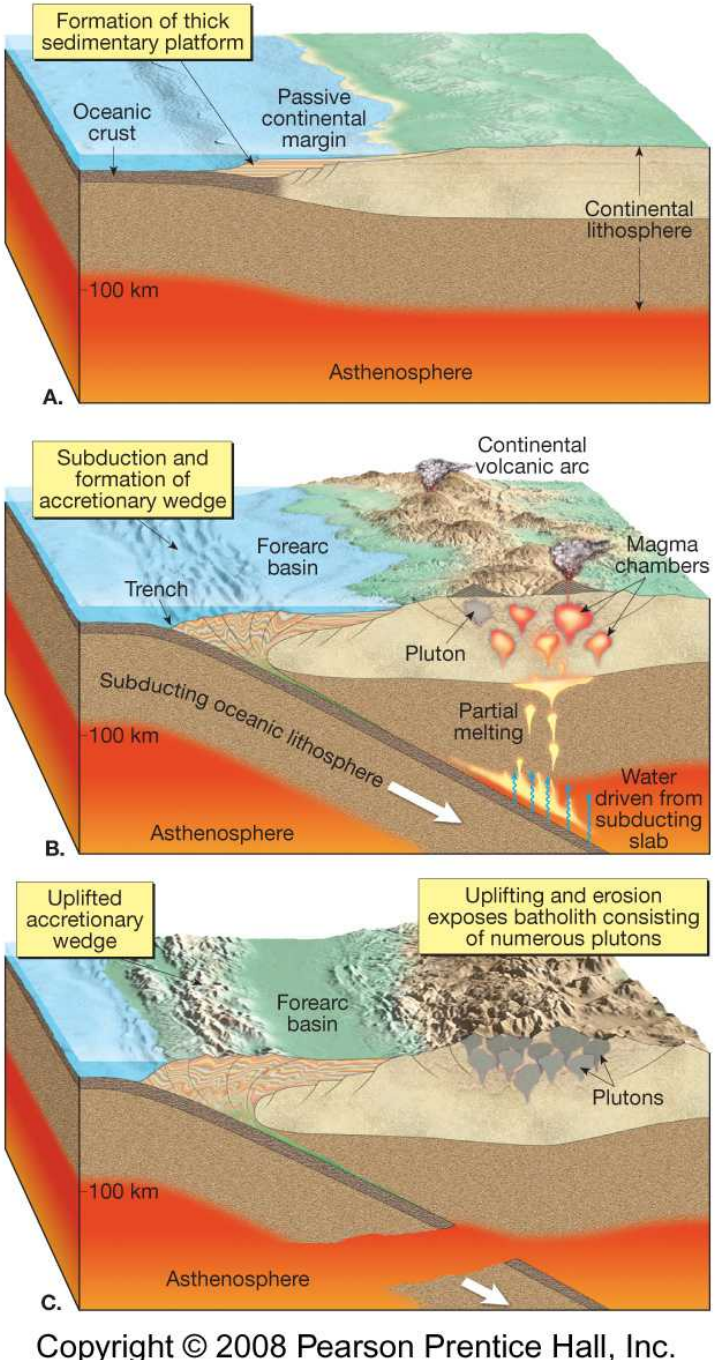
Beispiel: Aleutian

Ozean - Kontinent



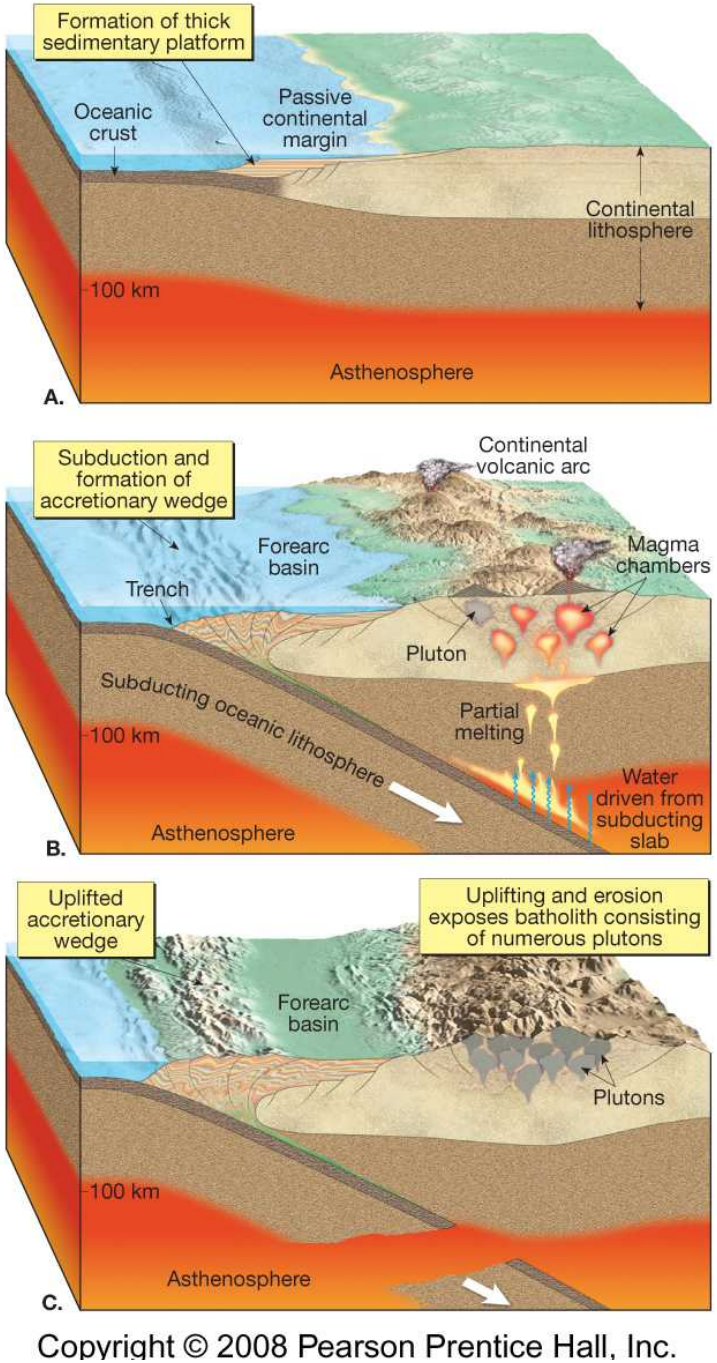
dichtere Platte (= ozeanische) sinkt hinunter
Aufschmelzung in überschobener Platte
Kontinentale Vulkanbögen: Anden, Cascades (USA)

Andean-type mountain building



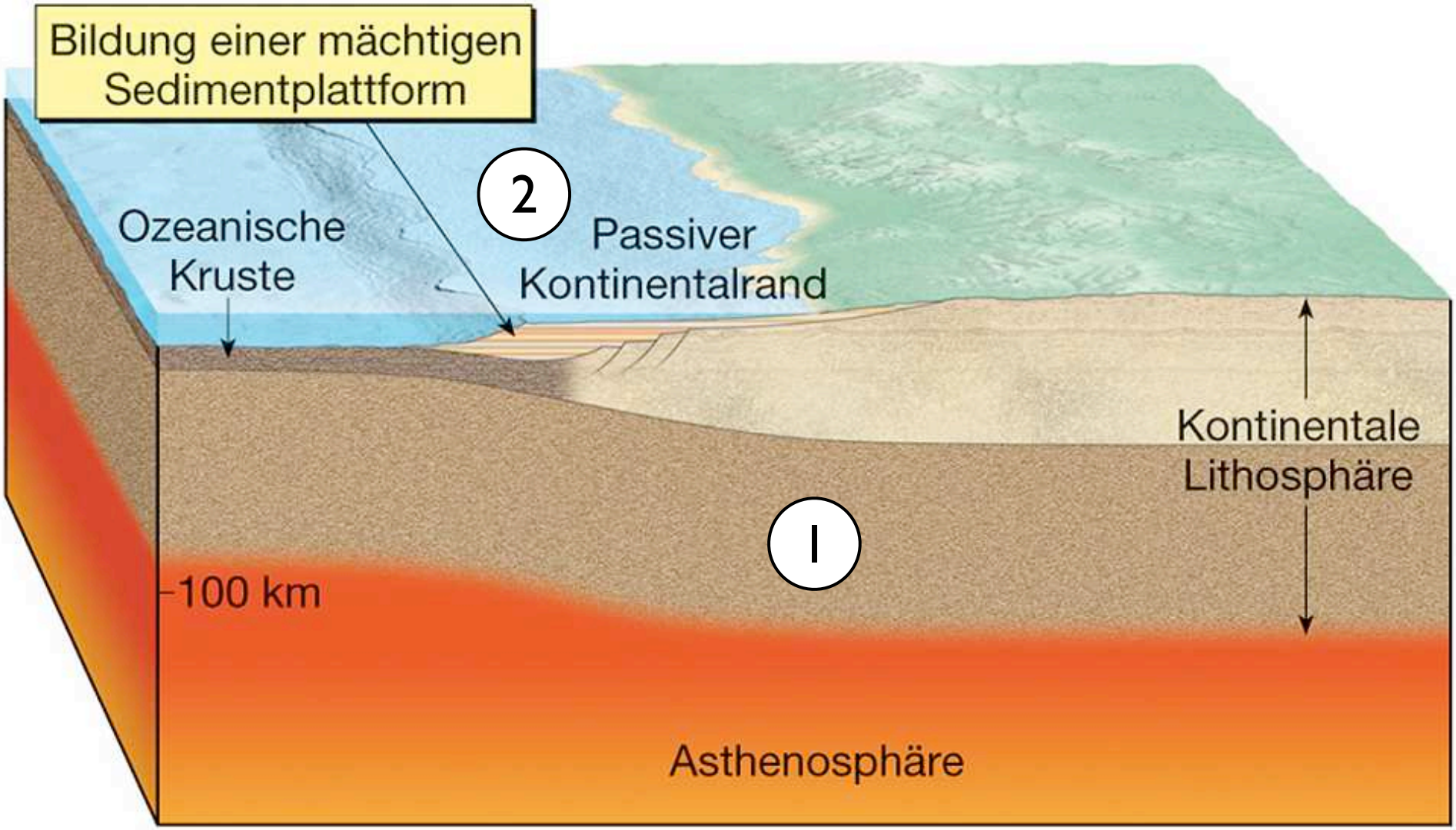
- Mountain building along continental margins
- Involves the convergence of an oceanic plate and a plate whose leading edge contains continental crust
- Building a volcanic arc
  - Subduction and partial melting of mantle rock generates primary magmas
  - Magma is less dense than surrounding rock so it begins to buoyantly rise
  - Differentiation of magma produces andesitic volcanism dominated by pyroclastics and lavas

Andean-type mountain building



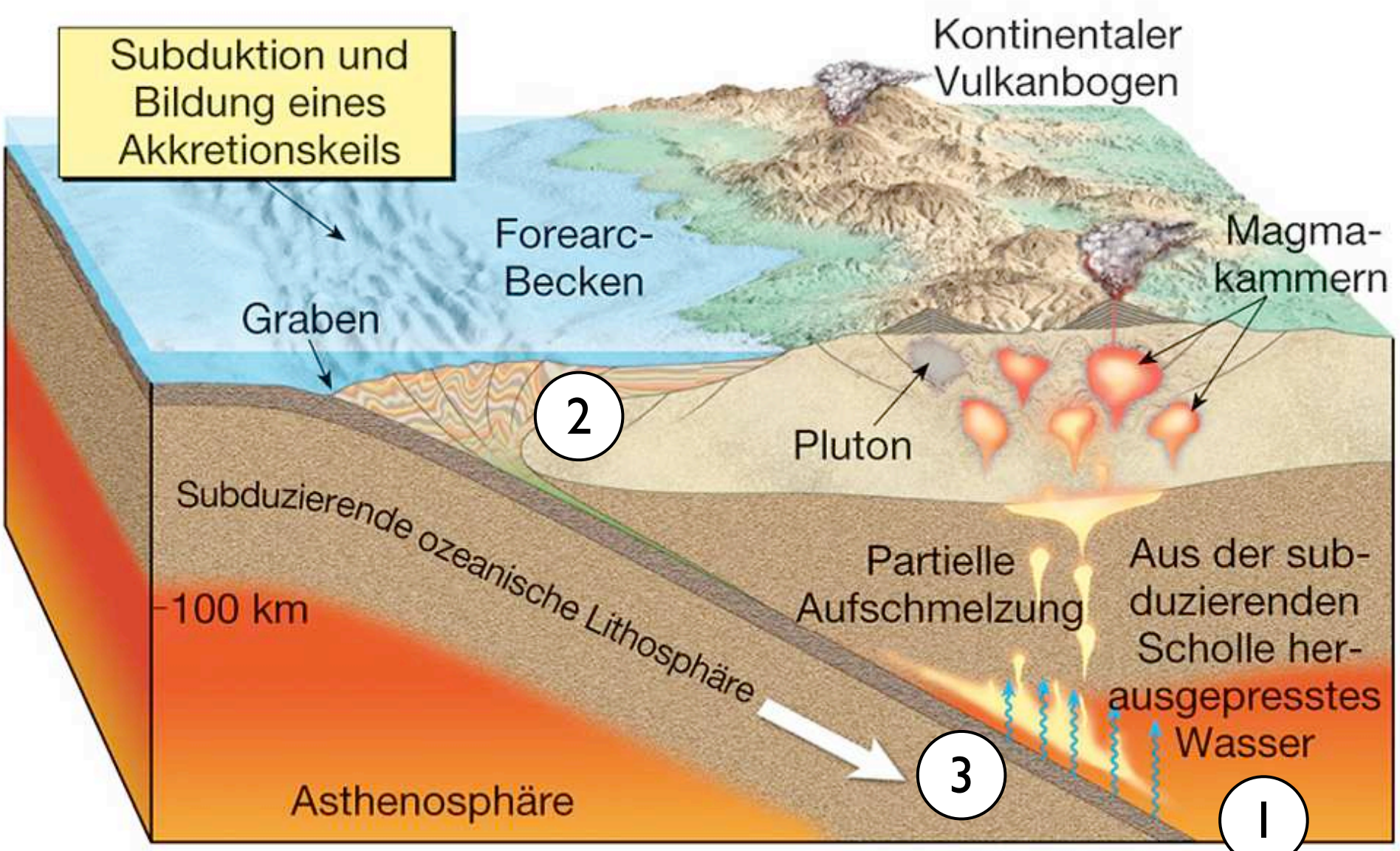
- Emplacement of plutons
- Thick continental crust impedes the ascent of magma
- A large percentage of the magma never reaches the surface and is emplaced as plutons
- Uplift and erosion exposes these massive structures called batholiths (i.e., Sierra Nevada in California and Peruvian Andes)
- Batholiths are typically intermediate to felsic compositions

Orogenese an Subduktionszone



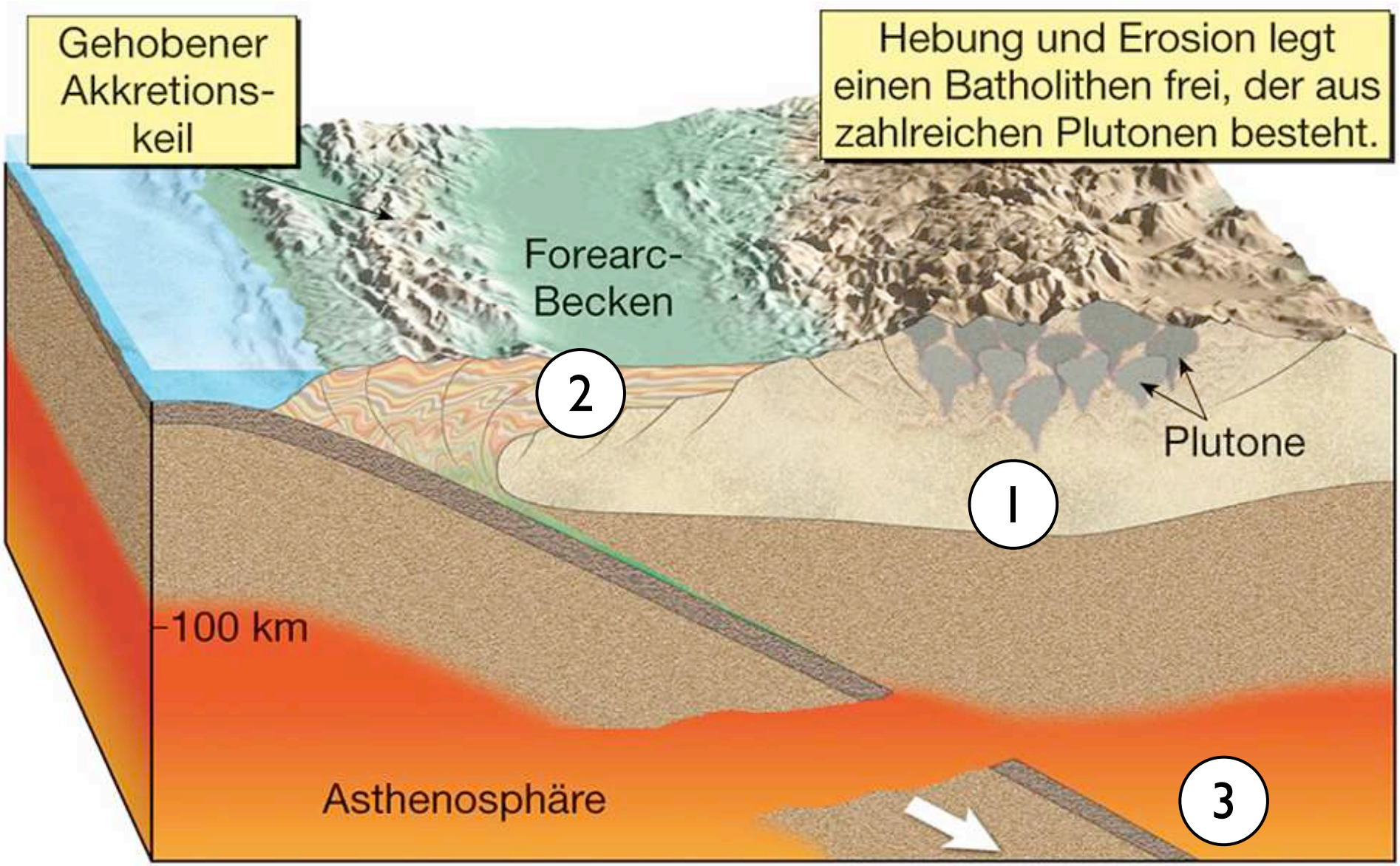
1 Konvergenz: Ozeanische Platte - Platte mit Kontinentalrand
2 Bildung einer mächtigen Sedimentplattform

Orogenese an Subduktionszone



1 Wassser führt zu Aufschmelzung - andesitischer Vulkanismus
2 Bildung eines Akkretionskeils 3 druckbetonte Metamorphose

Orogenese an Subduktionszone

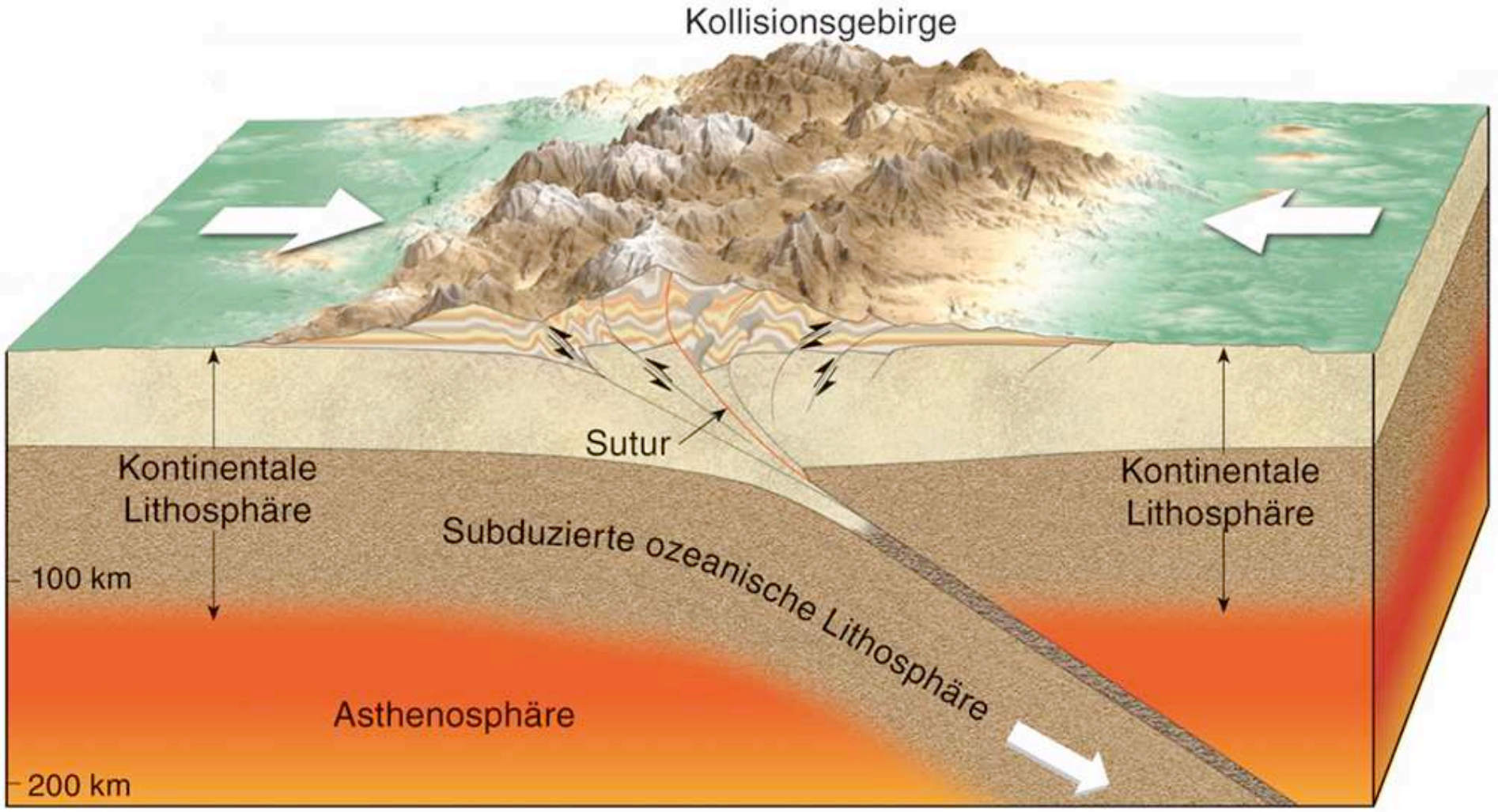


1 Plutone (Batholite) - Metamorphismus

2 Forearc Becken

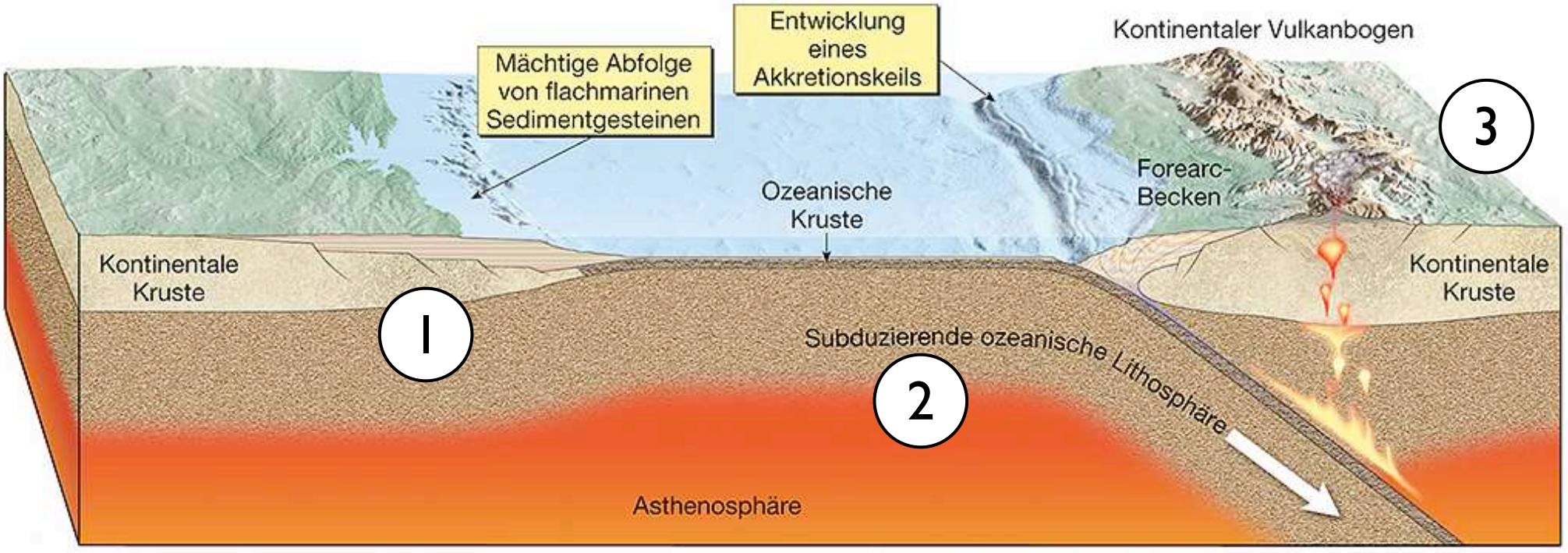
3 Slab break-off

Kontinent - Kontinent



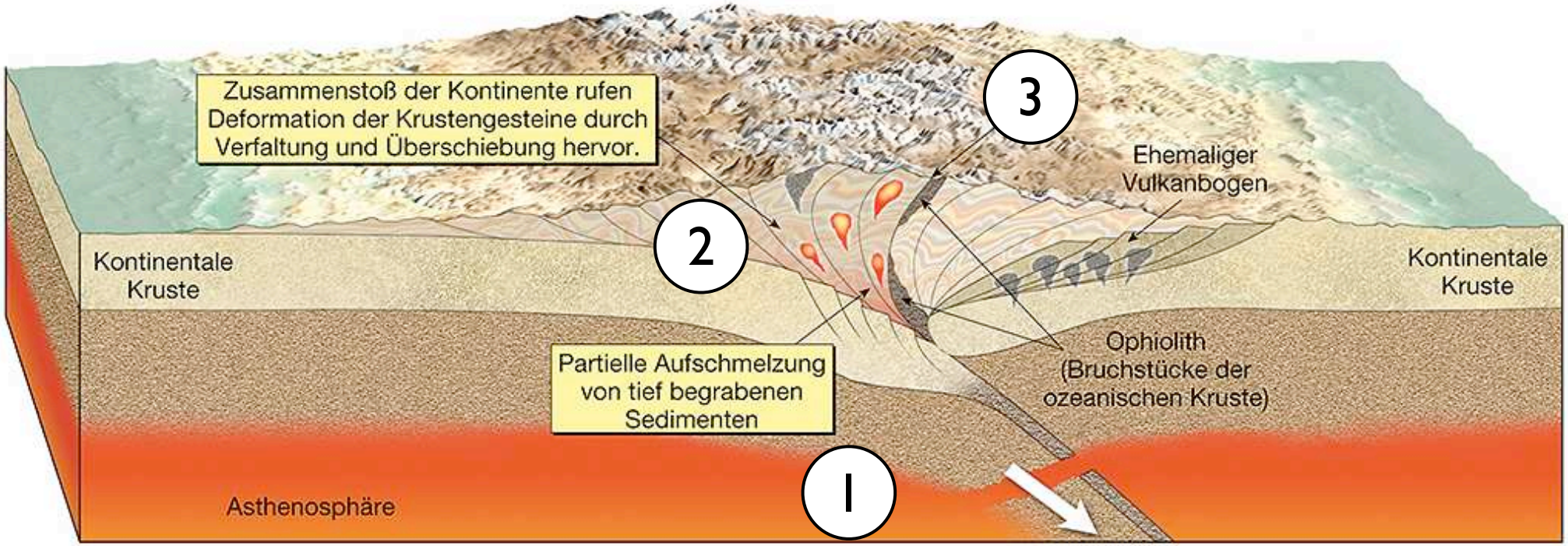
Fortgesetzte Subduktion → kontinentale Kollision
dichtere Platte wird subduziert
Kollisionsgebirge: Himalaya, Alpen, Appalachen

Gebirgsbildung



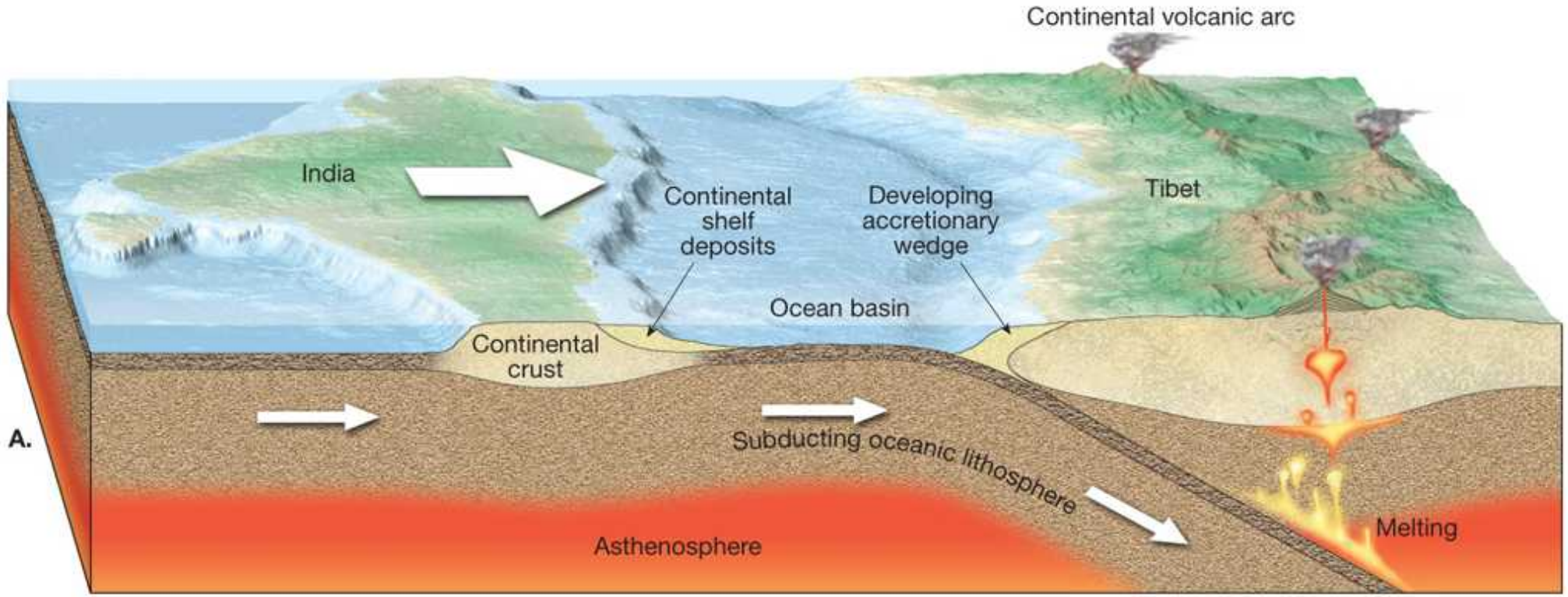
1 Öffnung eines Ozeans, Sedimente am passiven Kontinentalrand
2 Konvergenz: Schliessung des Ozeans
3 Kontinentaler Volkanbogen

Kontinentale Kollision



1 Kontinentale Kollision
2 Verdickung der Kruste, Faltengebirge (fold and thrust belt)
3 Sutur: Nahtstelle zwischen Kontinentalplatten

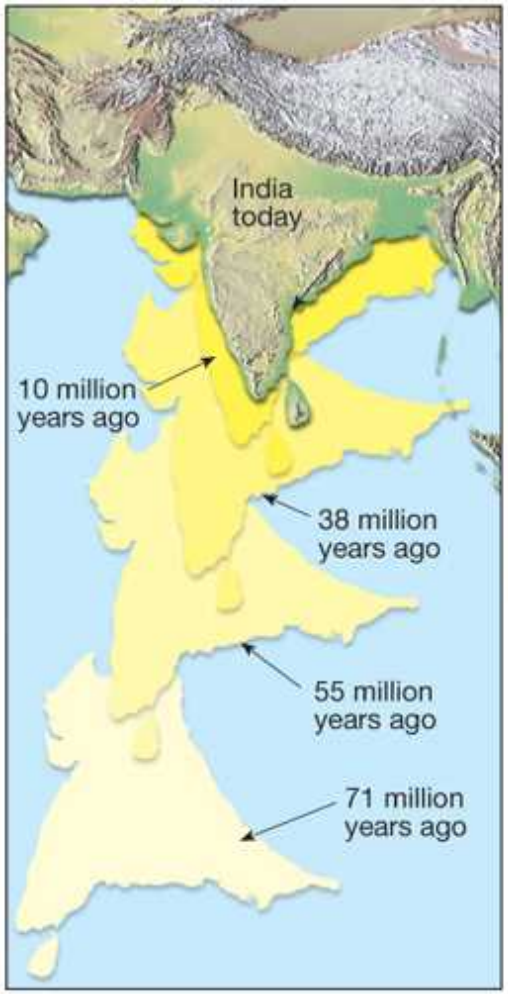
Beispiel: Himalaya

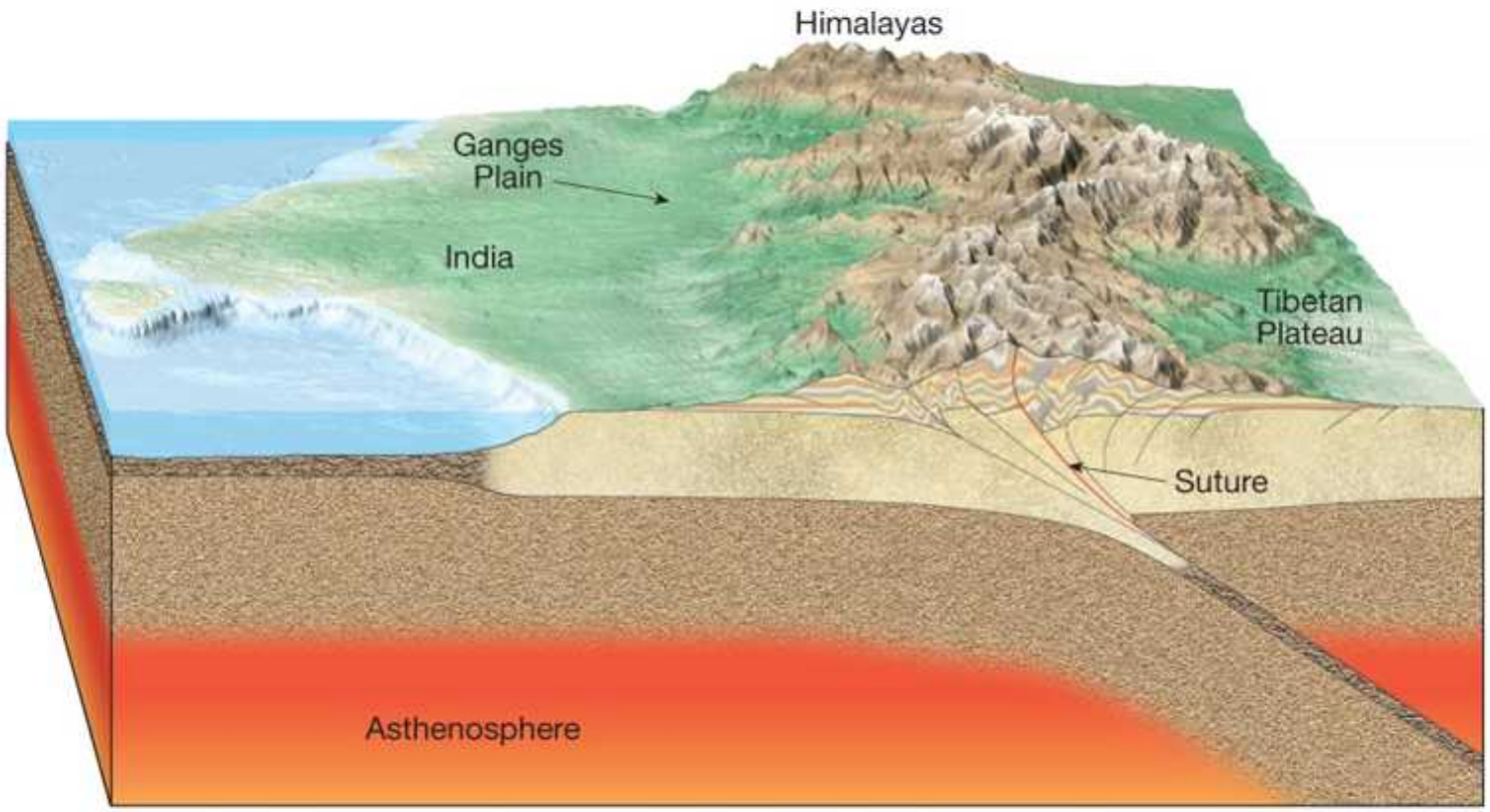


Kollision vor 45 Ma

Kollision Indische - Eurasische Platte

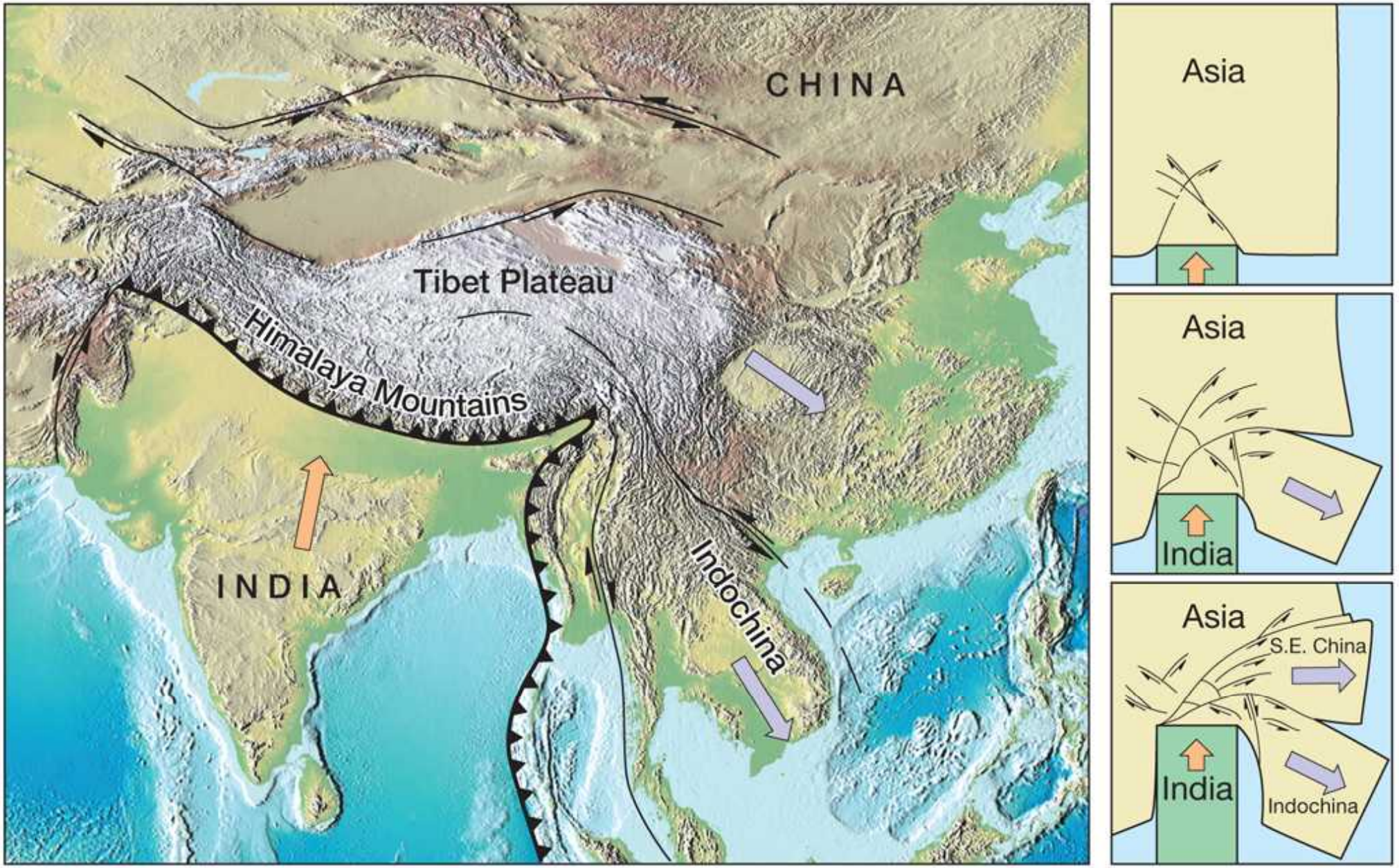
Beispiel: Himalaya



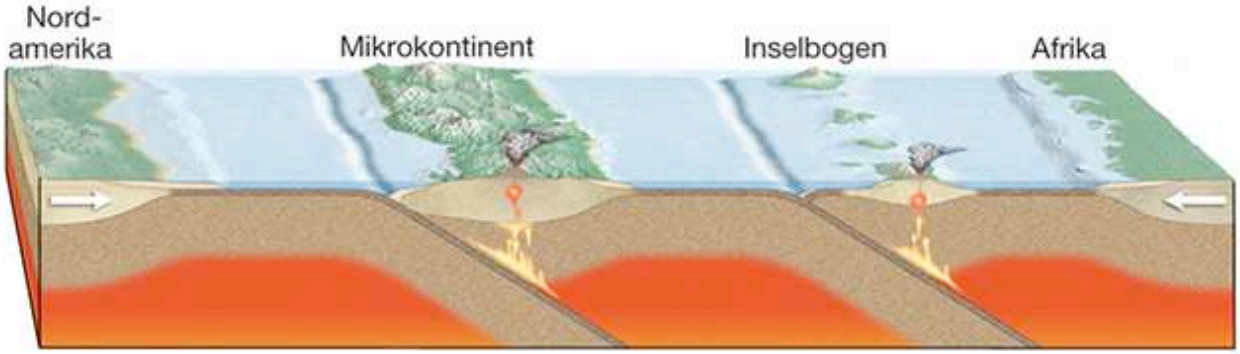


C.

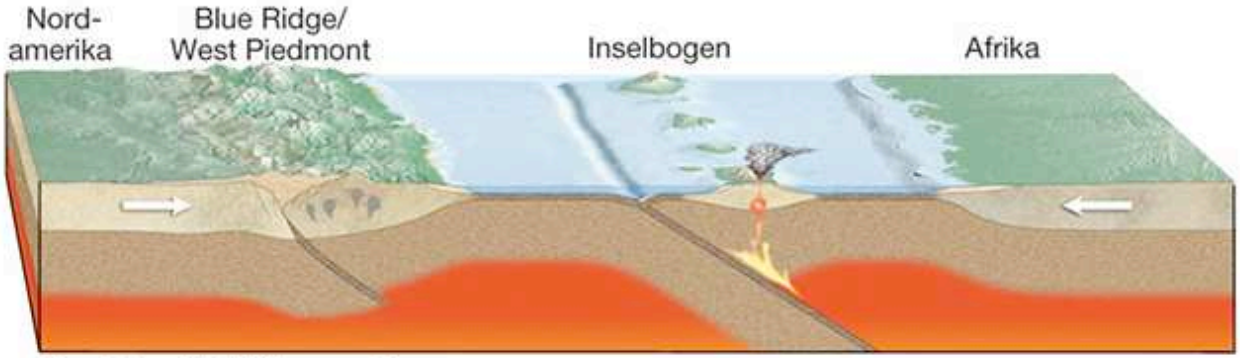
Beispiel: Himalaya



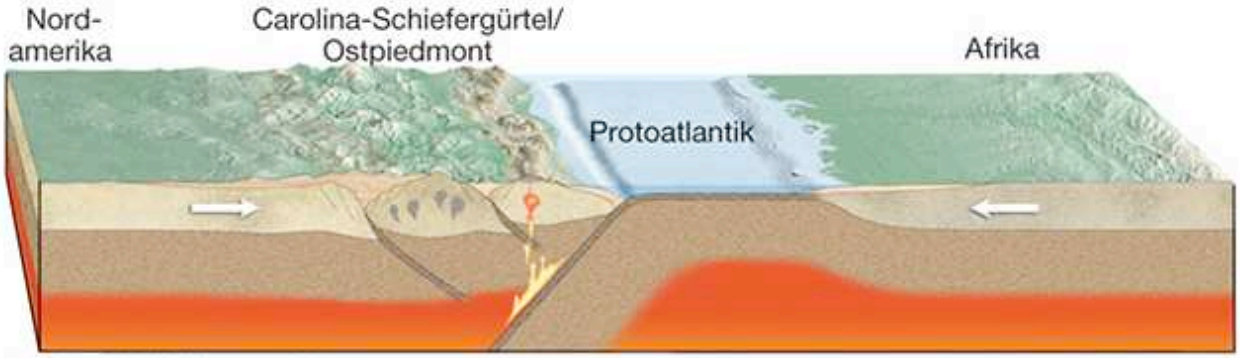
Beispiel: Appalachen



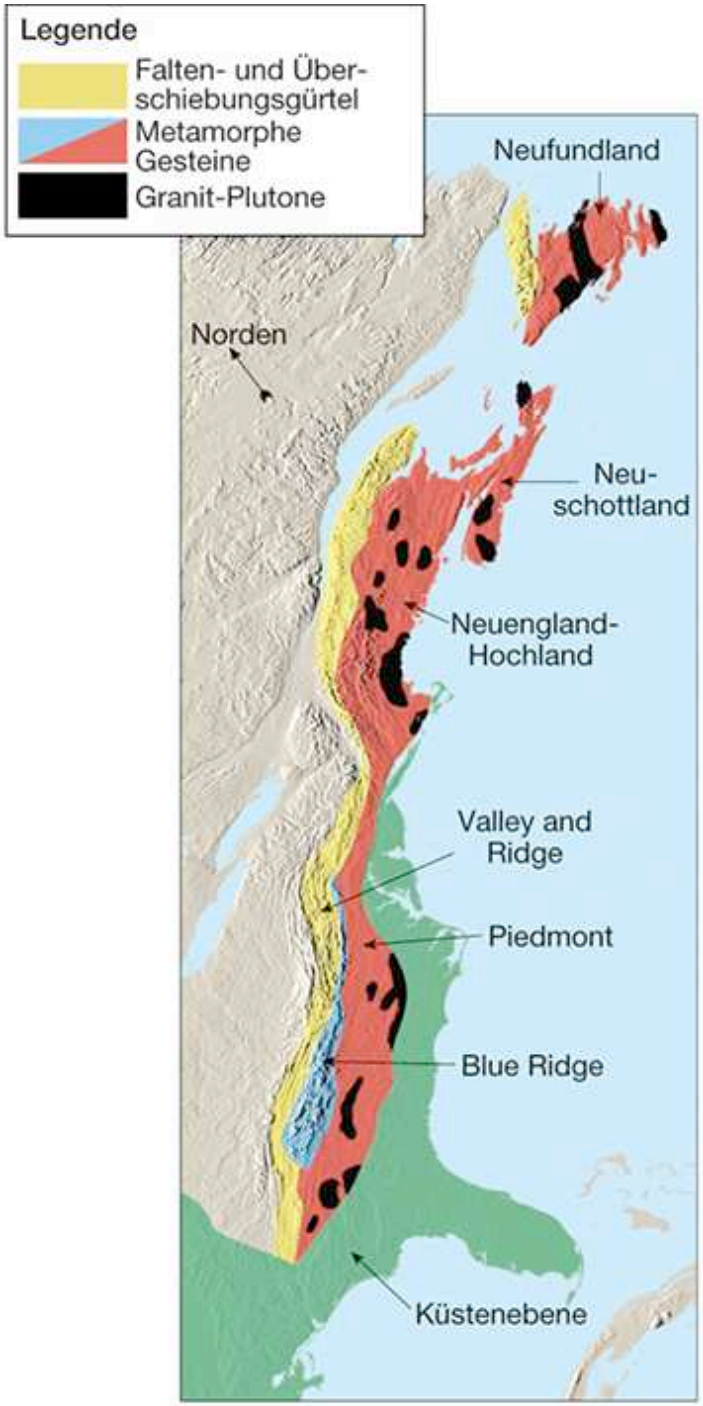
600 Ma



450 - 500 Ma

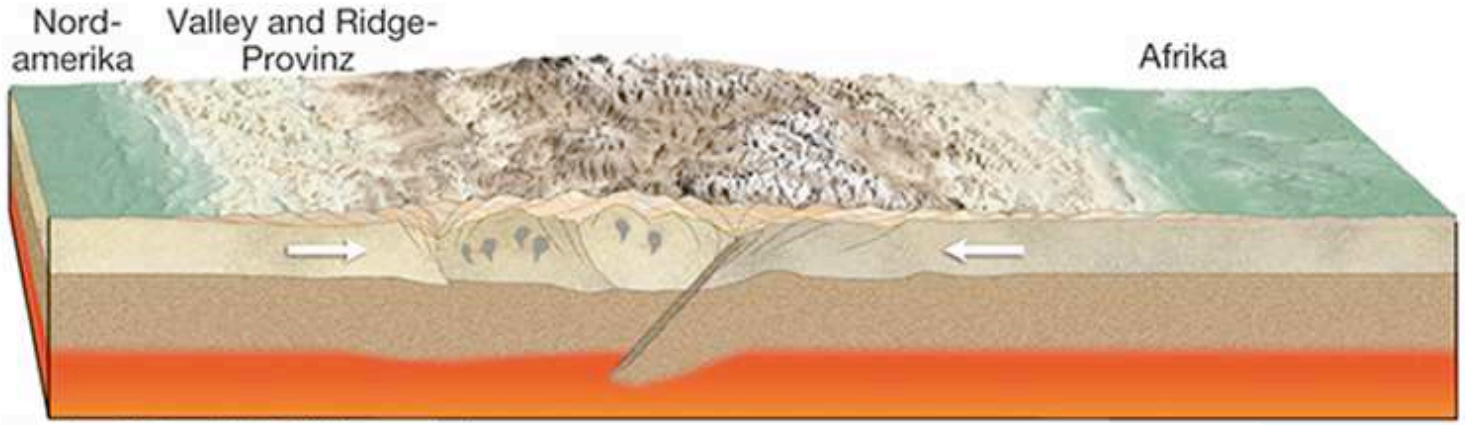


400 Ma

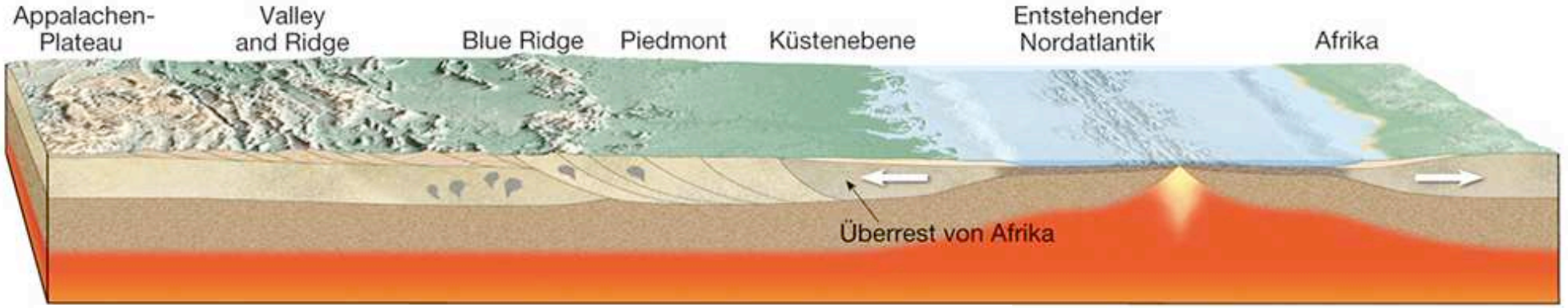


Hauptstrukturen der Appalachen

Beispiel: Appalachen

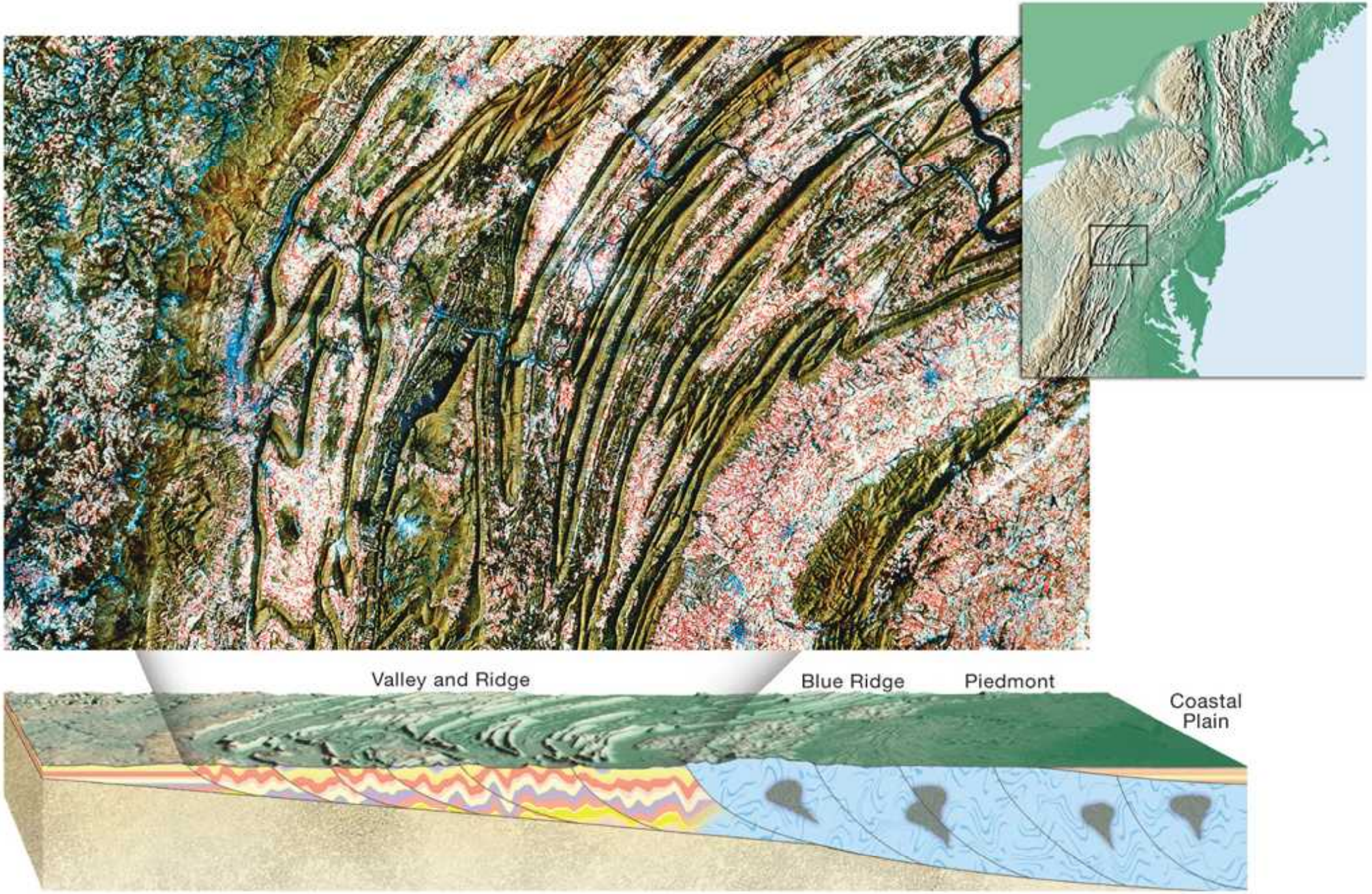


250 - 300 Ma



150 Ma

Beispiel: Appalachen



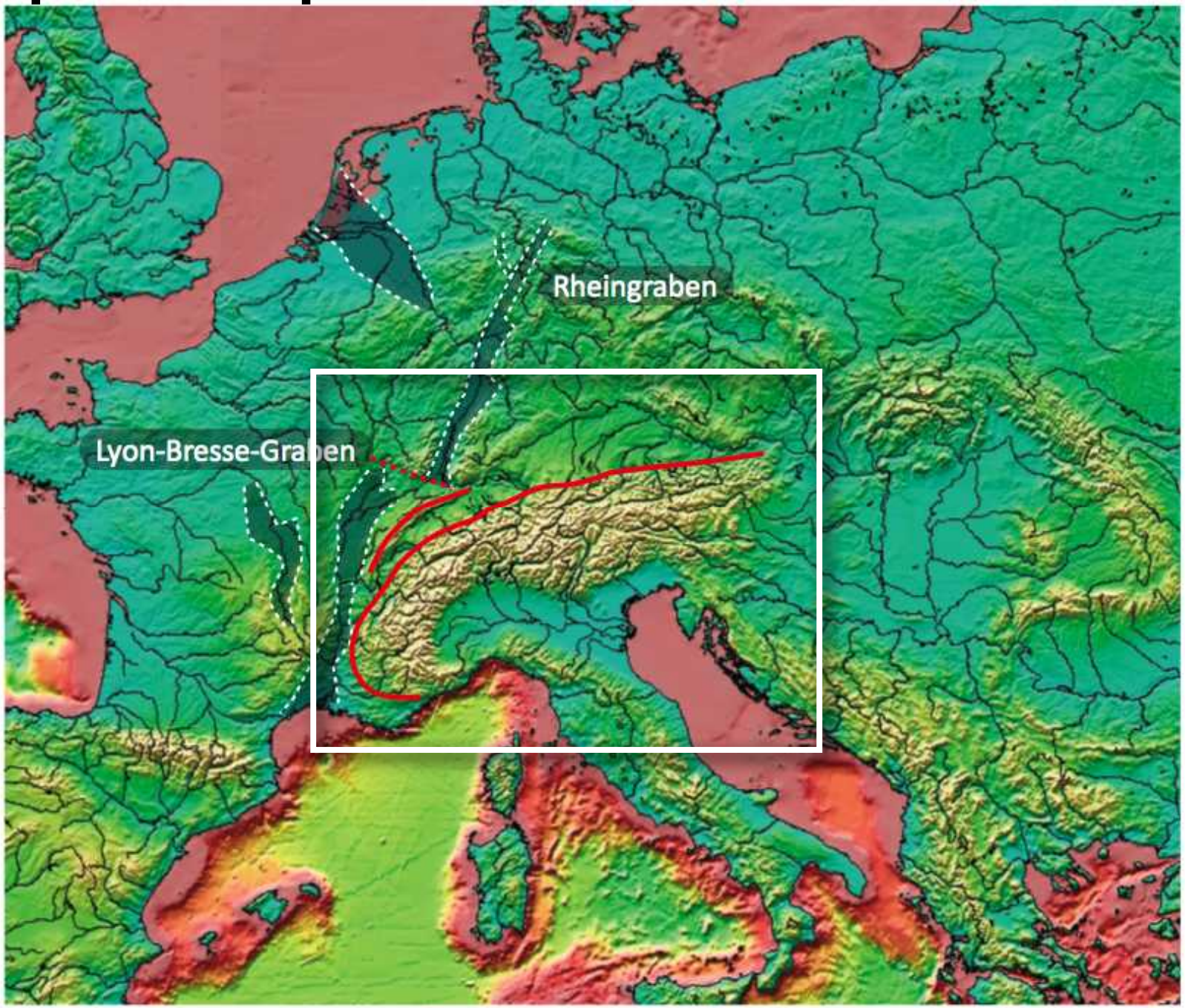
Phanerozoikum: Appalachen

Late Paleozoic Alleghenian orogeny

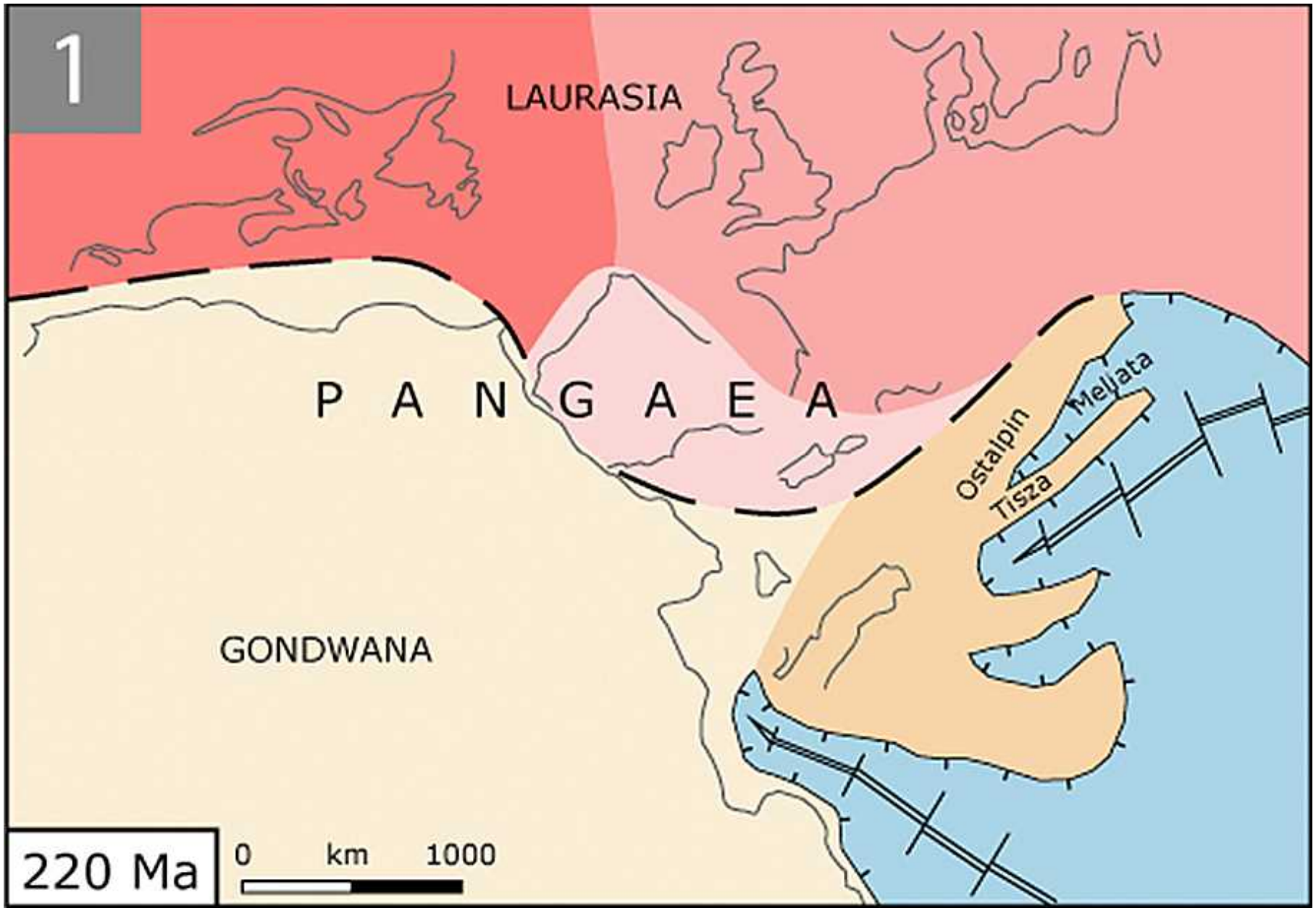
Phanerozoikum: Appalachen

Late Paleozoic Alleghenian orogeny

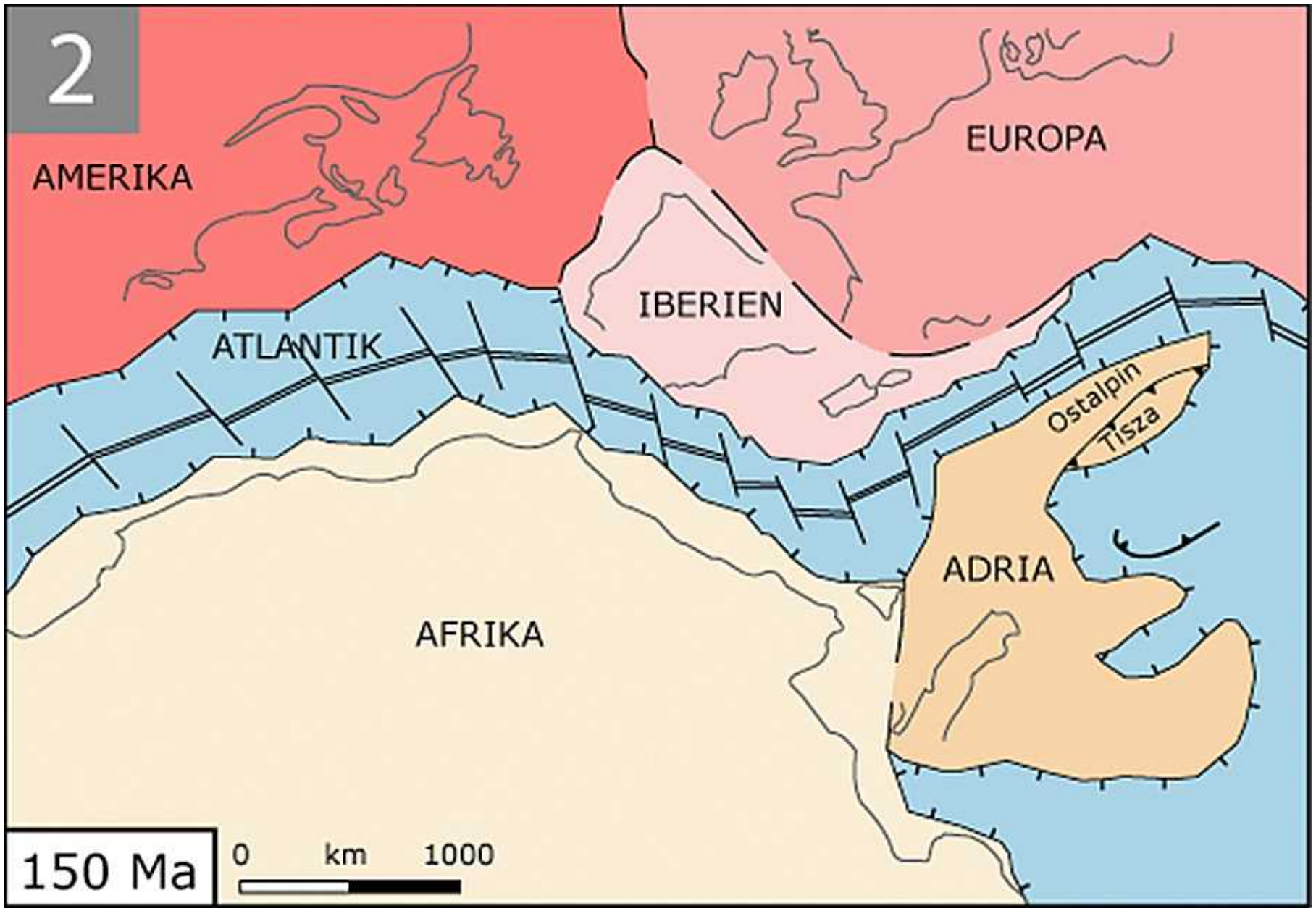
Beispiel: Alpen



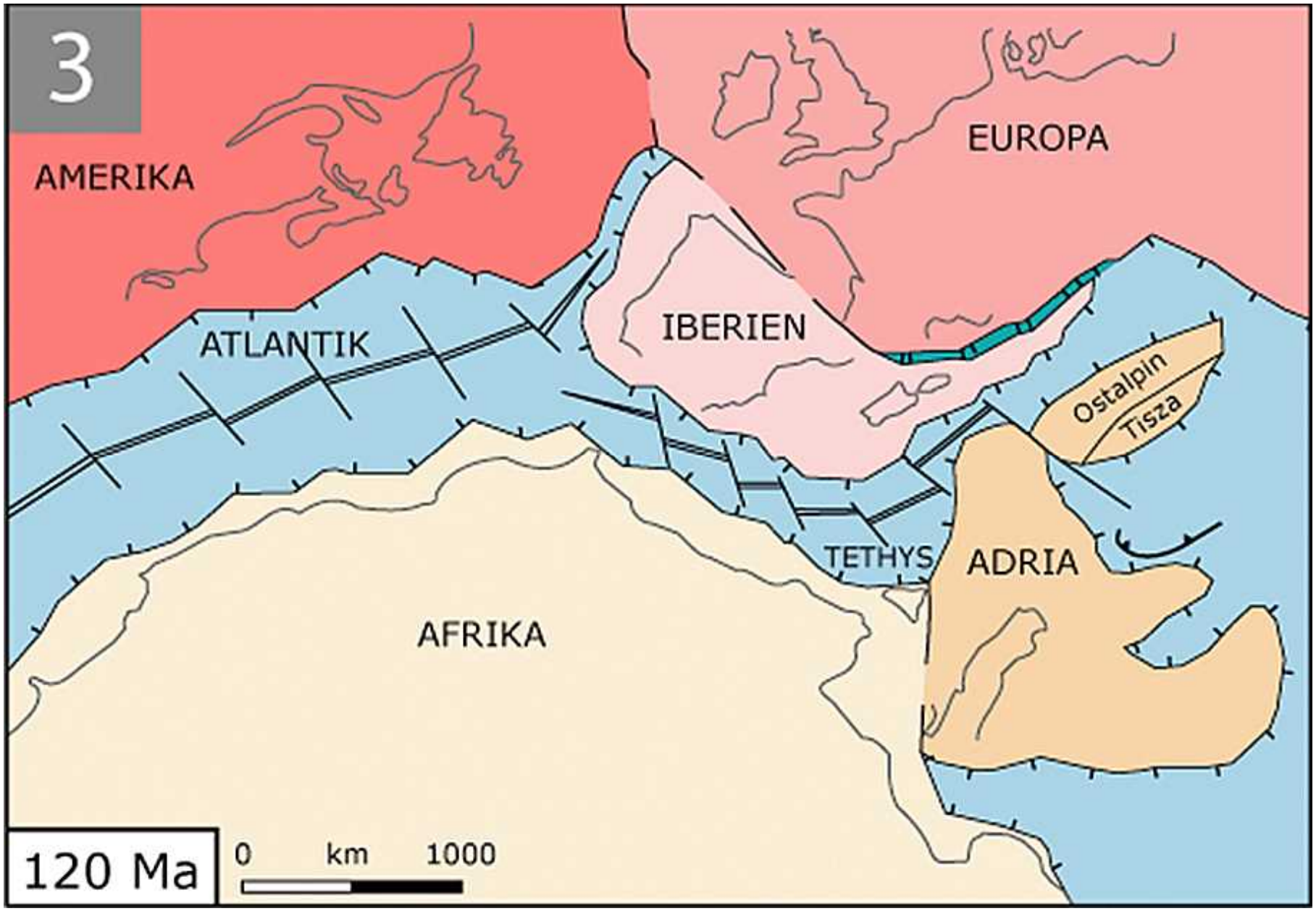
Phase 1:
Neuer Raum wird geschaffen ("Rifting Phase")



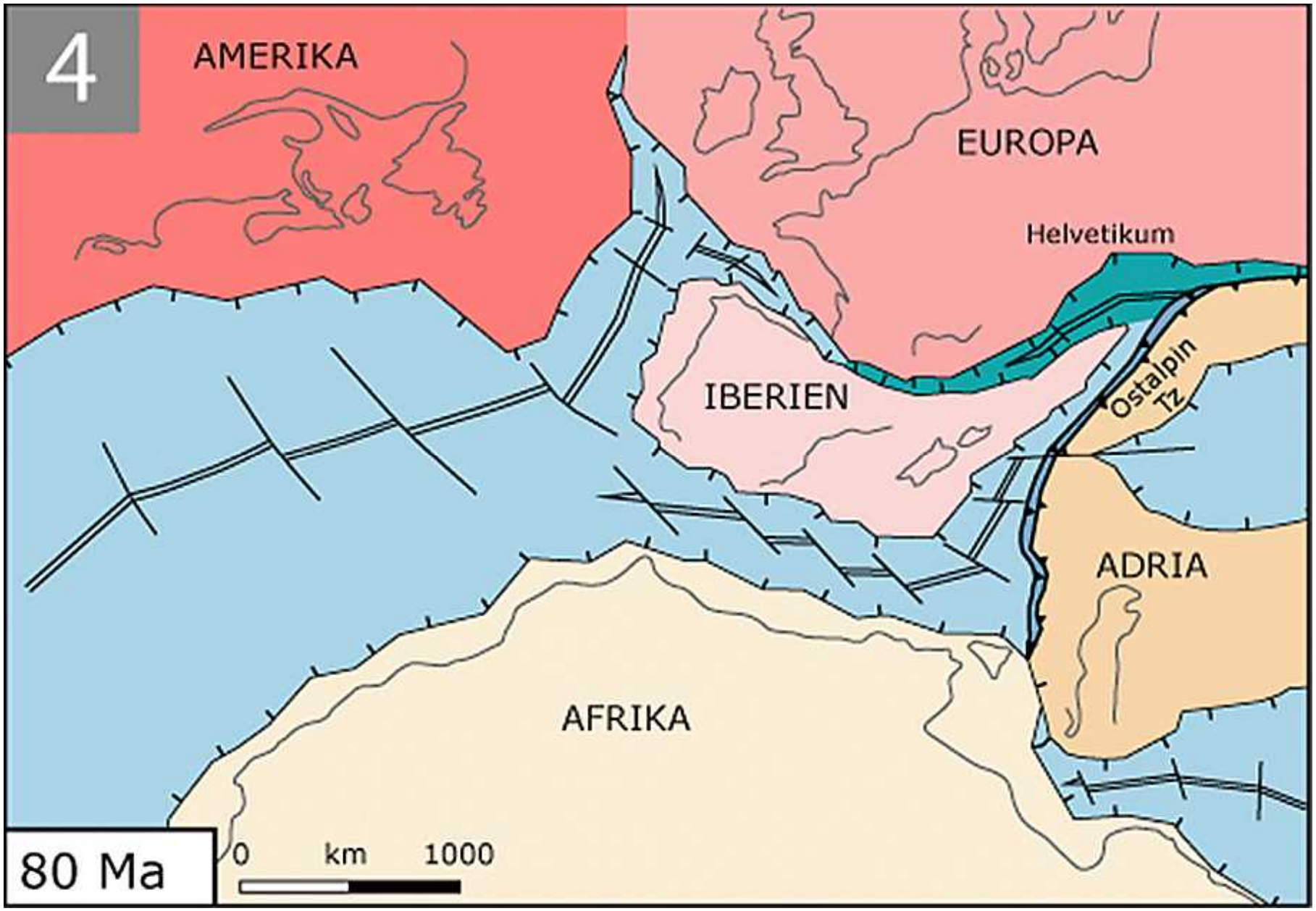
Phase 2:
Neue ozean. Kruste wird gebildet ("Drifting Phase")



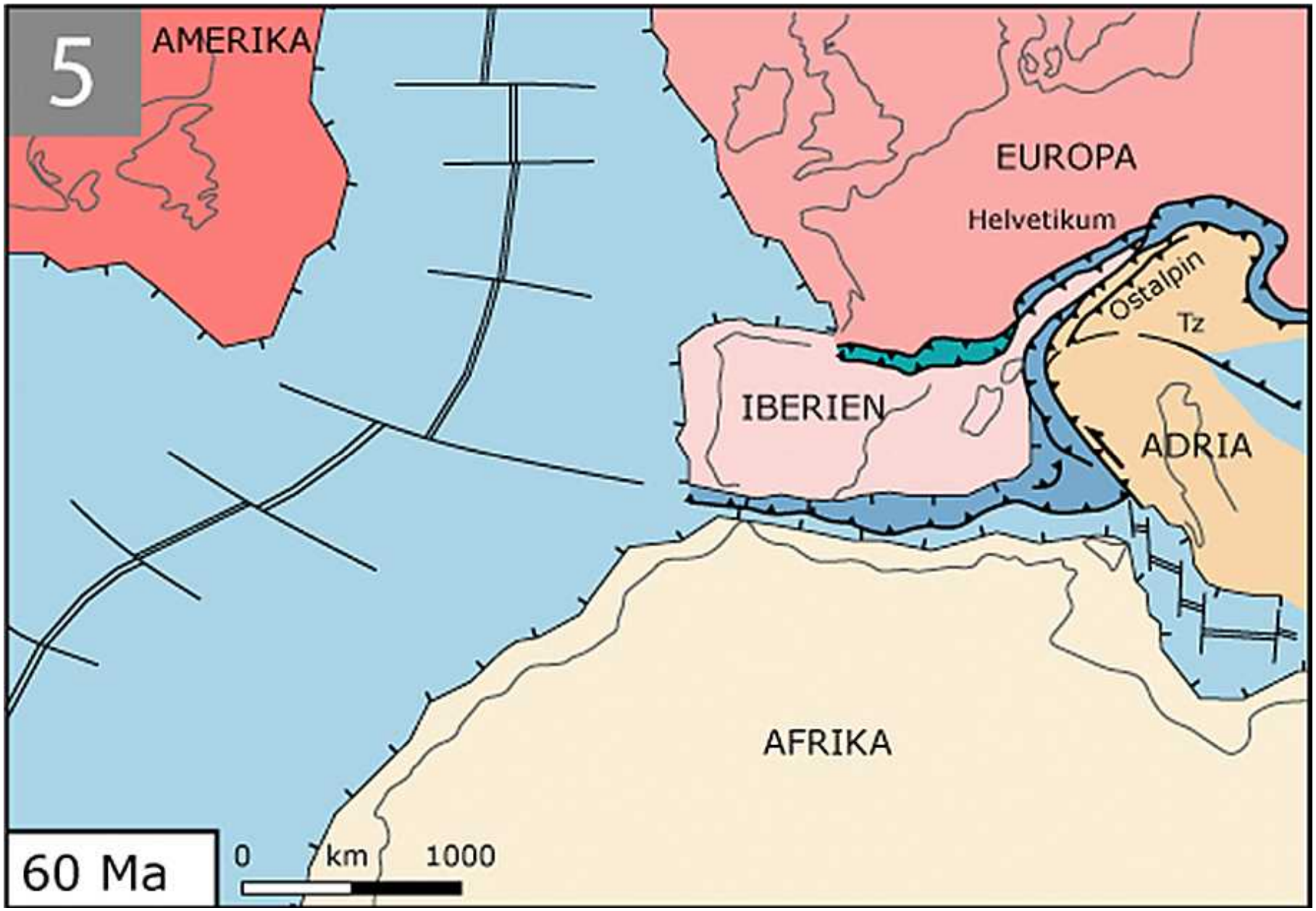
Phase 3:
Ozeanische Kruste und Transform-Brüche



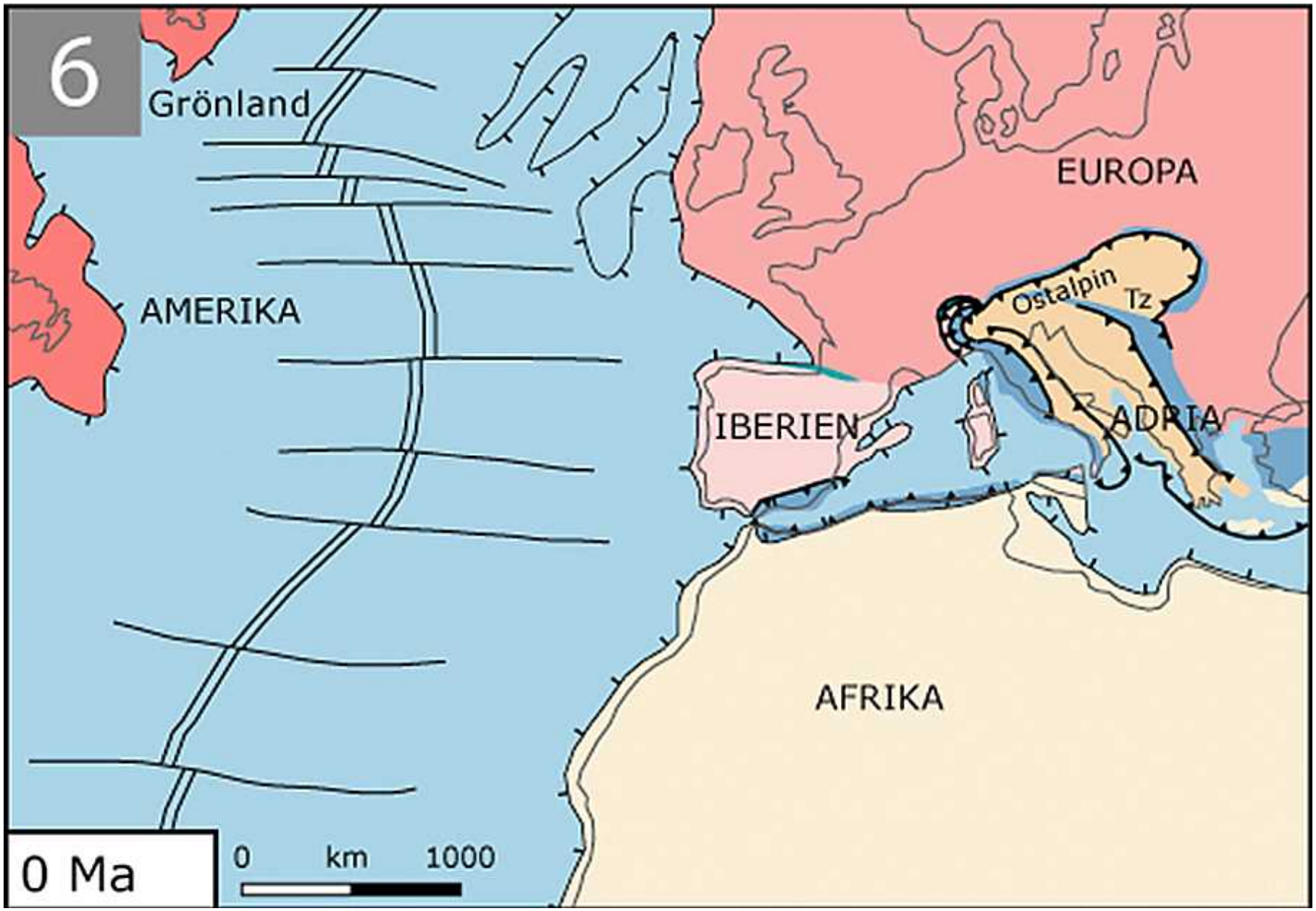
Phase 4:
Subduktion



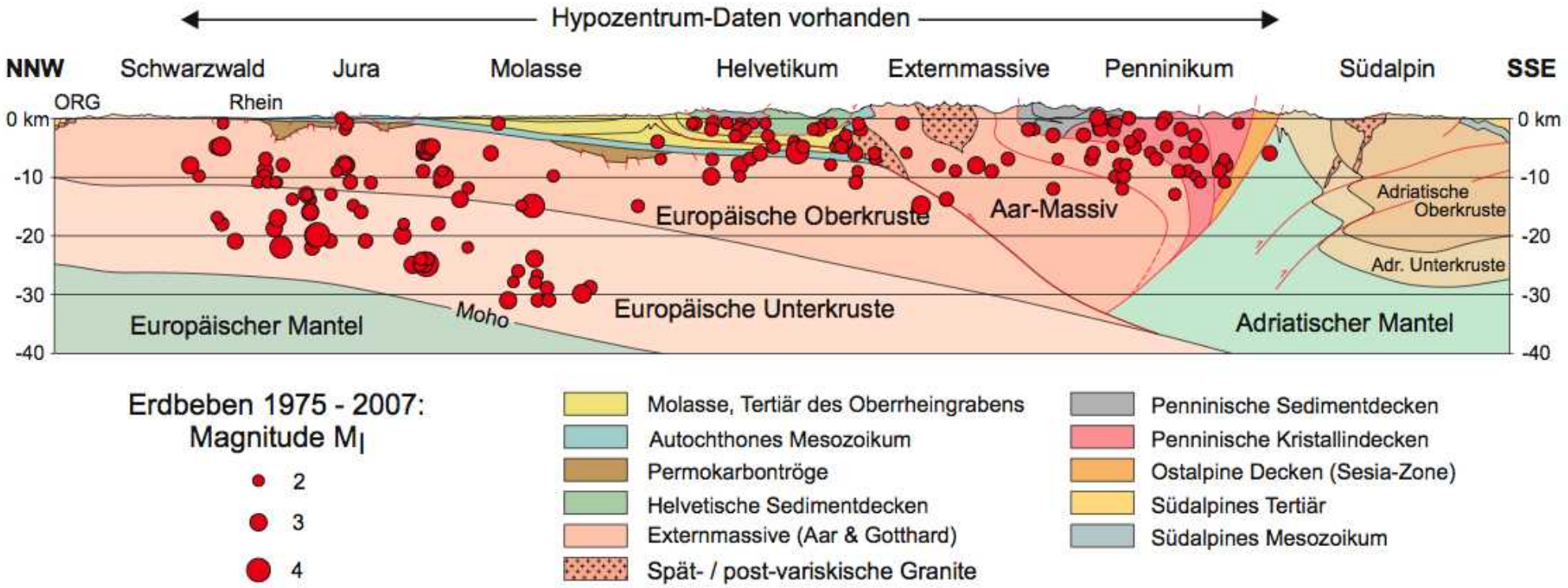
Phase 5:
Kollision der Kontinente

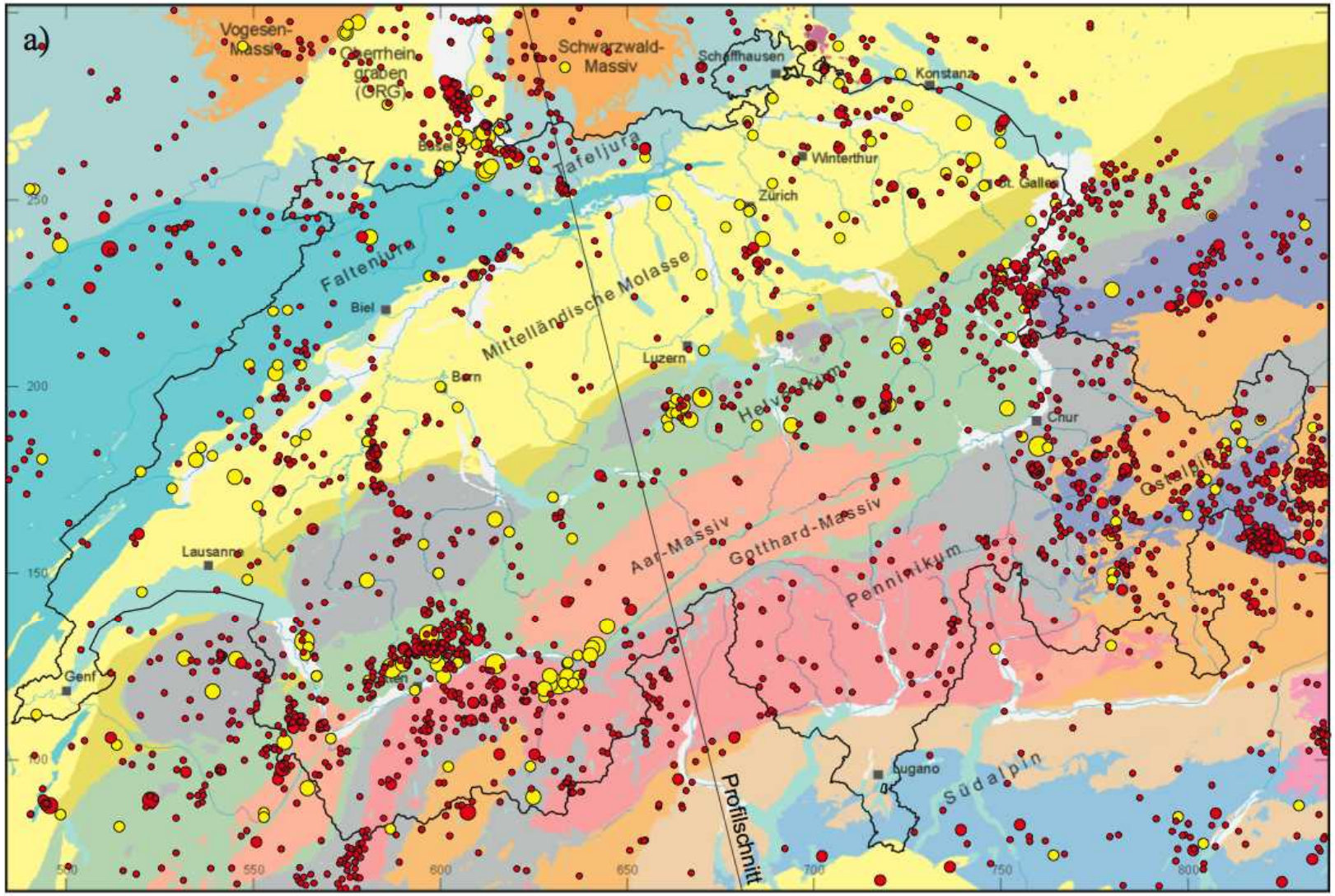


Phase 6:
Die Alpen heute



Seismische Aktivität in den Alpen





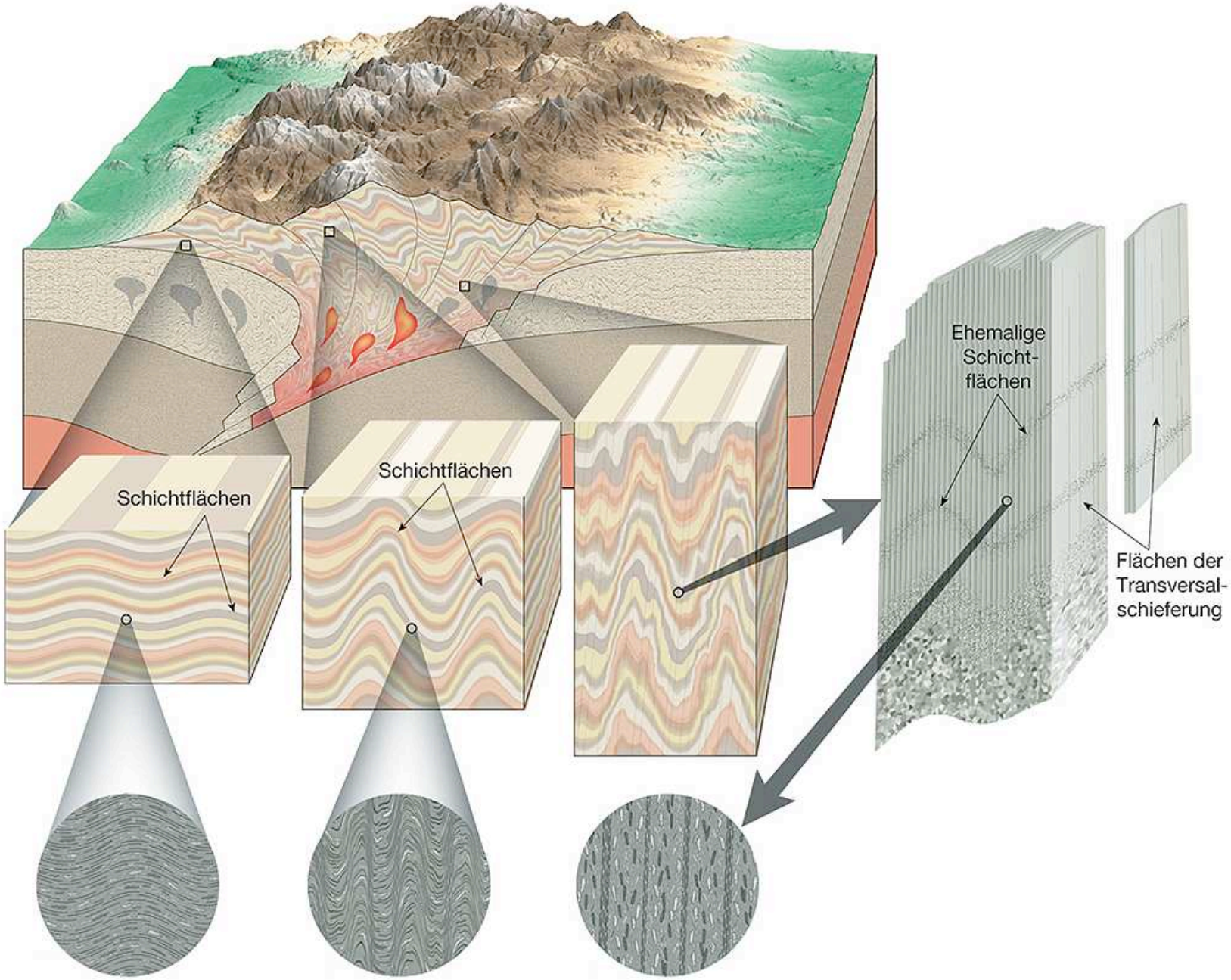
Erdbebenkatalog ECOS

ca. 1000 - 1974: Makroseismisch Magnitude M_W	1975 - 2007: Instrumentell Magnitude M_W
4 - 5	1.8 - 3
5 - 6	3 - 4
6 - 7	4 - 5

Tektonische Einheiten

- Vogesen- und Schwarzwald-Massiv
- Mittelländische Molasse, Tertiär des Oberrheingrabens und des Po-Beckens
- Subalpine Molasse
- Tafeljura
- Faltenjura
- Helvetische Sedimentdecken
- Externmassive
- Penninische Sedimentdecken (inkl. Sesia-Zone)
- Penninische Kristallindecken
- Ostalpine Sedimentdecken
- Ostalpine Kristallindecken
- Südalpin, Kristallin
- Südalpin, Sedimente
- Tertiäre Intrusiva (Bergell und Adamello)
- Tertiäre Ergussgesteine (Hegau)

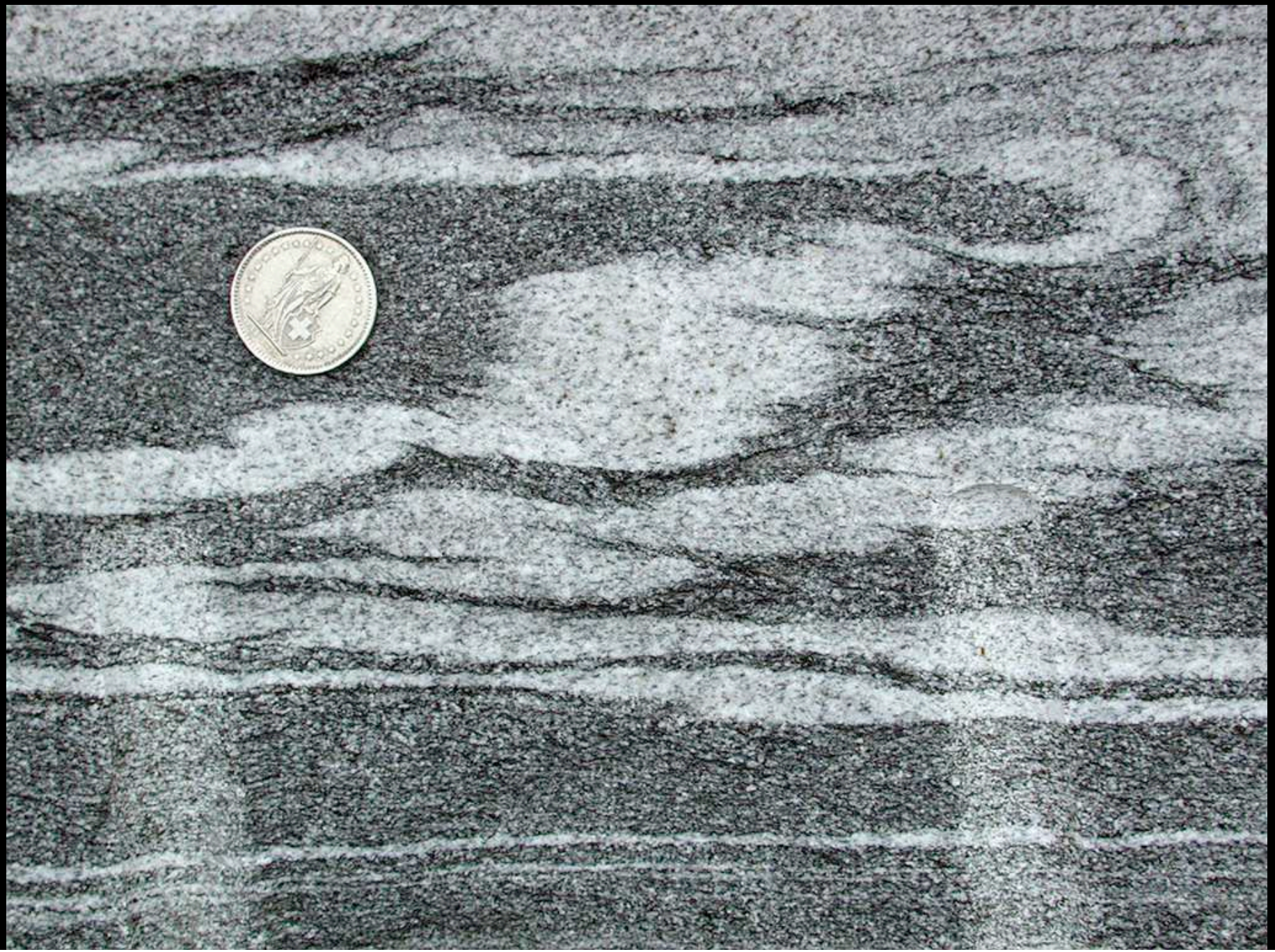
Metamorphose und Deformation



Scherzone (Alpe Laghetti, TI)

Gneiss Quader Steinbruch, TI

Falten im Gneiss, Lavertezzo, TI



Falten im Gneiss, Lavertezzo, TI

Falten im Gneiss, Lavertezzo, TI