

# Tatort Plattengrenze

Renée Heilbronner

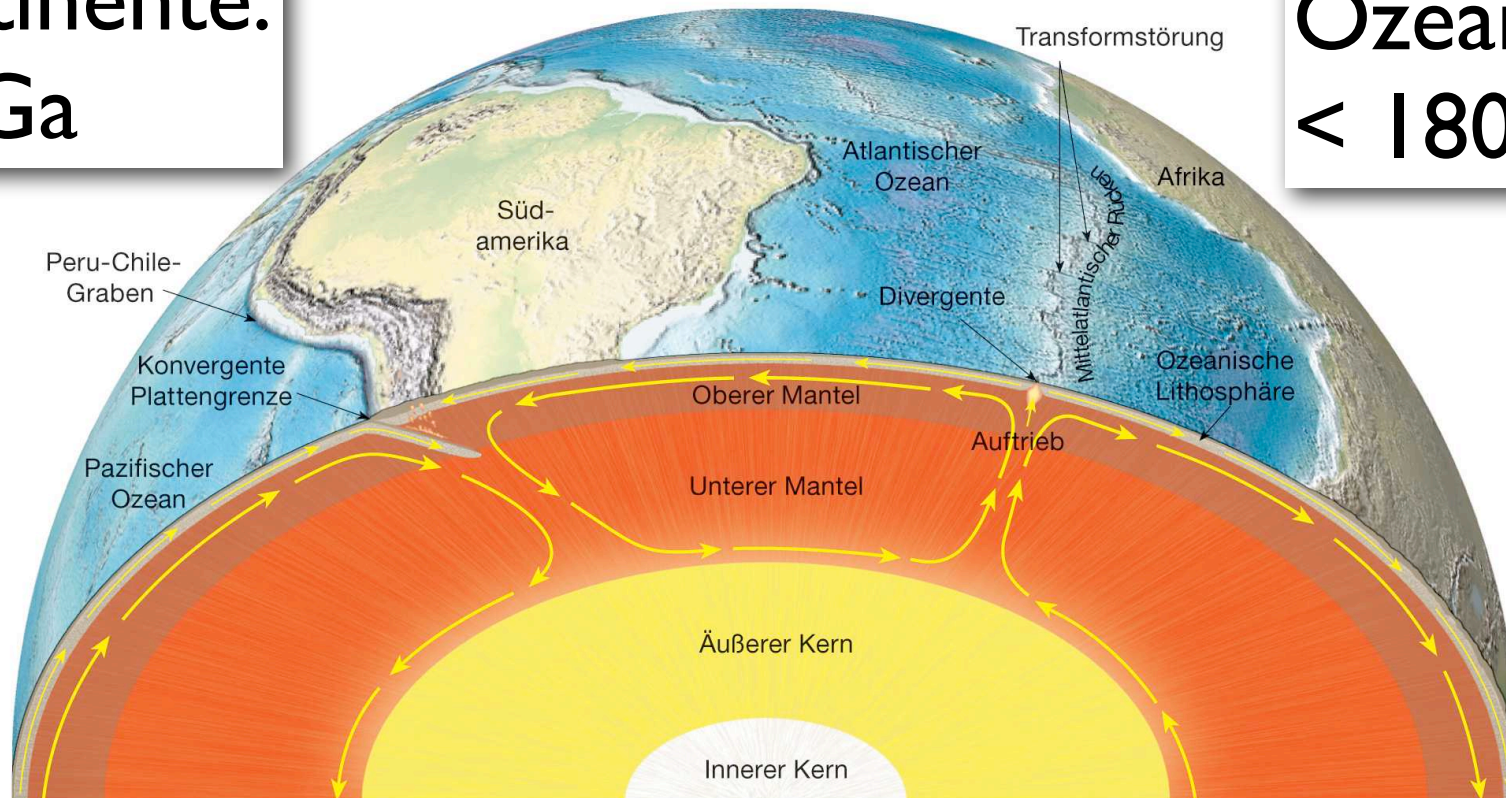
5. Nov. 12. Nov. 19. Nov. 26. Nov.

# 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:

$70 \cdot 10^6 \cdot 0.07 \approx 5 \cdot 10^6 \text{ m}^2$  (= 5 km<sup>2</sup>)

Gesamtoberfläche der Erde ( $S = 4\pi r^2$ ):

$4 \cdot 3.14 \cdot (6370 \text{ km})^2 = 4 \cdot 3.14 \cdot 6.37^2 \cdot 10^{12} \text{ m}^2$

$\approx 500 \cdot 10^{12} \text{ m}^2$  (= 500 Mio. km<sup>2</sup>)

# Produktion von Lithosphäre

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

⇒

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



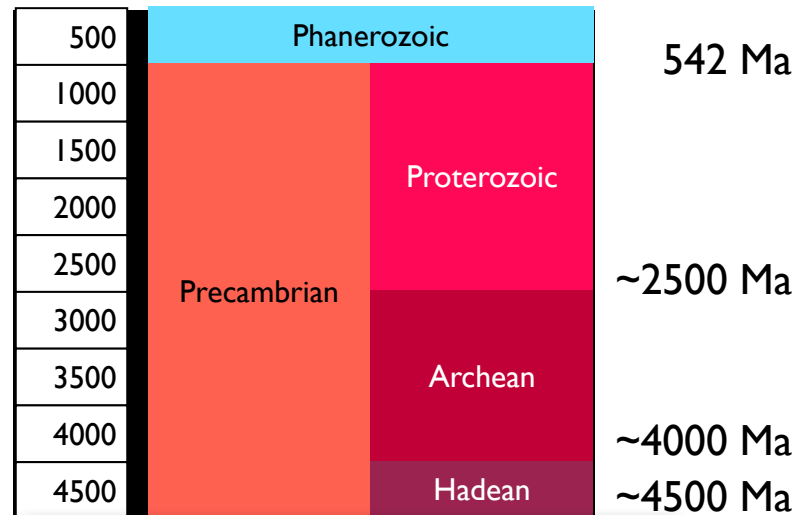
Kontinent - Kontinent

... und woher kommt die kontinentale Kruste ?!

# Die Anfänge der Geodynamik

Entstehung ...

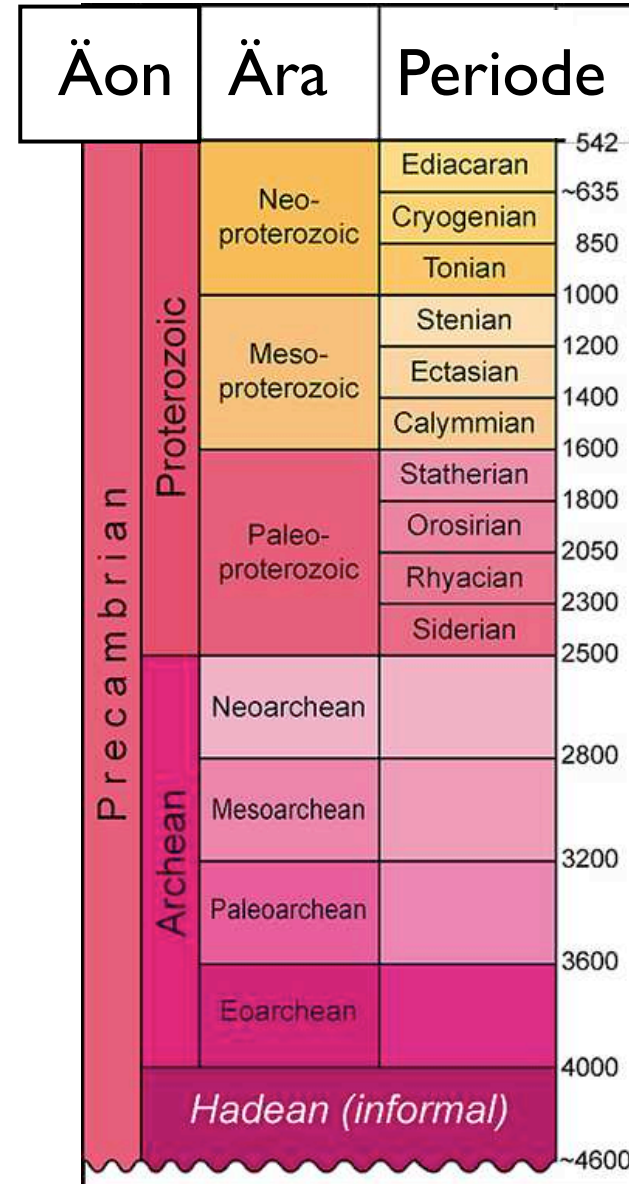
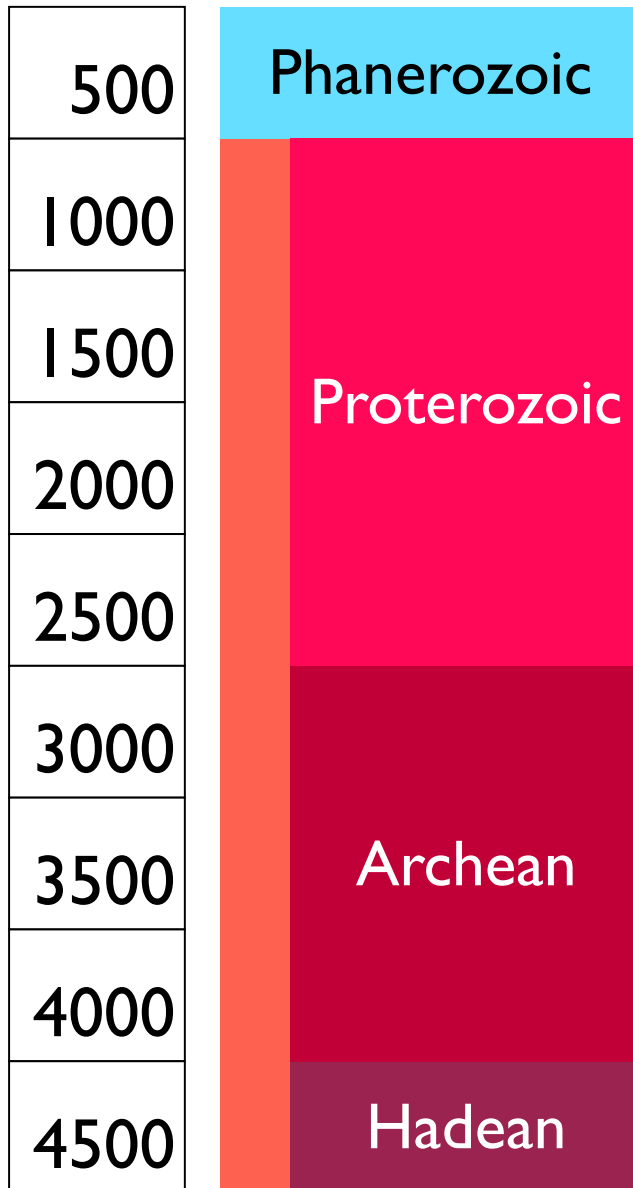
... der Erde  
~ 4.5 Ga



... des Universums  
~13.7 Ga



# Präkambrium



# Hadaikum

~4.5 bis ~4.0 Ga



Hadean

Magma - Ozean



# Oldest rocks



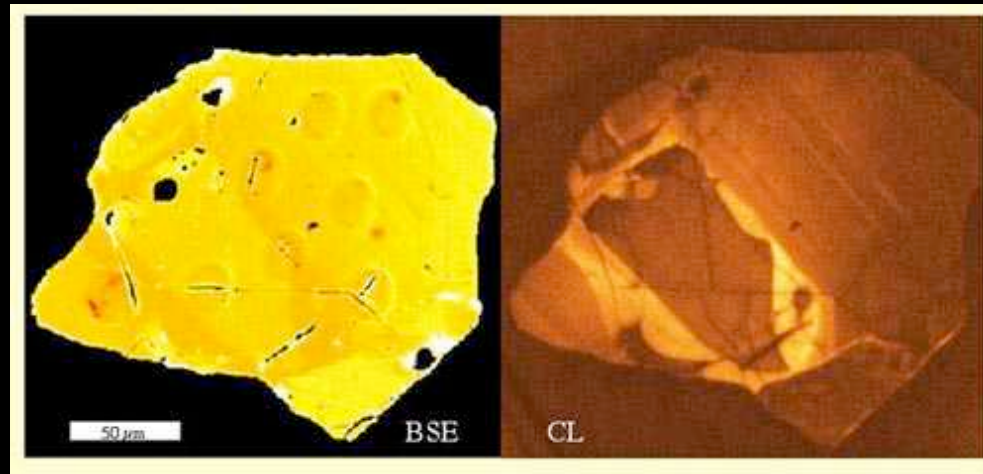
Lunar rocks (4.57 Ga)



Acasta gneiss (3.96 Ga)  
NW Territories, Canada

# Oldest minerals

Zirkon in Sandkorn, West Australien (4.2 Ga)

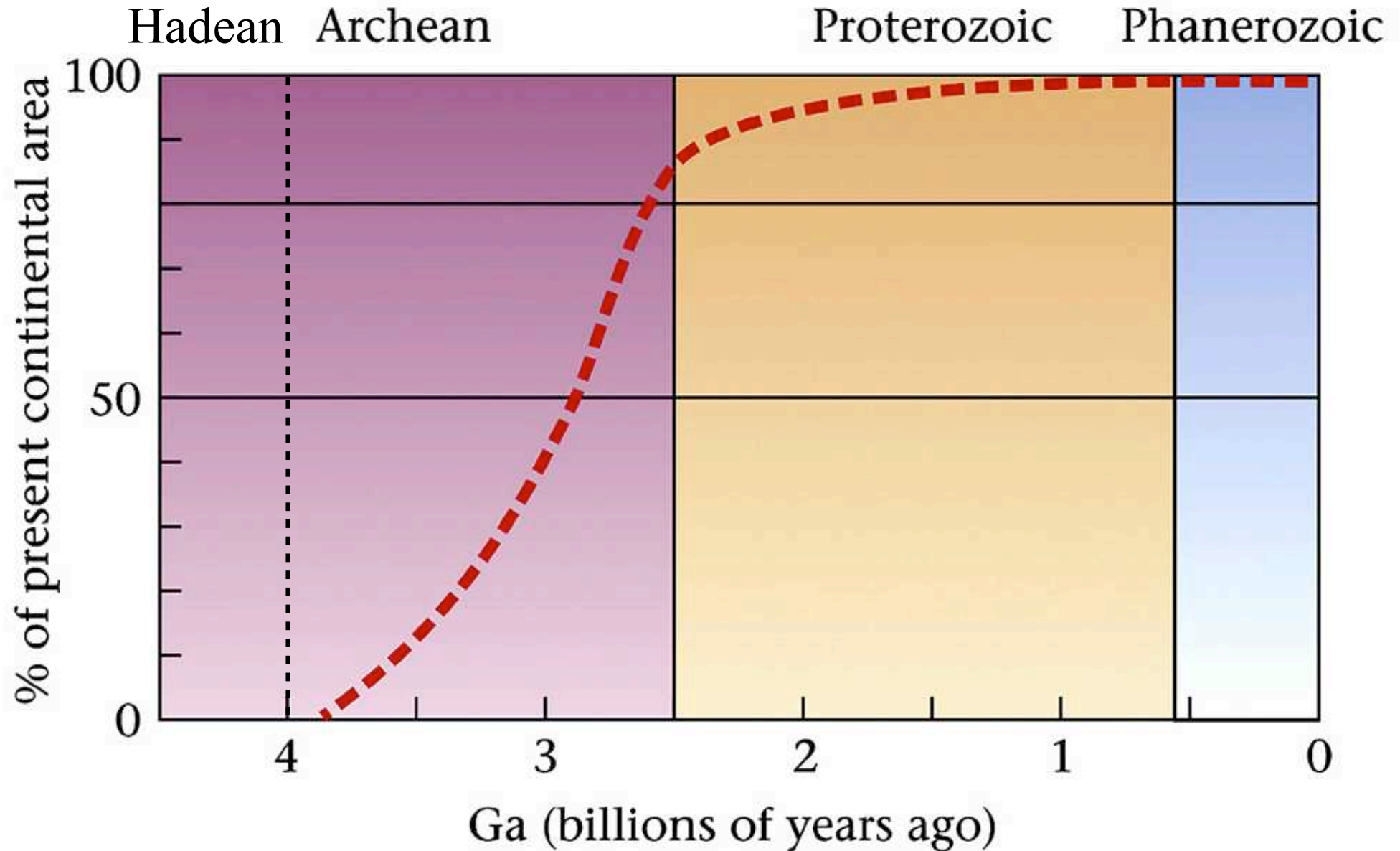


Alter des Minerals = Alter magmatisches Ereignis

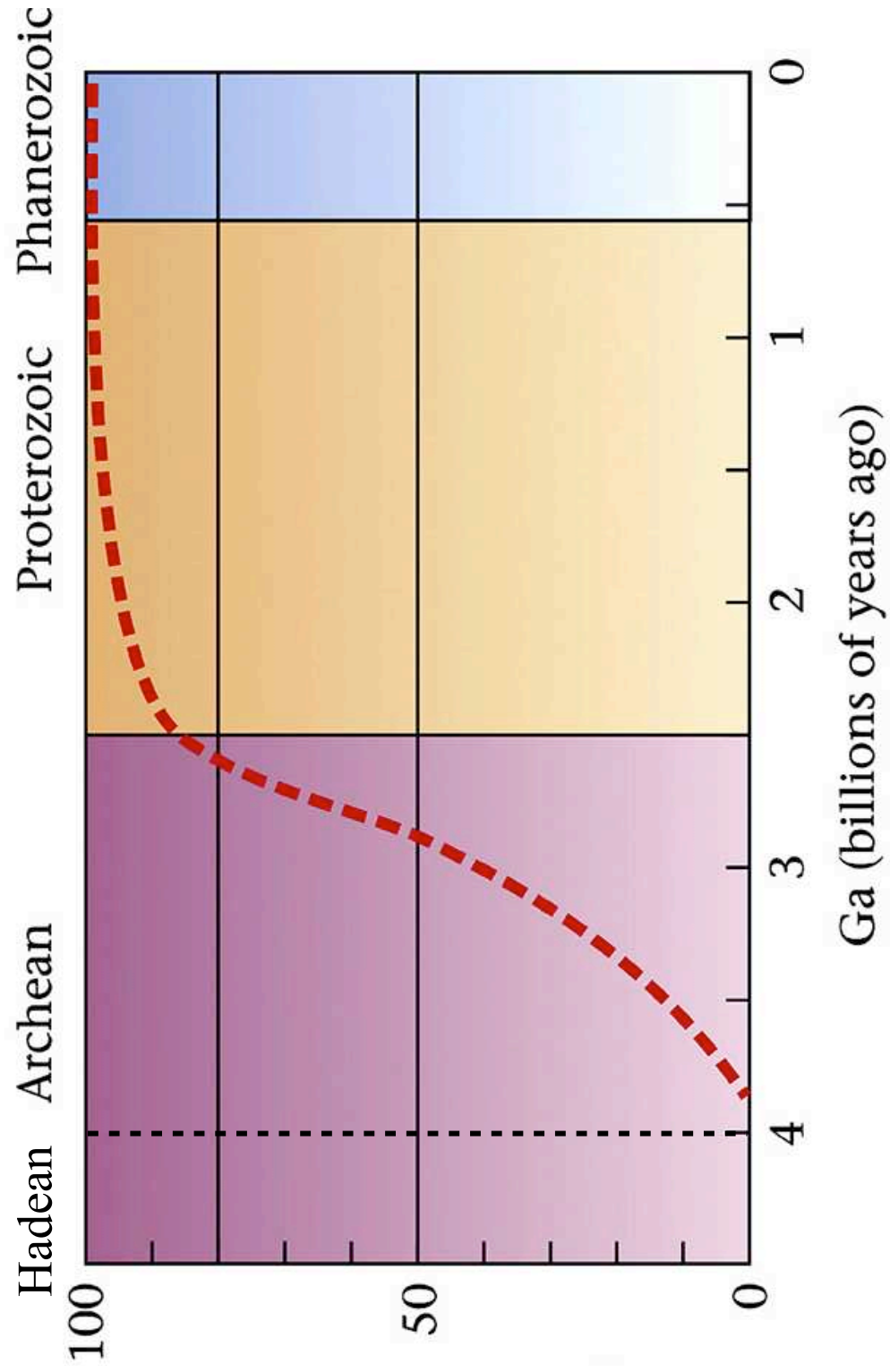
Alter des Sedimentgesteins < Alter Mineral

Deformation ist jünger als das deformierte Gestein

# Archaikum: Entwicklung der Kontinente



500
1000
1500
2000
2500
3000
3500
4000
4500



# 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

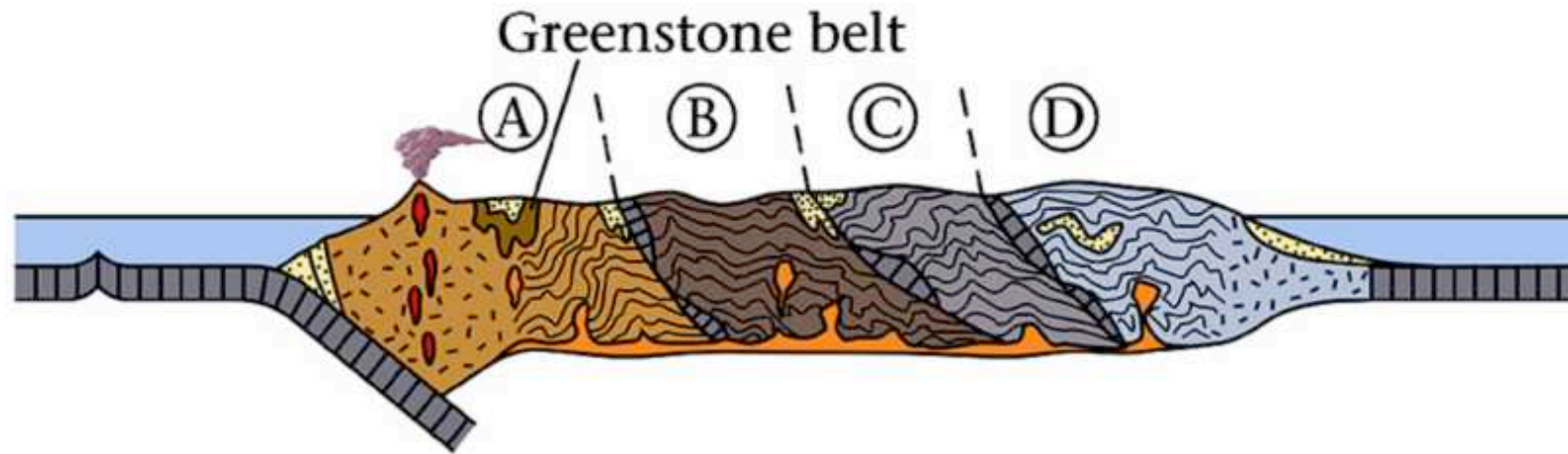
Meta-Quarzite

Vulkanisches Meta-Sedimente

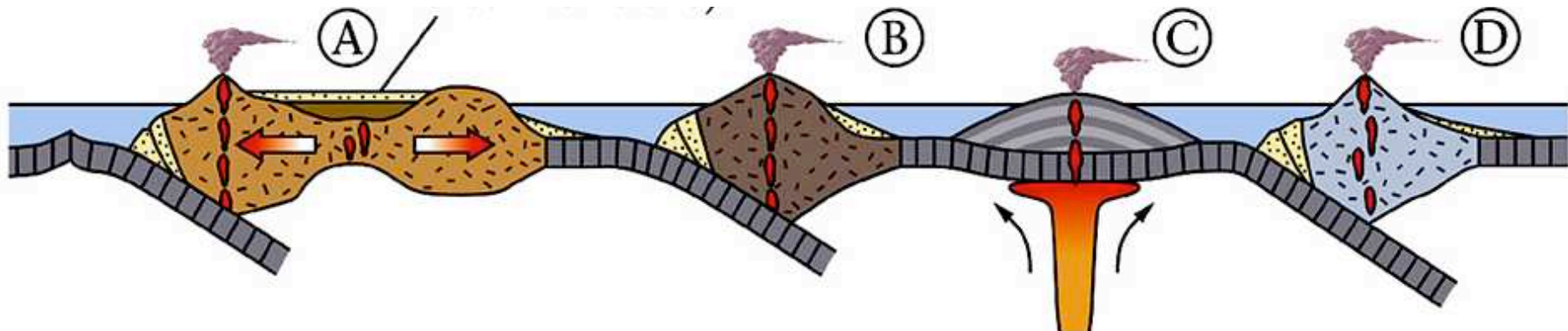
Eisenführende Formationen

Karbonate

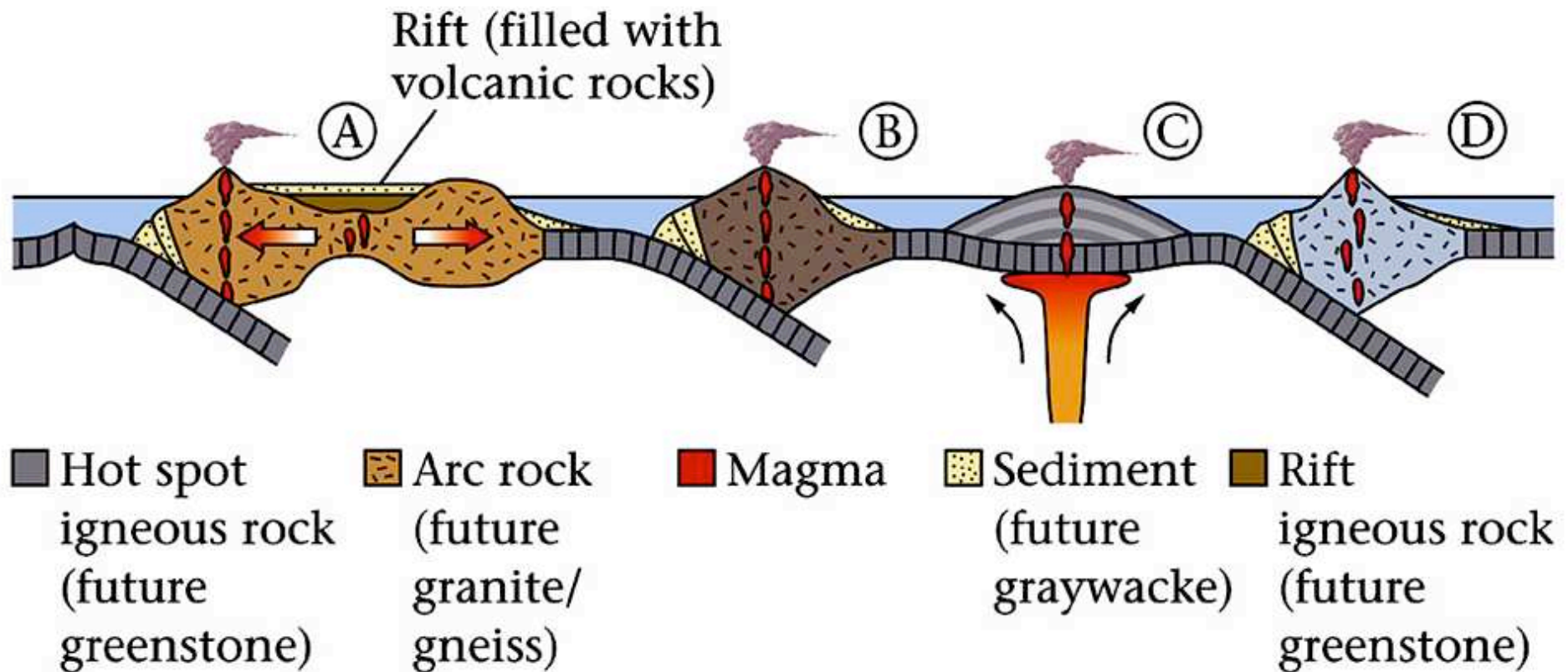
# Plattentektonik im Archaikum ?



## Plattentektonische Interpretation



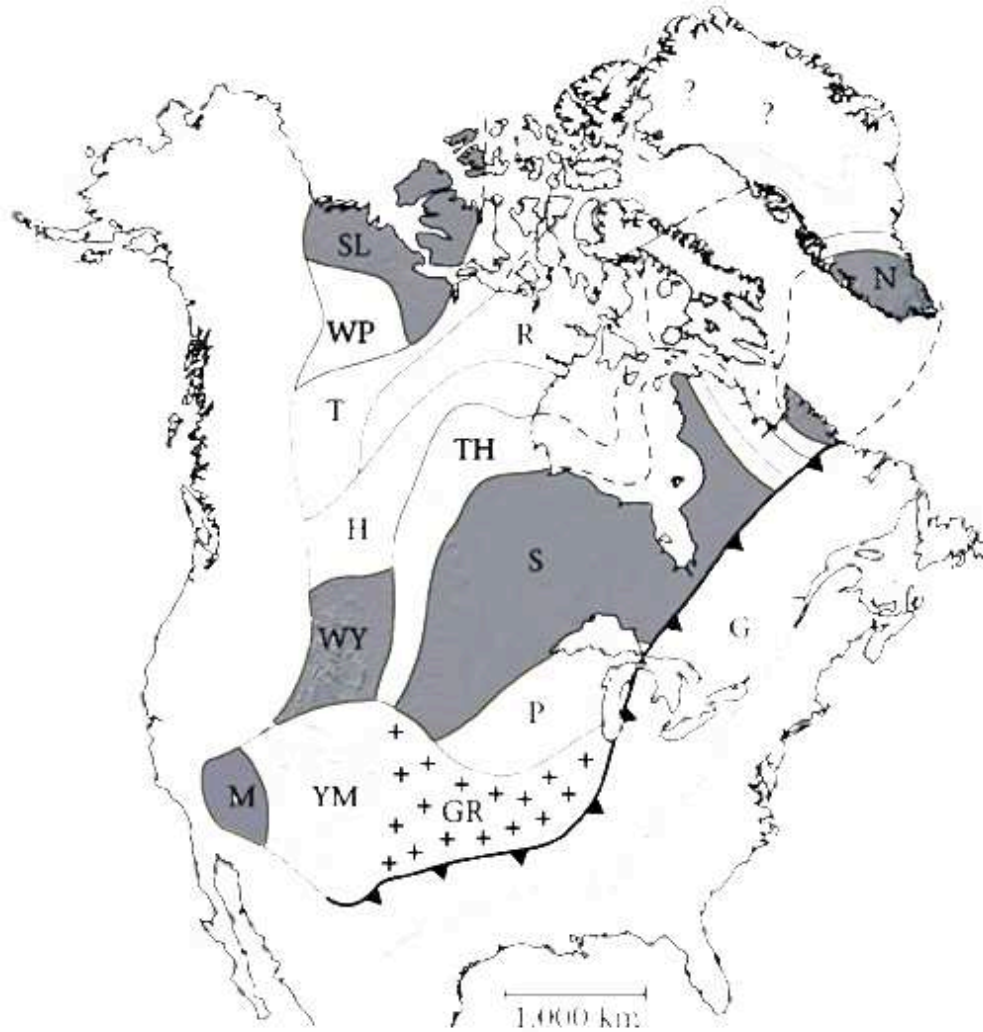
# Plattentektonik im Archaikum ?



⇒ schnelle und kleine Platten

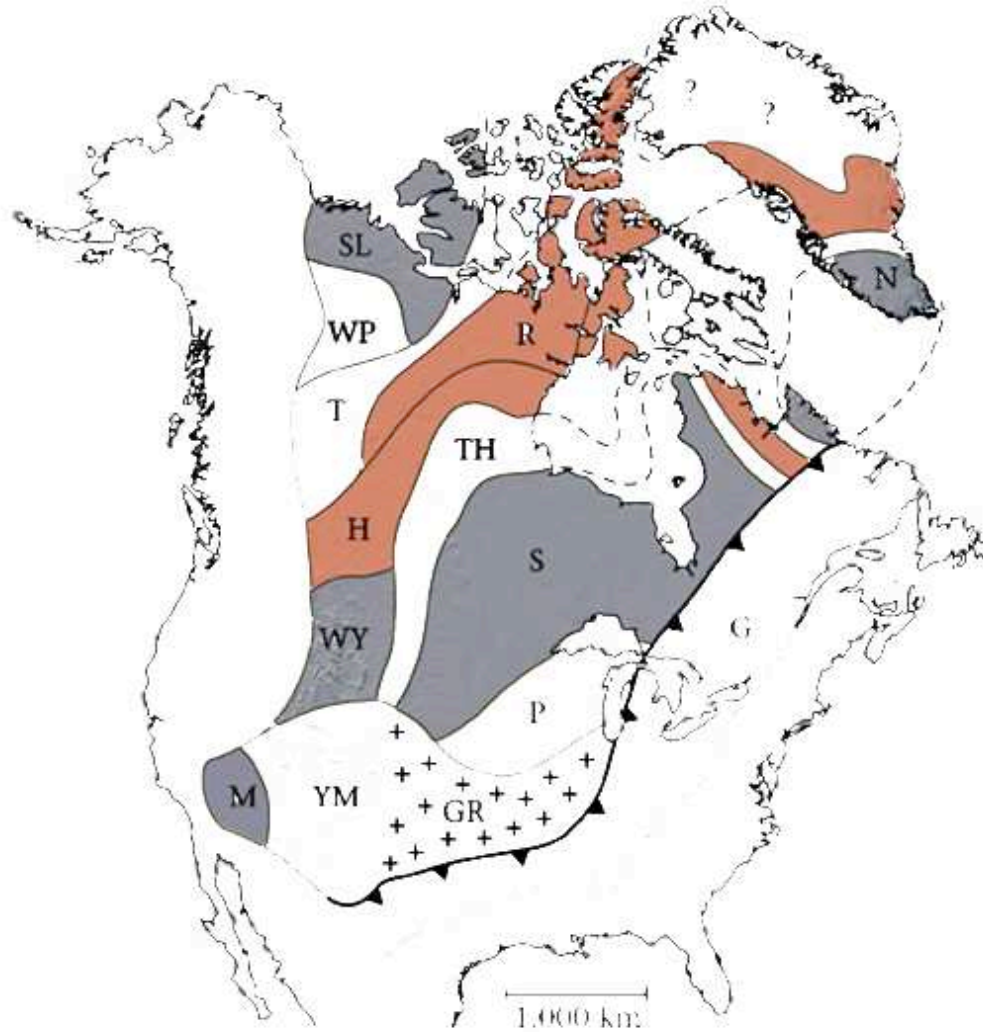


# Archaische Krustenanteile



	Eonothem Eon	Erathem Era	System Period	Age Ma
Precambrian	Proterozoic	Neo-proterozoic	Ediacaran	542
			Cryogenian	~635
			Tonian	850
		Meso-proterozoic	Stenian	1000
			Ectasian	1200
			Calymmian	1400
		Paleo-proterozoic	Statherian	1600
			Orosirian	1800
			Rhyacian	2050
			Siderian	2300
	Archean	Neoarchean	2500	
		Mesoarchean	2800	
		Paleoarchean	3200	
		Eoarchean	3600	
		<i>Hadean (informal)</i>		4000
				~4600

# Archaikum, metamorph überprägt (im Proterozoikum)

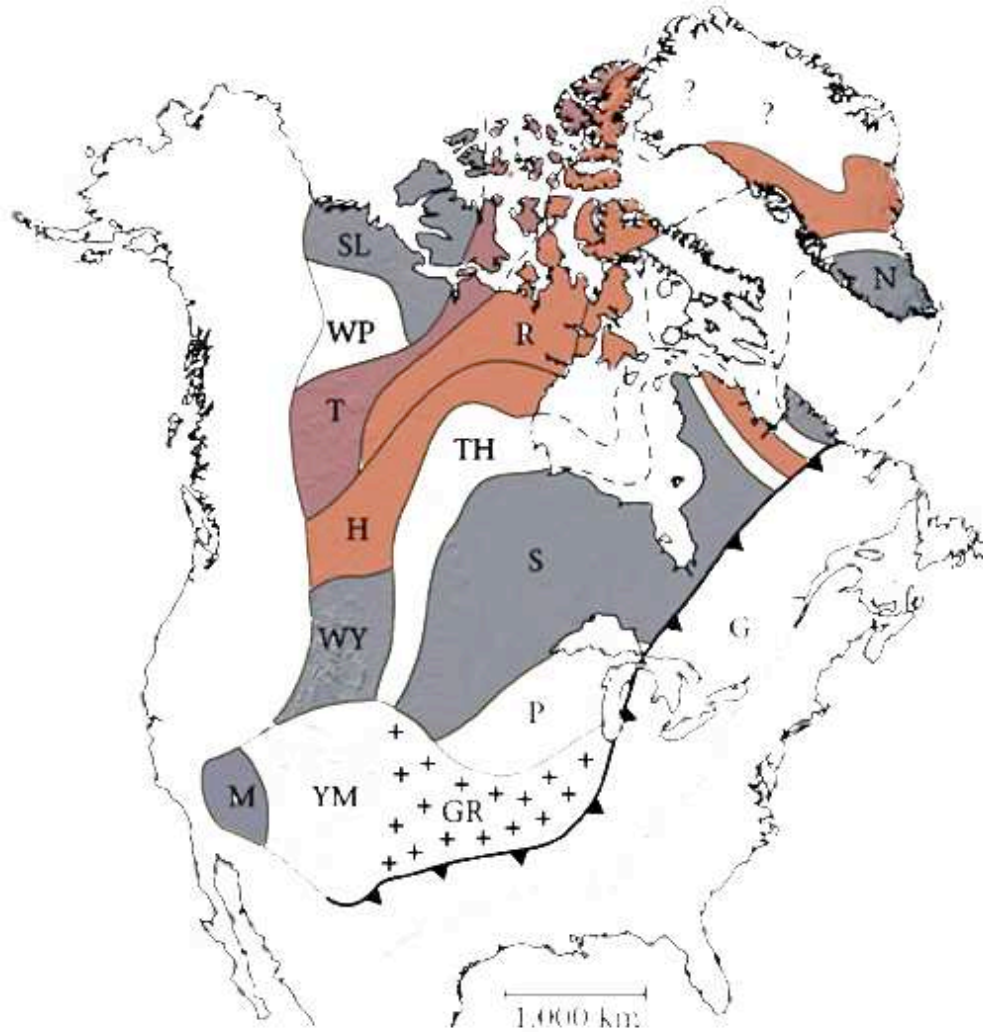


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# Proterozoikum

# 1.9 Ga

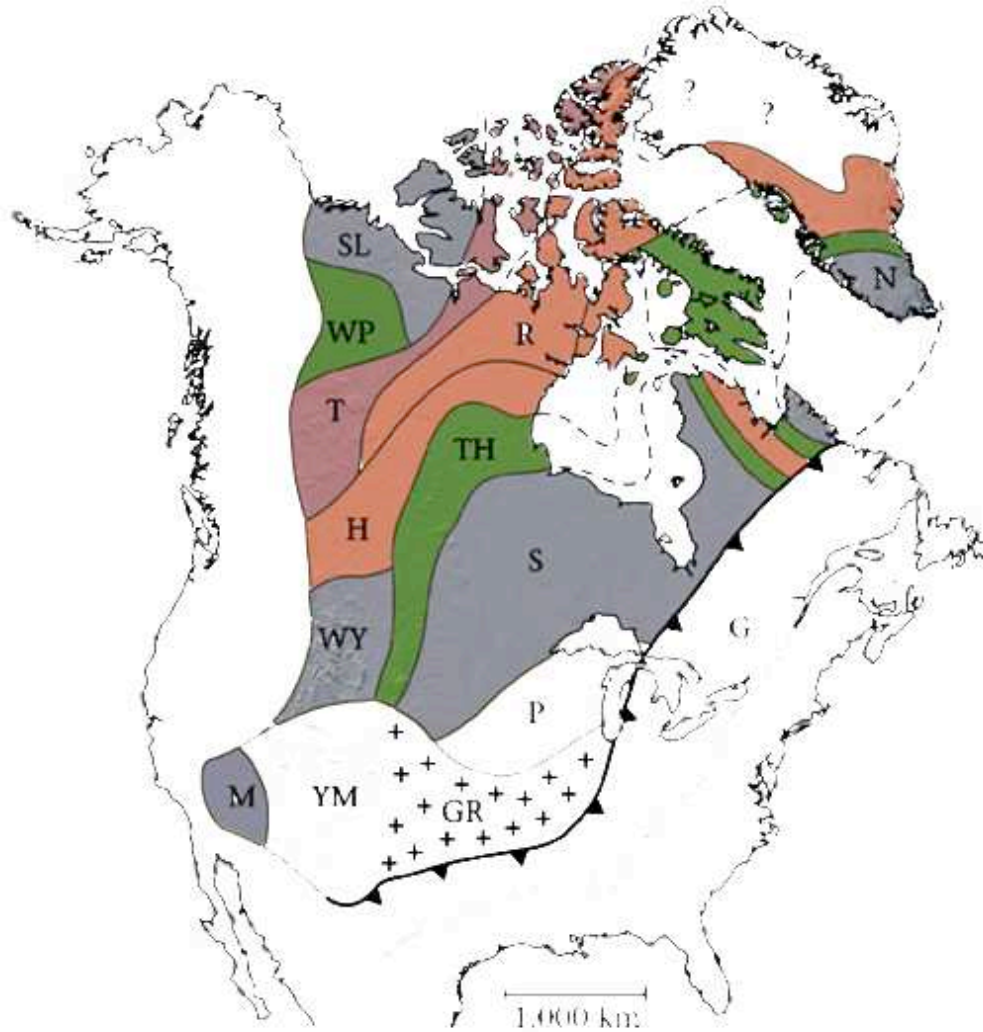


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## Kontinentale Kollision

# Proterozoikum

# 1.8 Ga

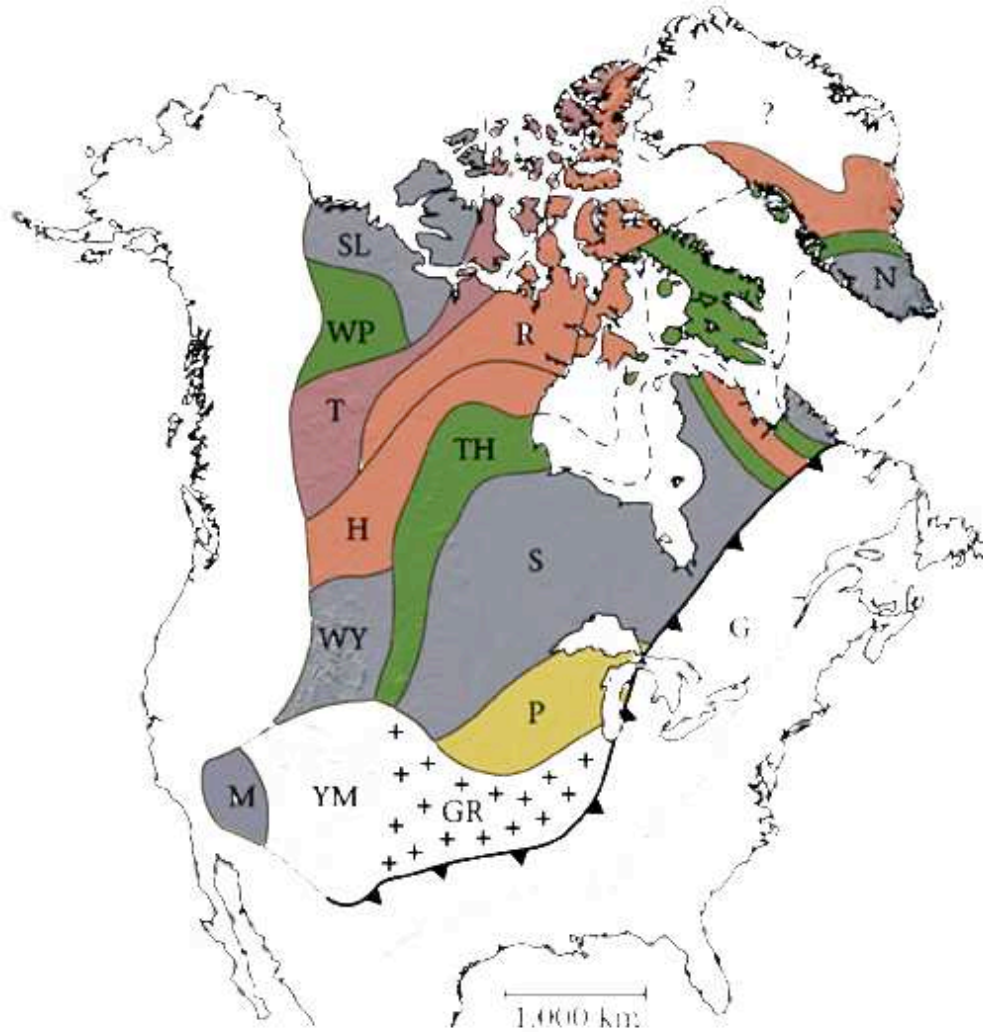


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# Kontinentale Kollision

# Proterozoikum

# 1.8 Ga

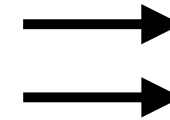
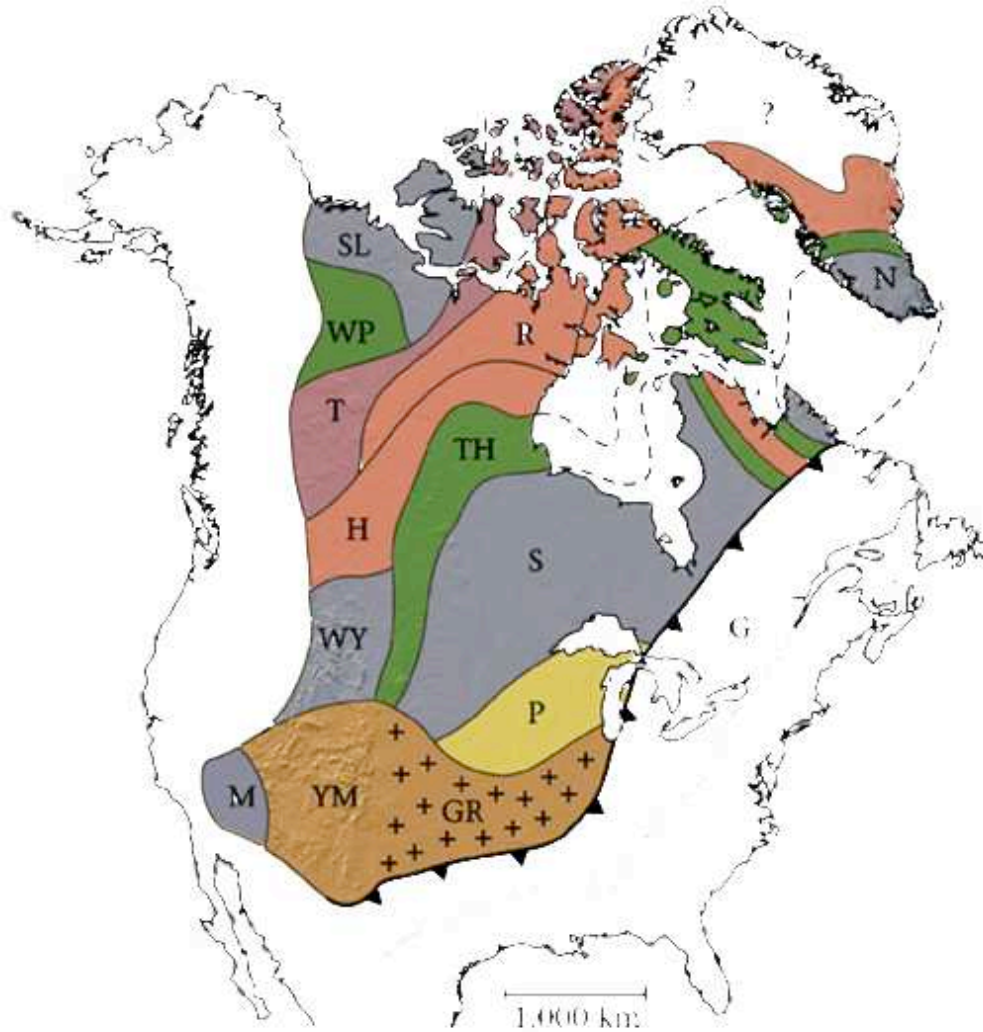


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## Akkretion von Kruste

# Proterozoikum

1.3 -1.7

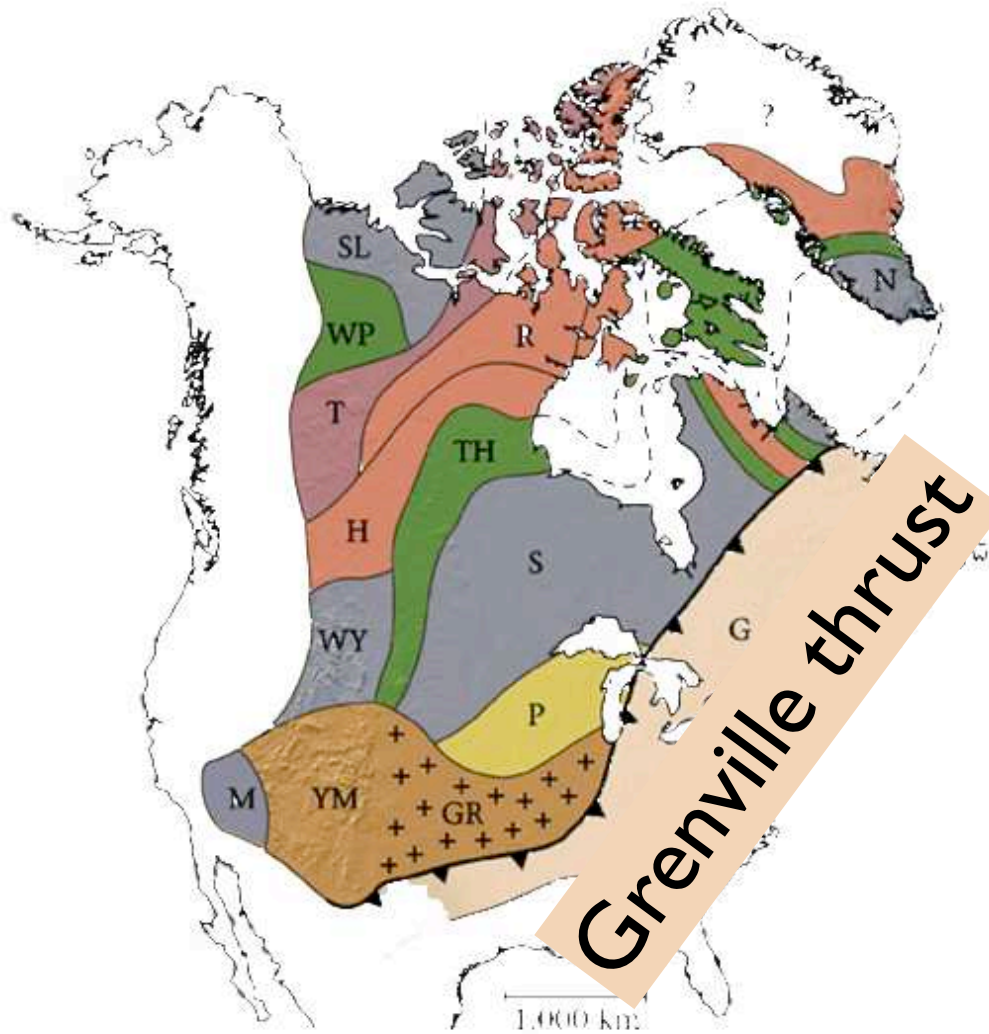


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			Paleoarchean	3600
		Eoarchean	4000	
		<i>Hadean (informal)</i>	~4600	

Akkretion von Kruste

# Proterozoikum

# 1.1 Ga

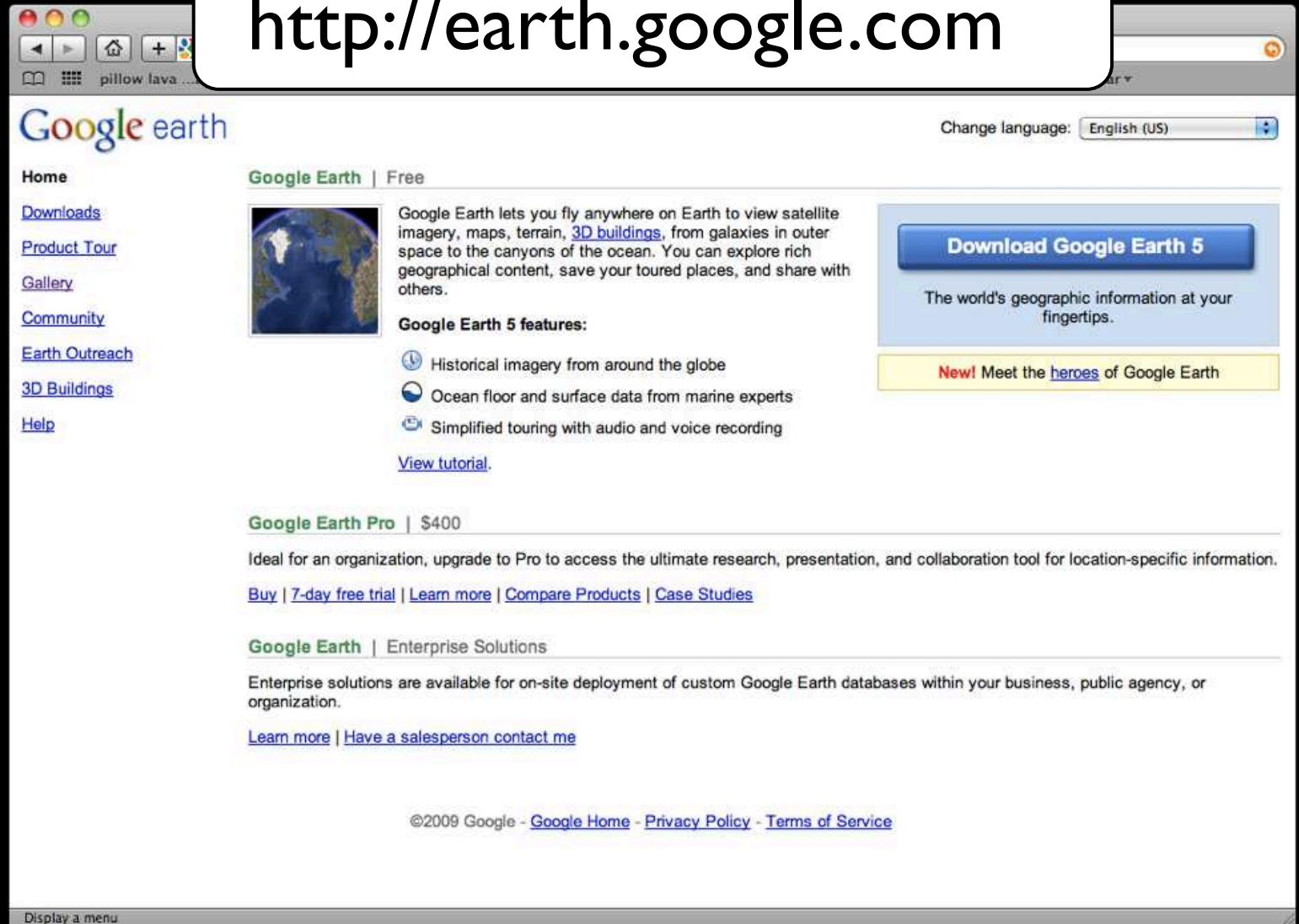


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		Siderian	2300	
			2500	
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		Paleoarchean		3600
Eoarchean			4000	
	Hadean (informal)			~4600

## Kontinentale Kollision

# Let's google !

<http://earth.google.com>



The screenshot shows the Google Earth website homepage. At the top left is the "Google earth" logo. To the right is a language selector set to "English (US)". A left-hand navigation menu includes links for Home, Downloads, Product Tour, Gallery, Community, Earth Outreach, 3D Buildings, and Help. The main content area features a "Google Earth | Free" section with a globe icon and a description of the software's capabilities. Below this is a list of "Google Earth 5 features" including historical imagery, ocean floor data, and simplified touring. A prominent blue button says "Download Google Earth 5" with the tagline "The world's geographic information at your fingertips." and a yellow banner below it that says "New! Meet the heroes of Google Earth". Further down, there are sections for "Google Earth Pro | \$400" and "Google Earth | Enterprise Solutions", each with a brief description and links to buy or learn more. At the bottom, there is a copyright notice for 2009 Google and links to Google Home, Privacy Policy, and Terms of Service.


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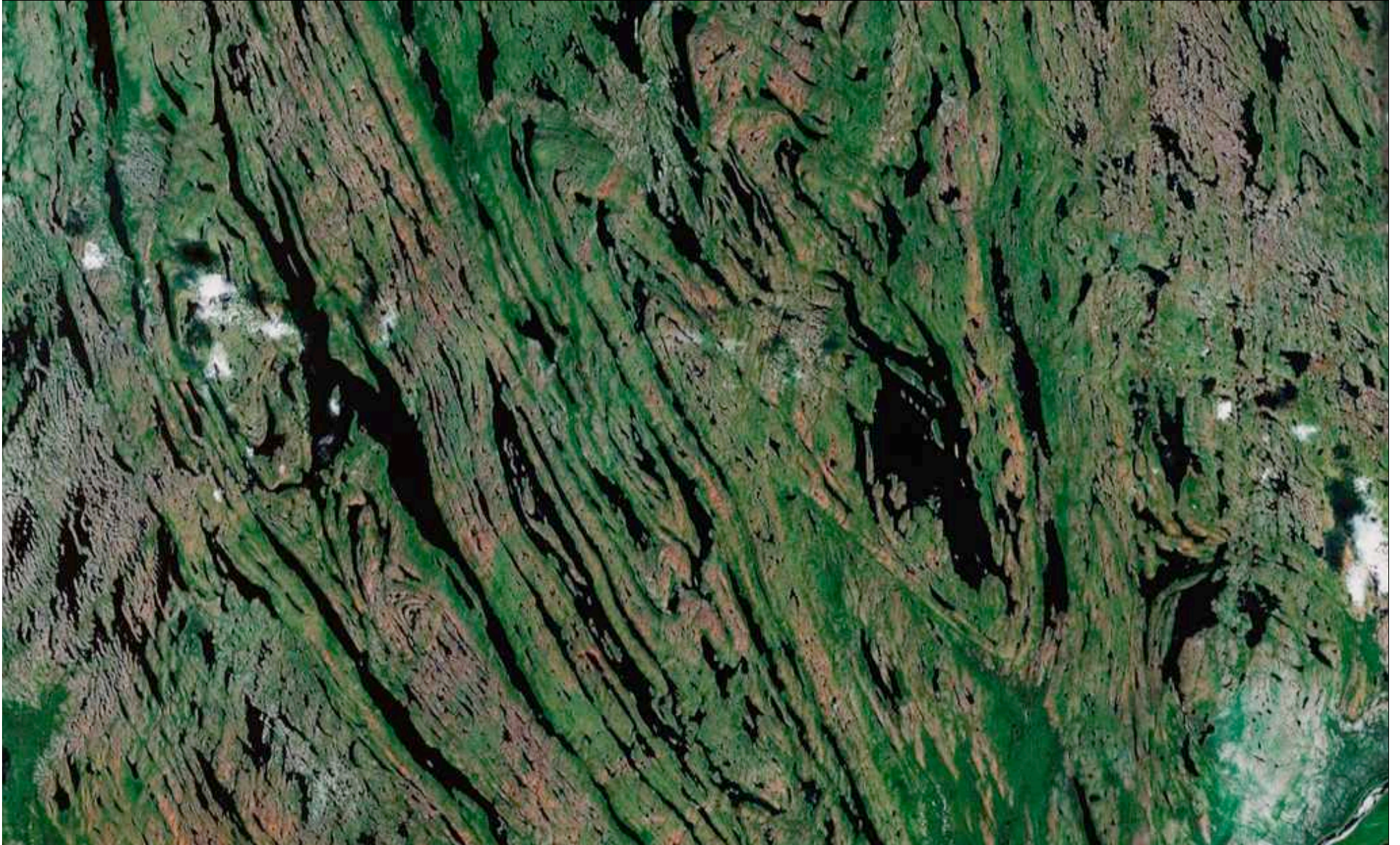
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# Kanadischer Schild: Archaikum



Precambrian (Archean) of the Canadian shield

# Grönland, Archaikum



Qeqertarsuatsiaat (Fiskenaesset)

# Ugab, Namibia: Proterozoikum



Proterozoische, verfaltete, steilgestellte Sedimente

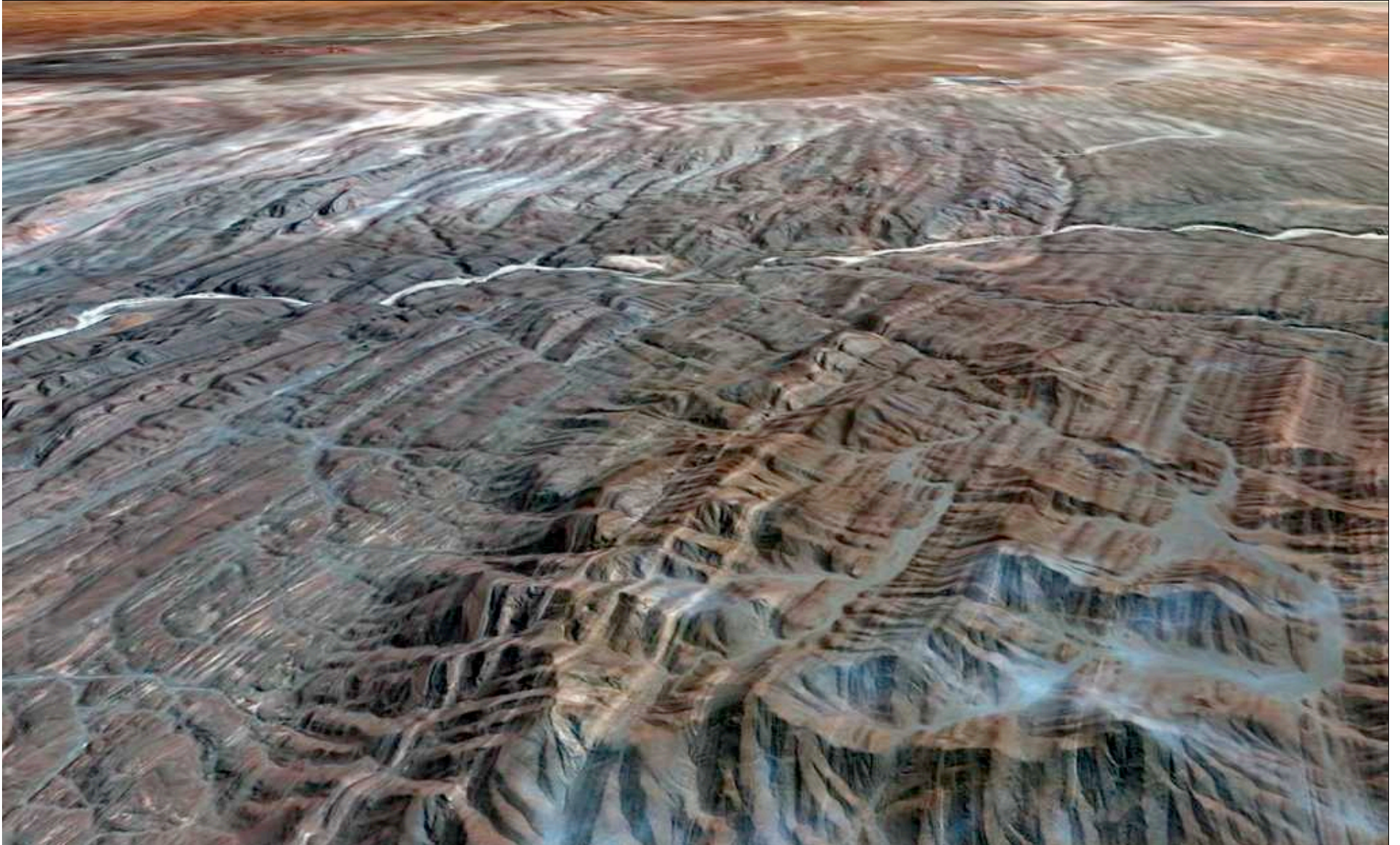
Ugab, Namibia

google Earth



Proterozoische, verfaltete, steilgestellte Sedimente

# Ugab, Namibia



Proterozoische, verfaltete, steilgestellte Sedimente

# Ugab, Namibia



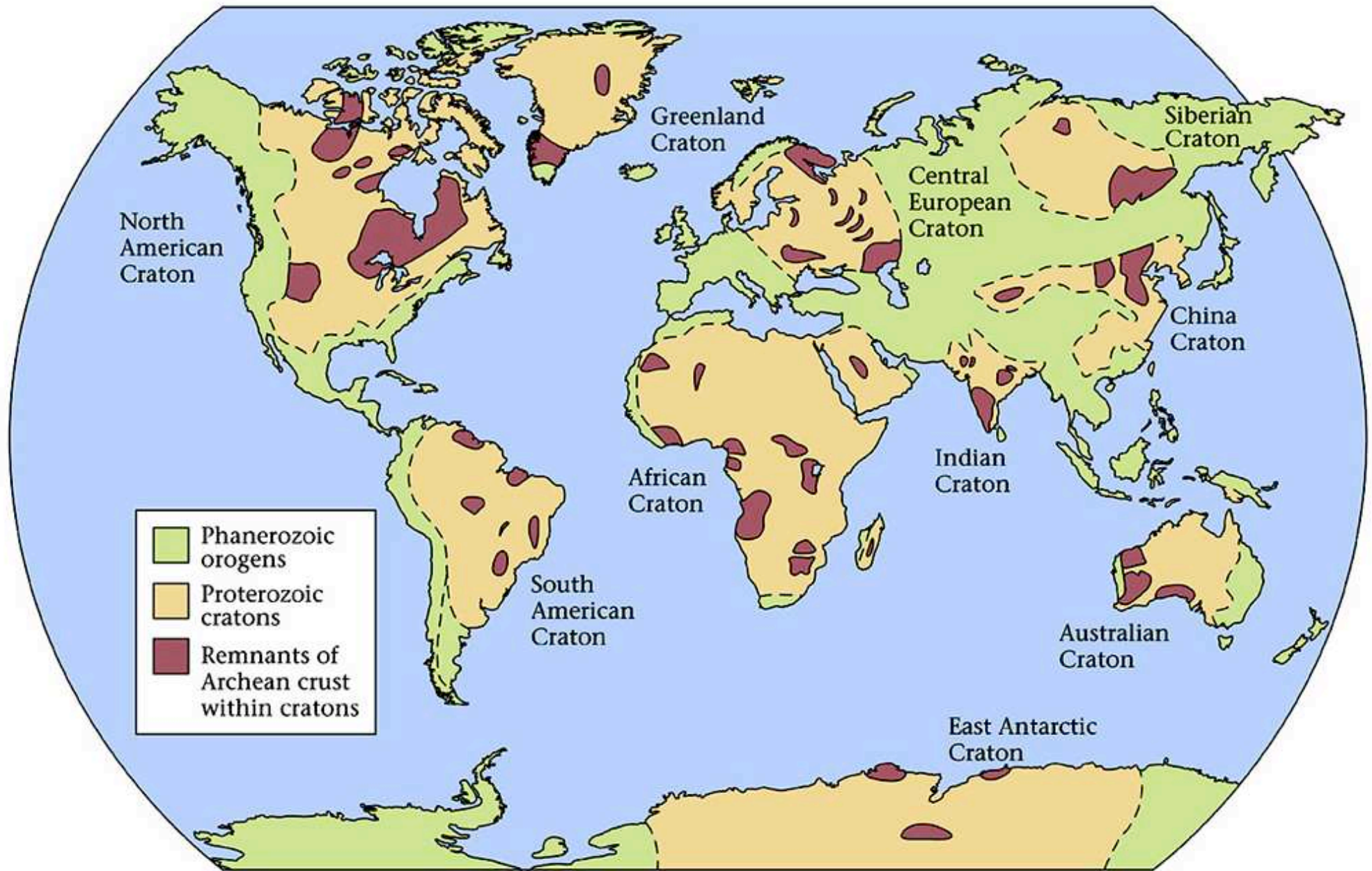
Proterozoische, verfaltete, steilgestellte Sedimente

# Ugab, Namibia



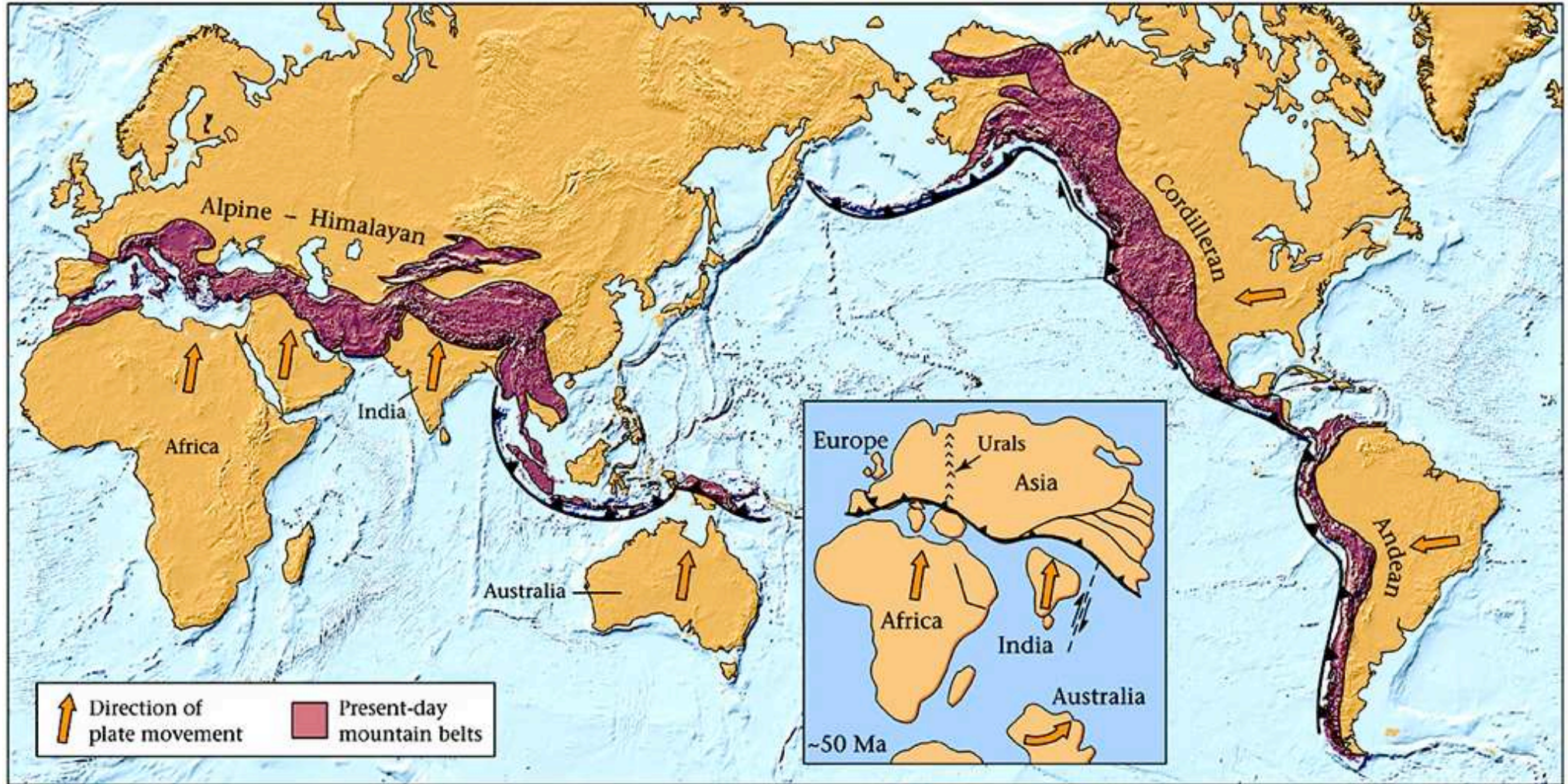
Proterozoische, verfaltete, steilgestellte Sedimente

# Präkambrische Kruste

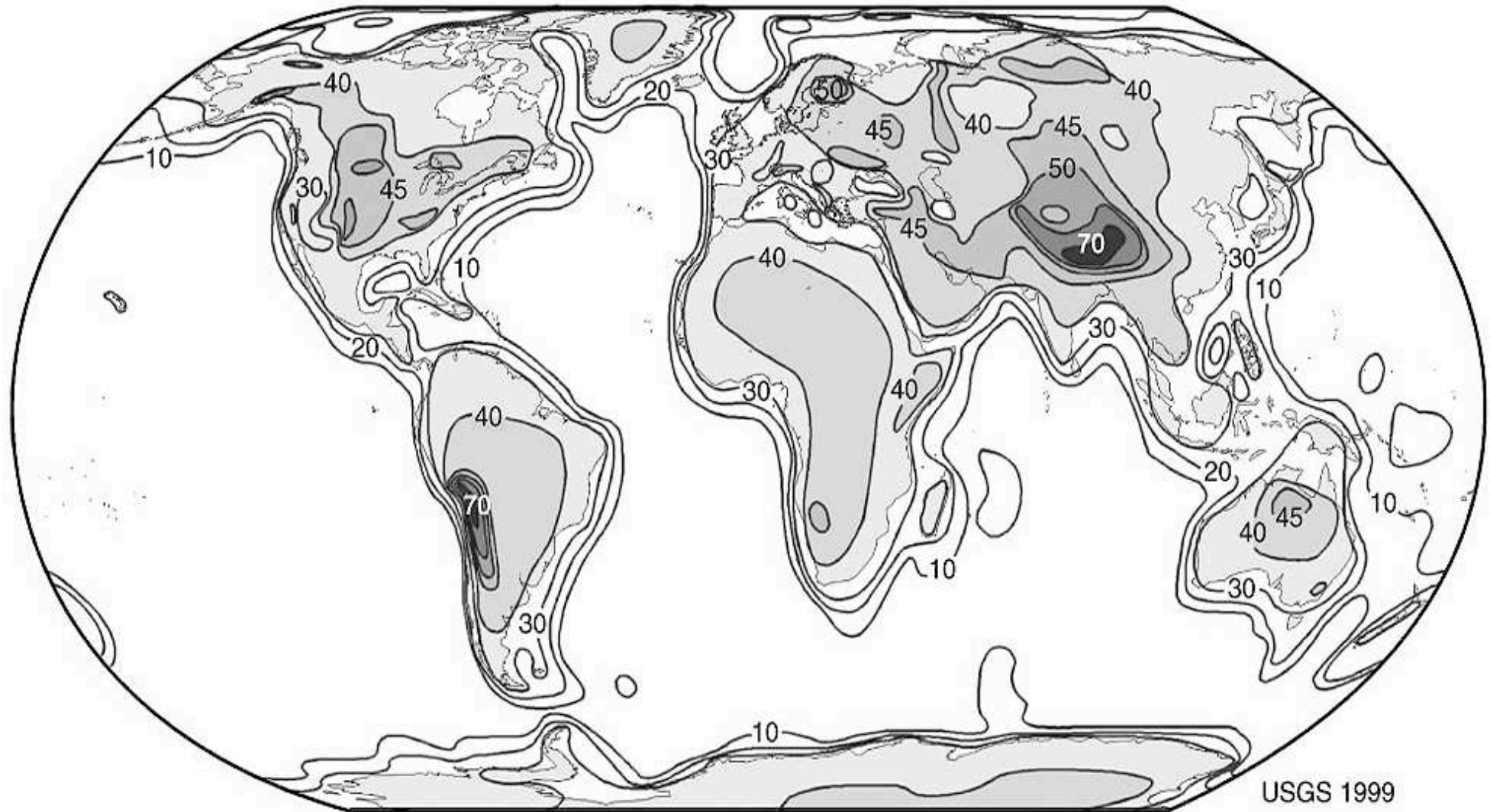




# Aktive kontinentale Gebirgssysteme



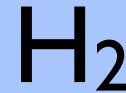
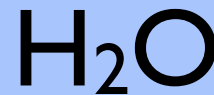
# Heute: Dicke der kontinentalen Kruste



# Erste Atmosphäre

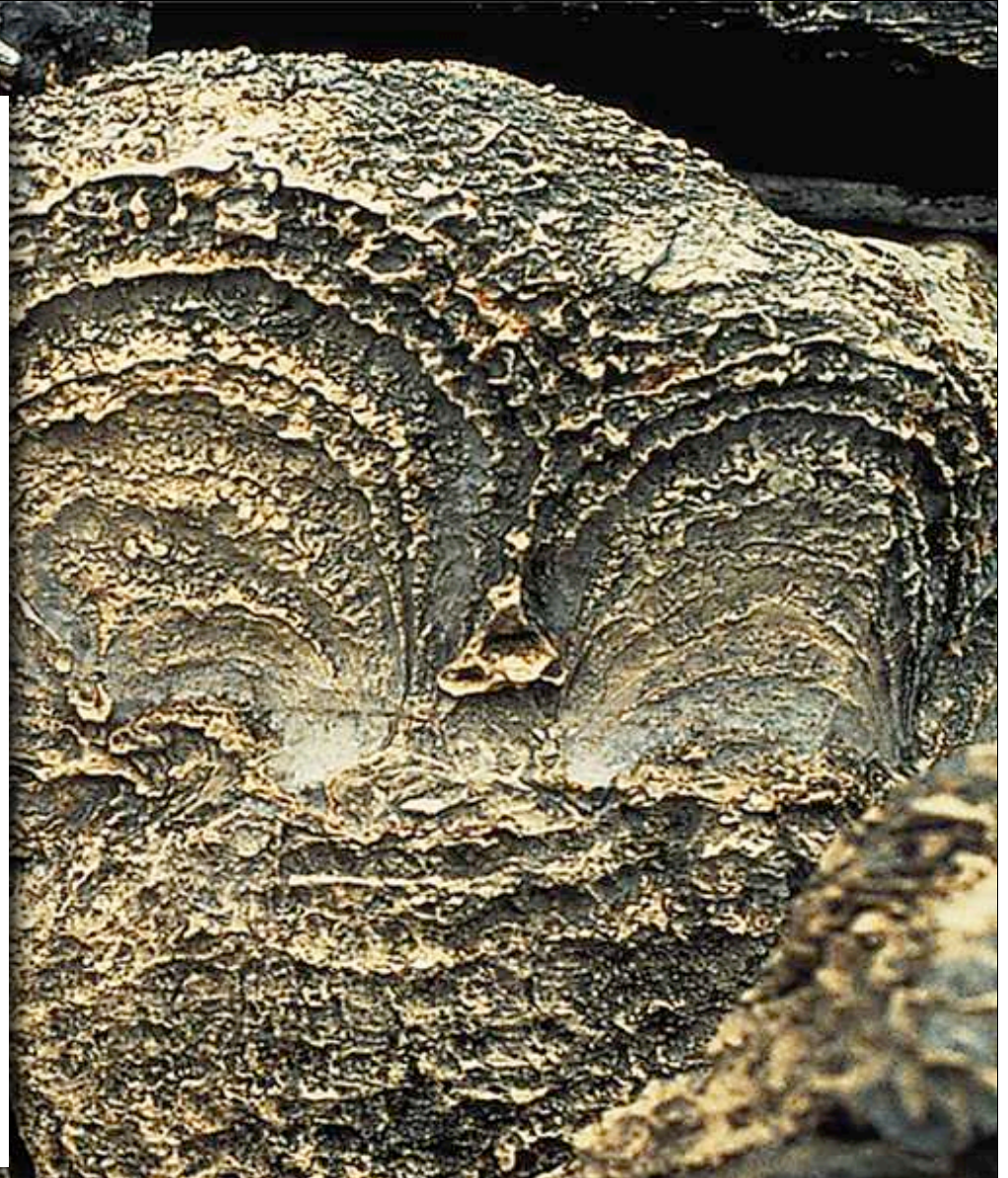
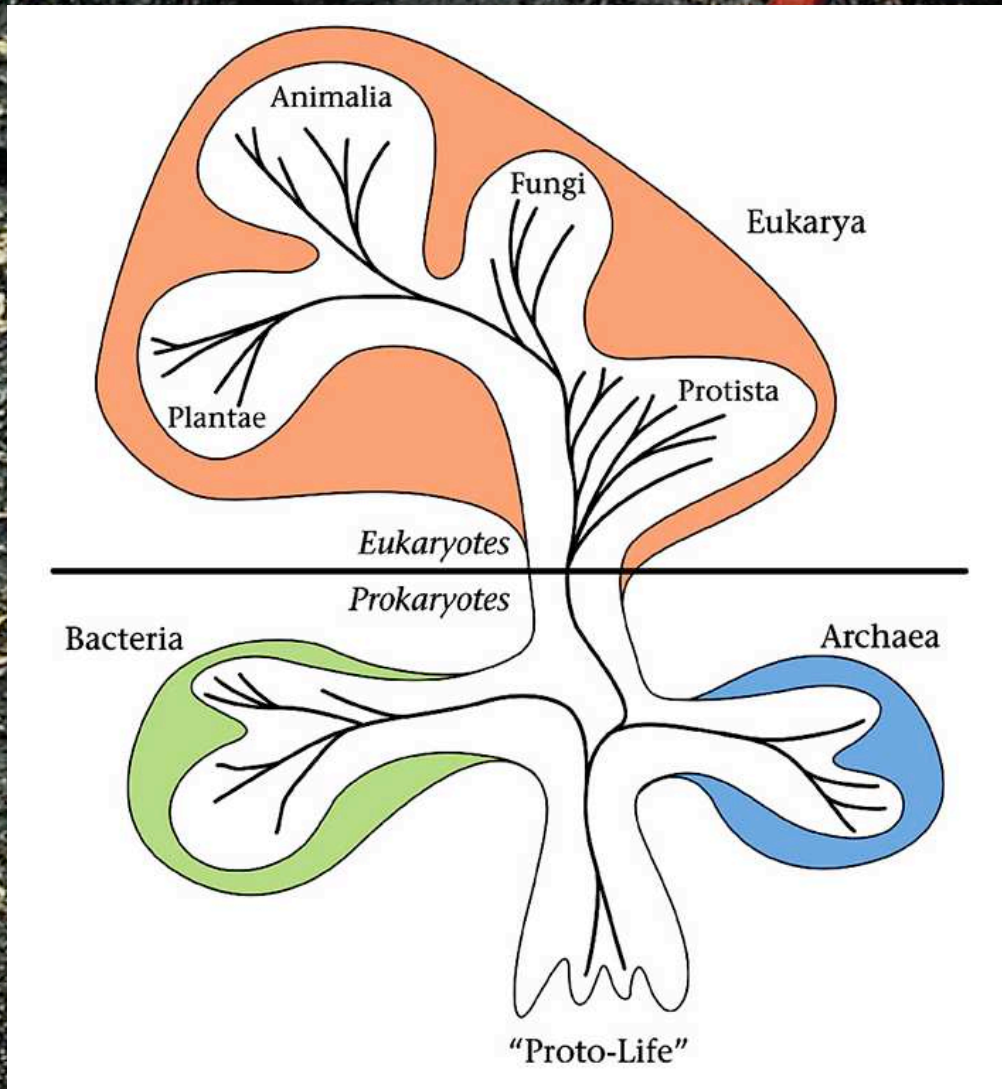


"Ursuppe"



ca. 250 mal dichter als heute

# Stromatolithe: Archaikum



Früheste Lebensform ~3.2 Ga: Cyanobacteria

# Banded Iron Formation (BIF)

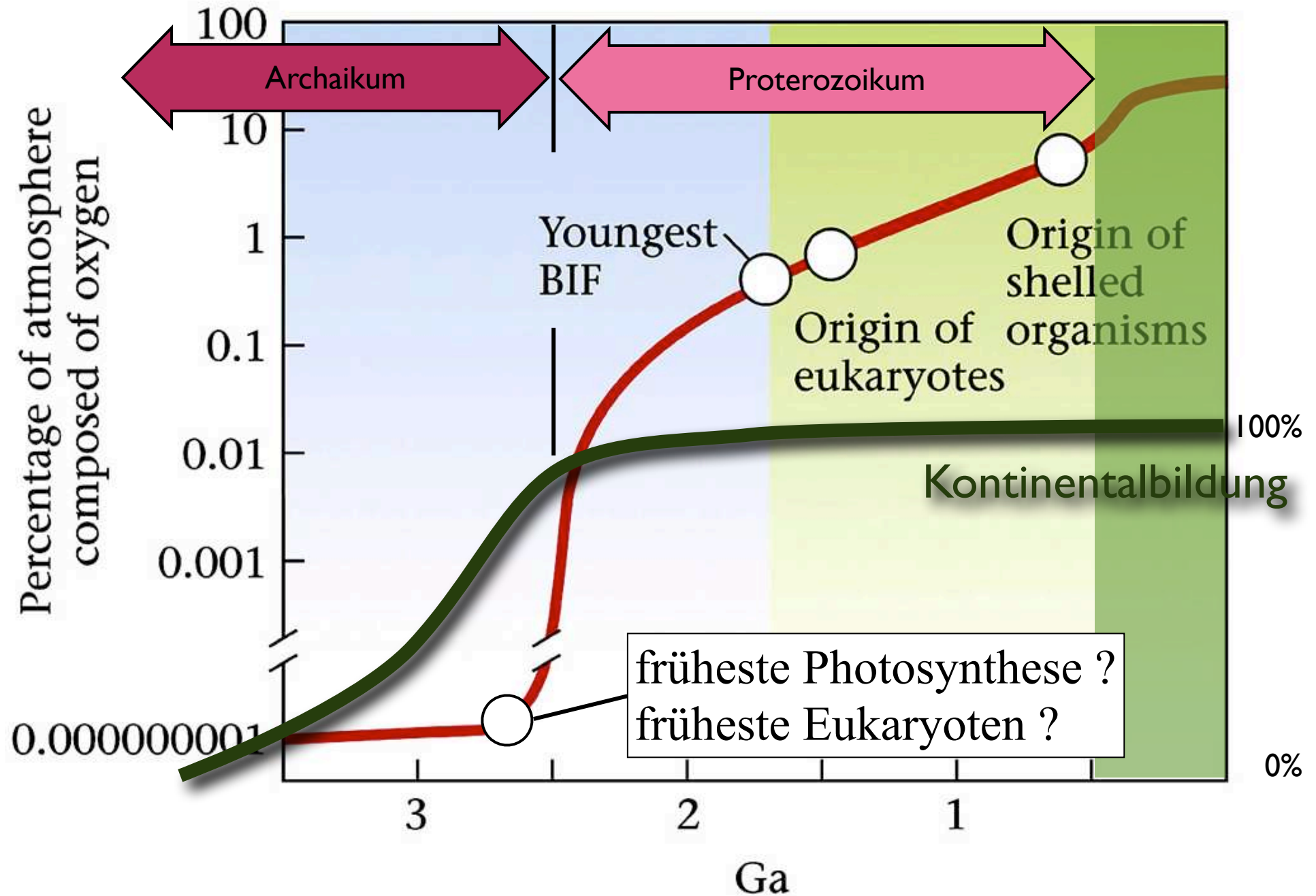


Jasper (red chert)

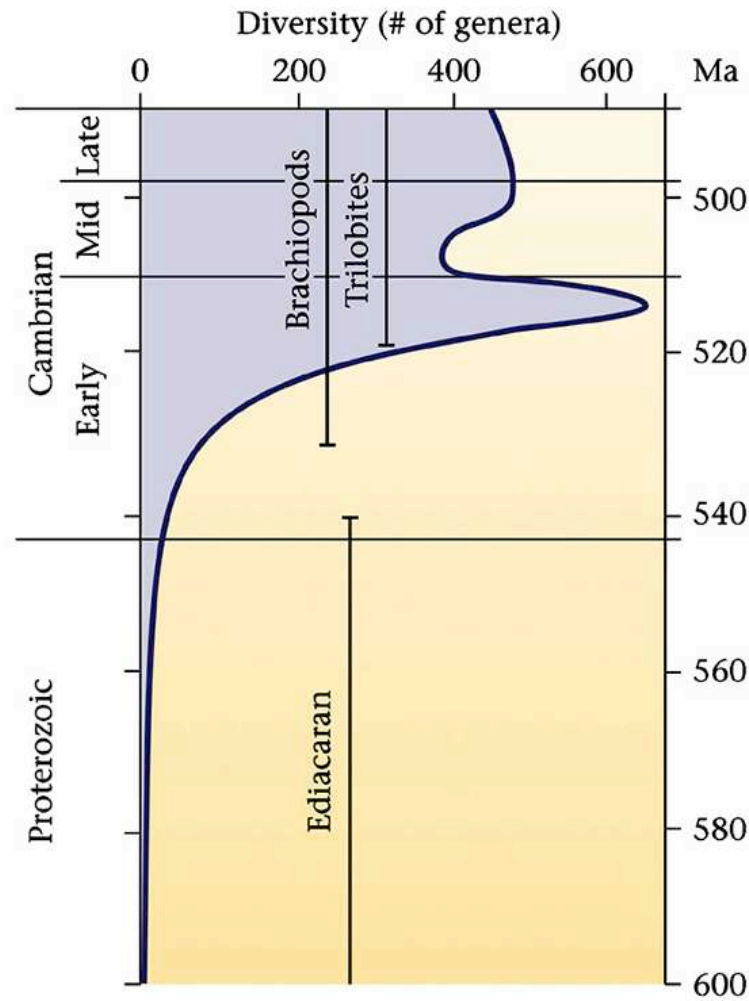
Hämatit

Iron Range, Michigan

# Sauerstoffgehalt in der Erdatmosphäre

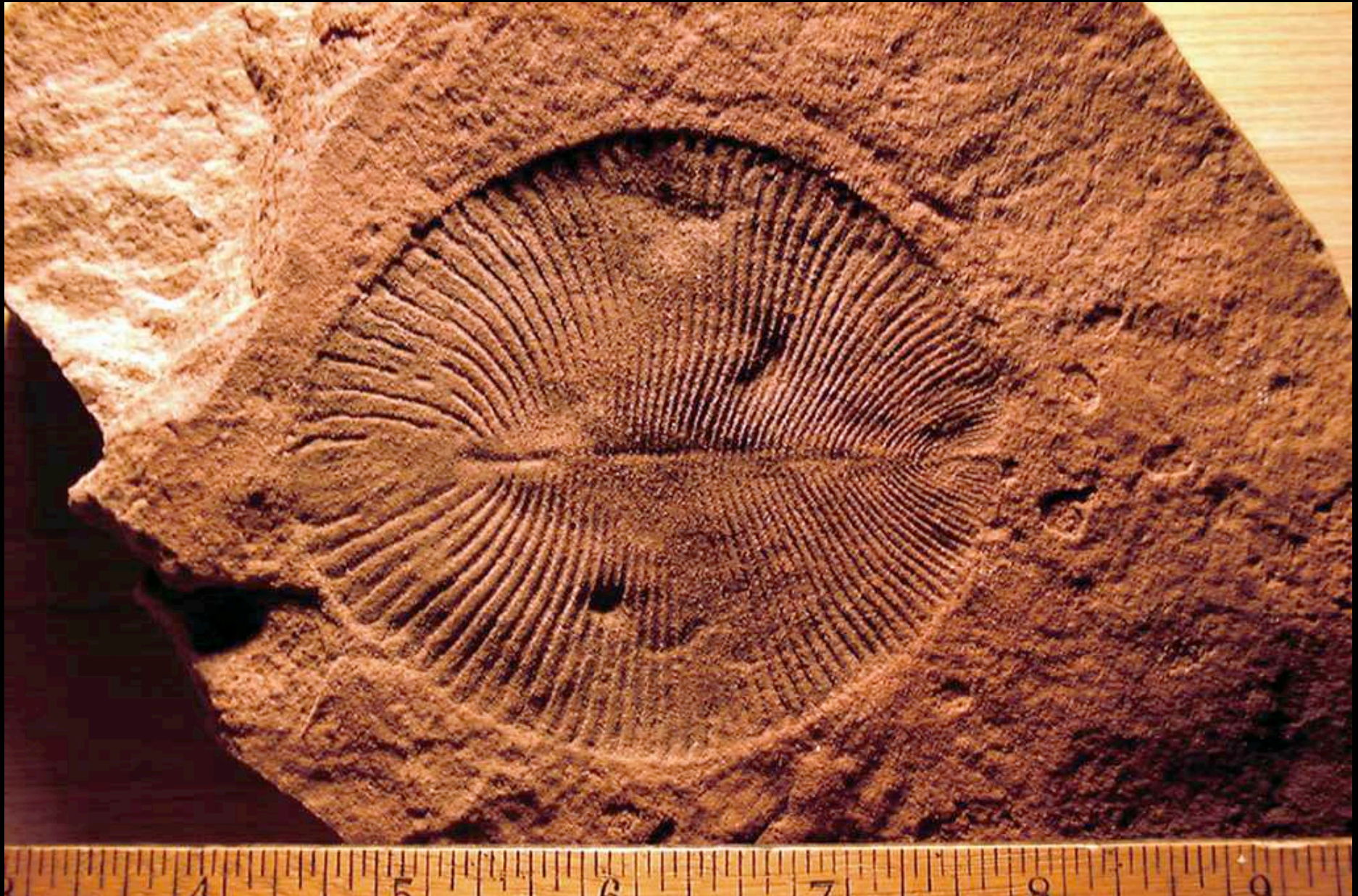


# Phanerozoikum



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

# Ediacara Fauna: Spät - Proterozoikum



Dickinsonia



# Ediacara Fauna: Spät - Proterozoikum



Rekonstruktion: Opabinia

# Frühes Paläozoikum



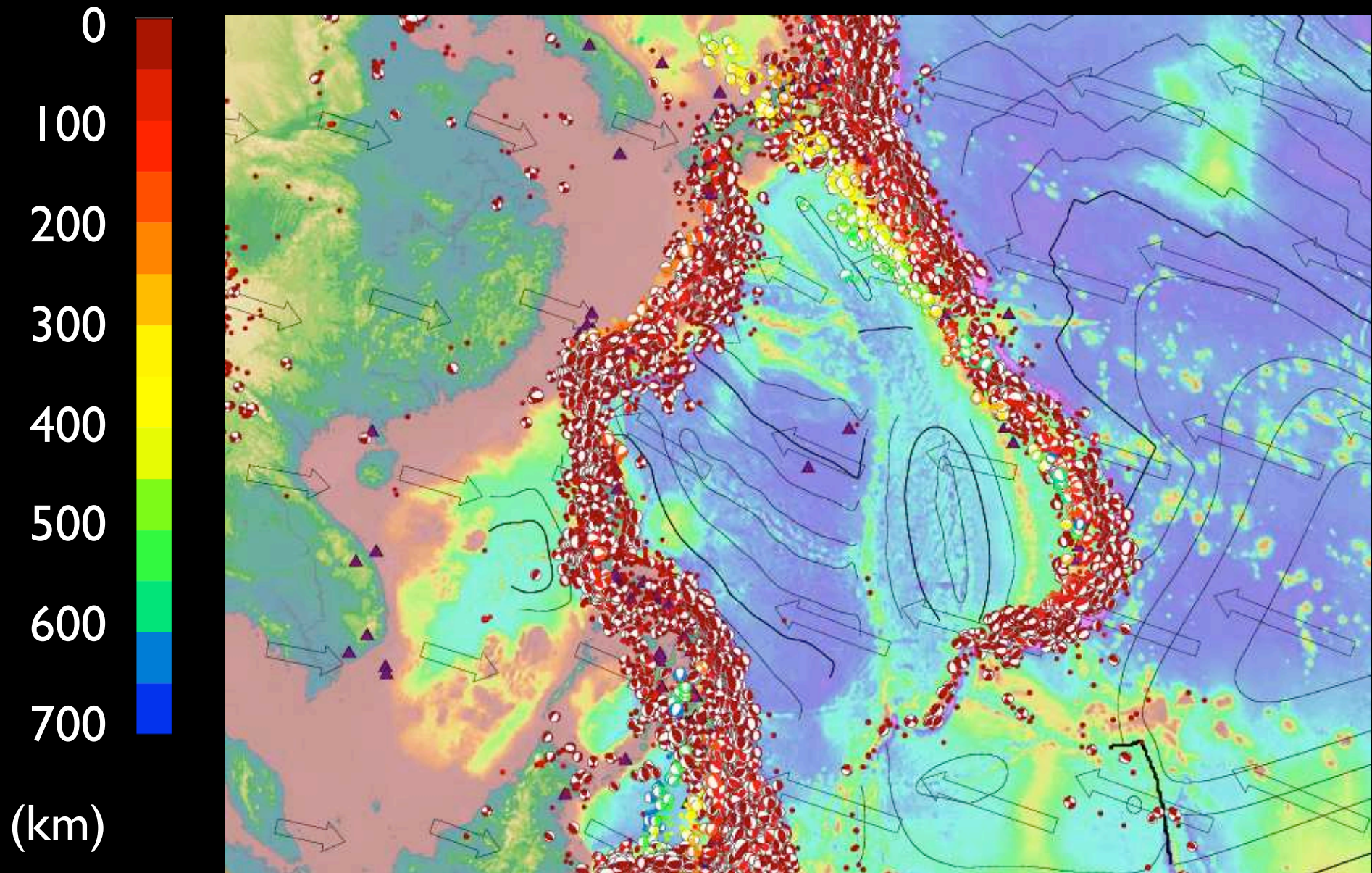
Trilobiten, Nautiliden

# Karbon

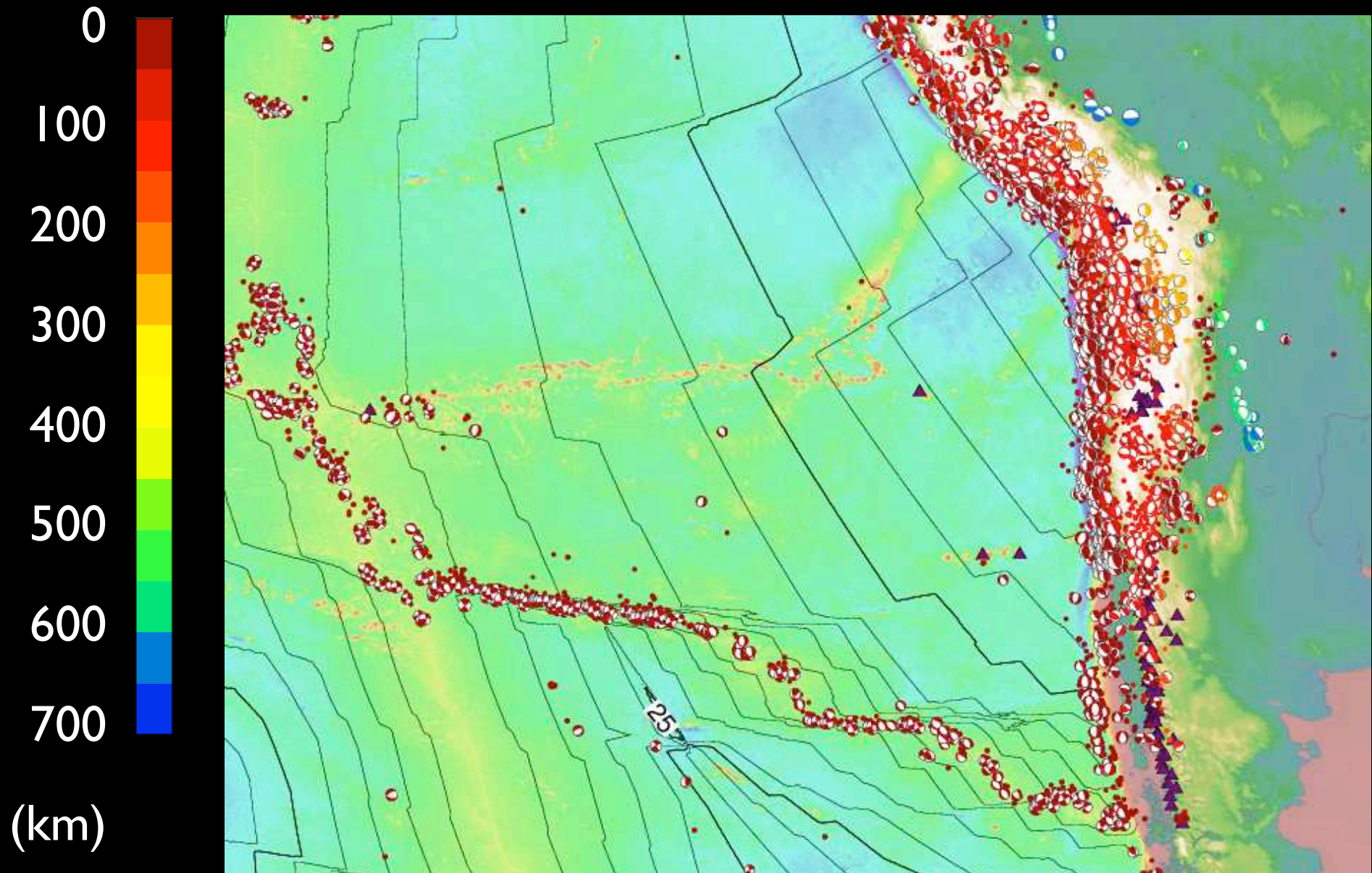


Giant dragonfly (wing span  $\approx$  1m)

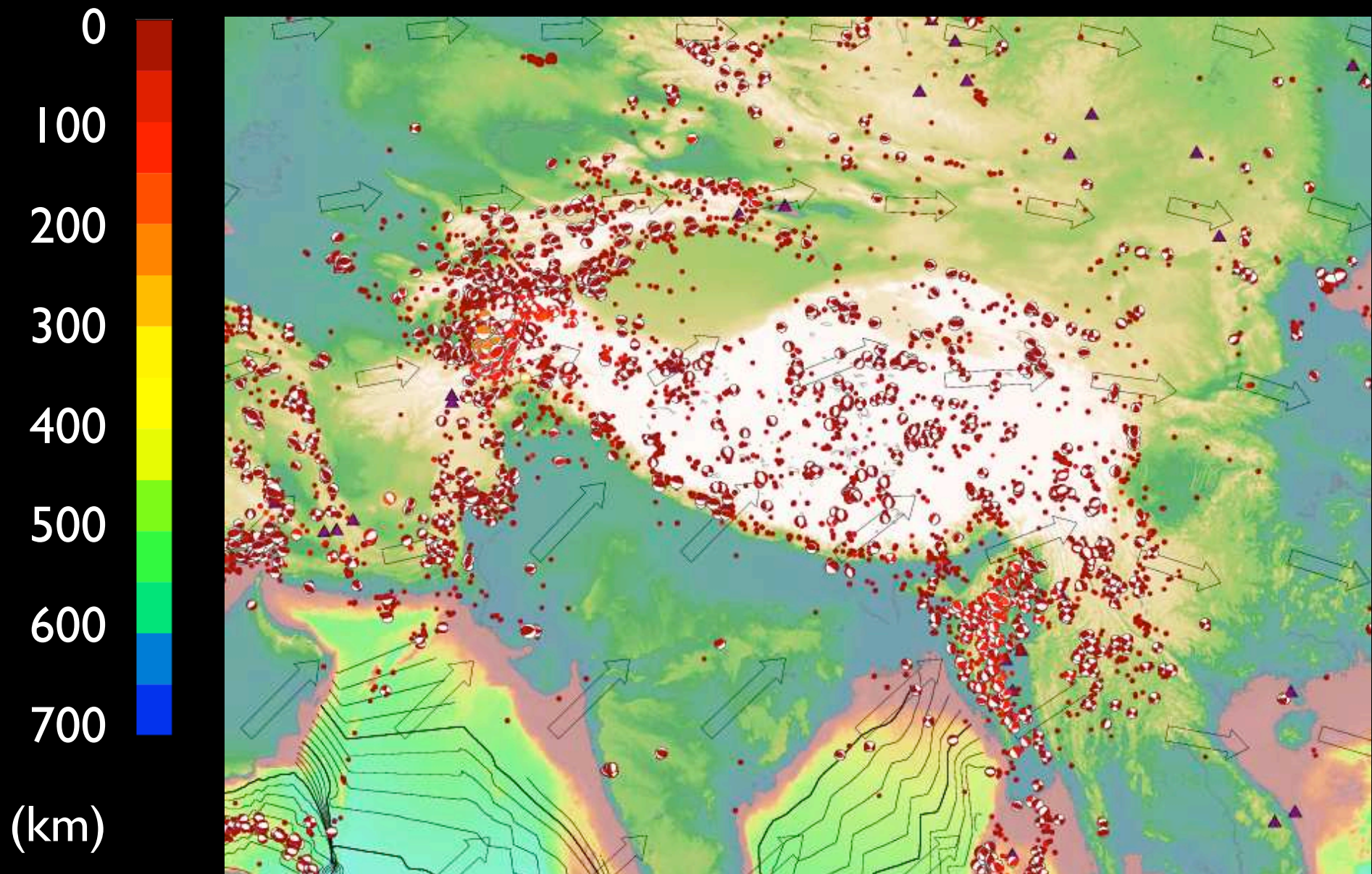
# Ozean - Ozean



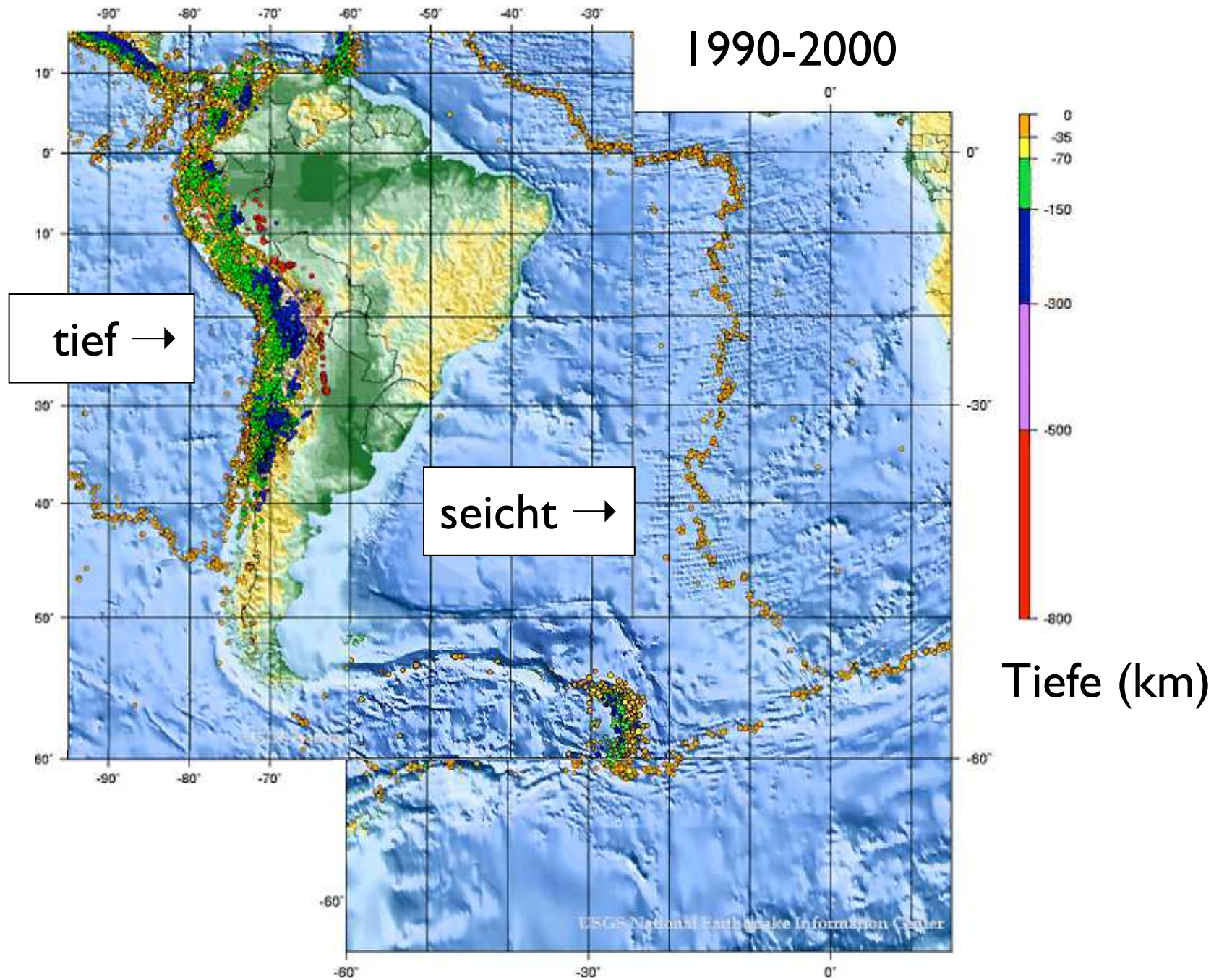
# Ozean - Kontinent



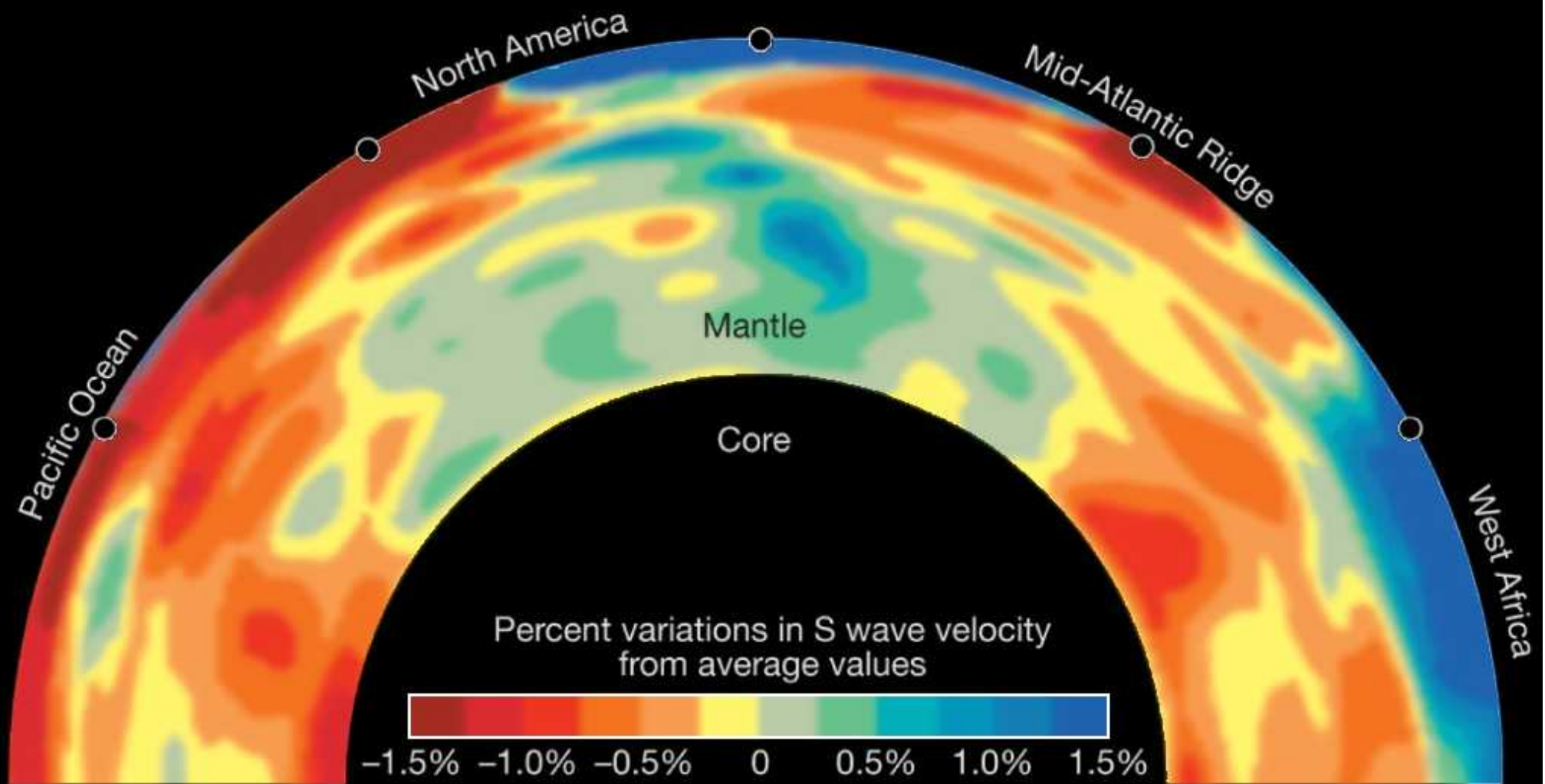
# Kontinent - Kontinent



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



# Seismische Tomographie



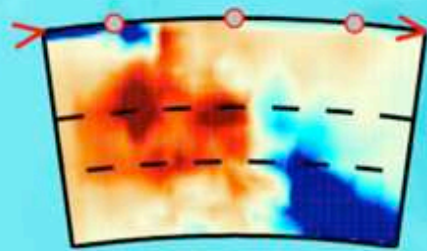
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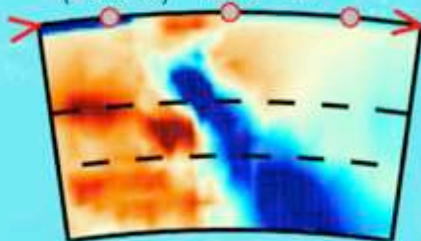
langsam  
warm



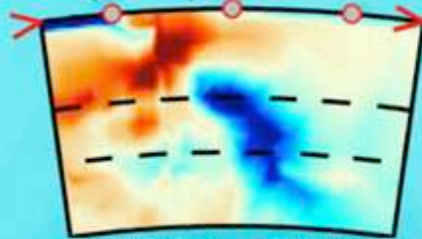
schnell  
kalt



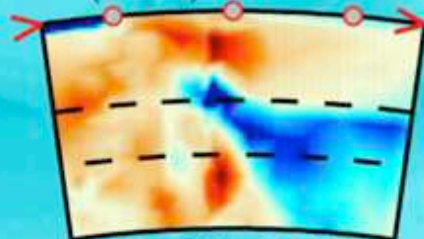
(±0.8%) 1000 km



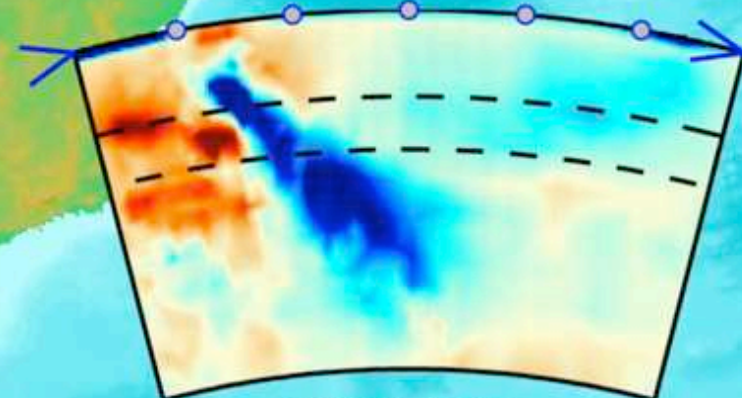
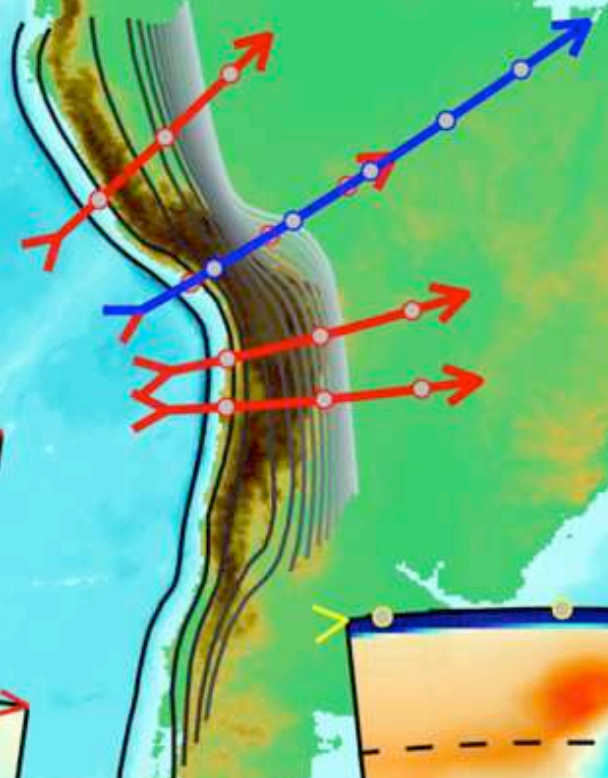
(±0.8%) 1000 km



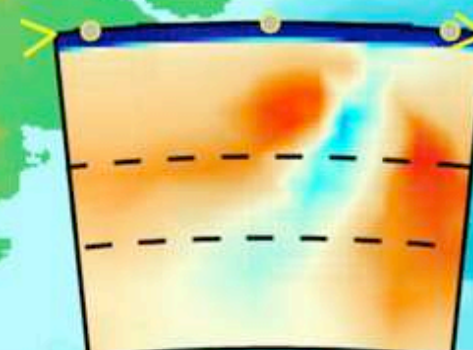
(±0.8%) 1000 km



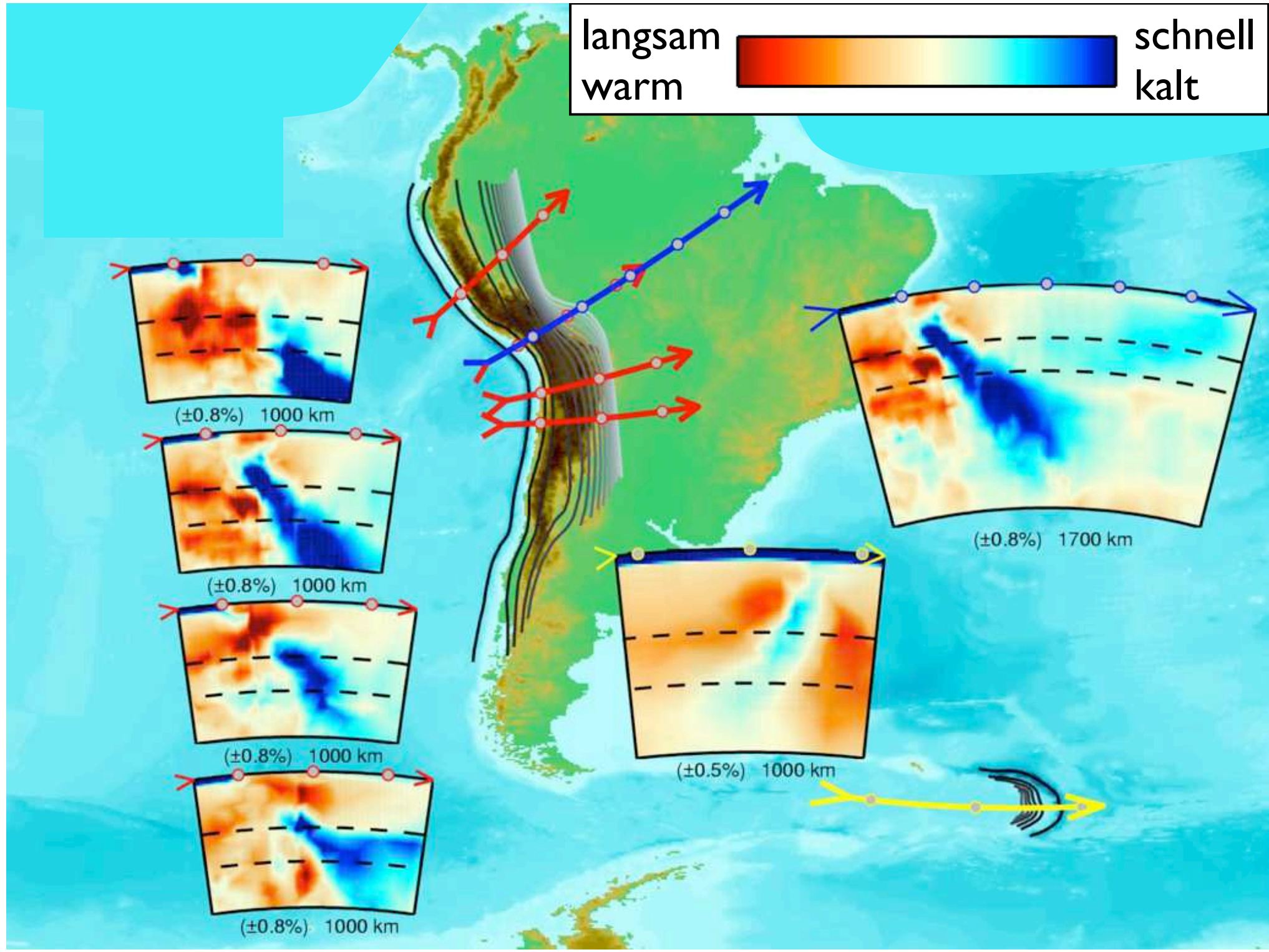
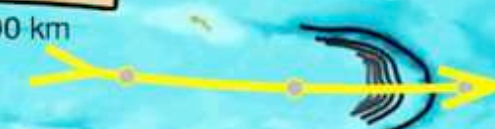
(±0.8%) 1000 km



(±0.8%) 1700 km



(±0.5%) 1000 km

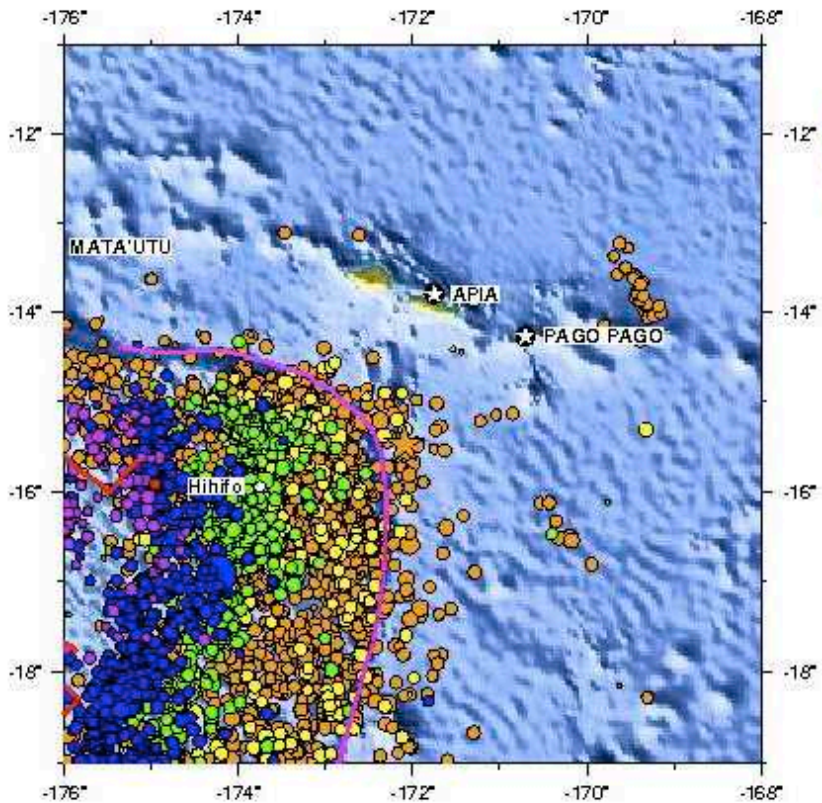


# Aktuell: Samoa Island, 29. 9. 2009

## Magnitude 8.1 SAMOA ISLANDS REGION

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

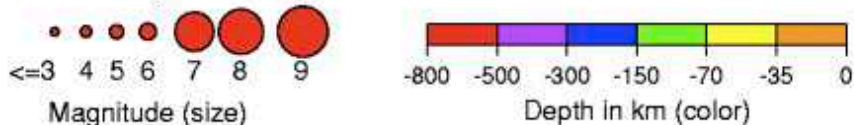
### Historic Seismicity



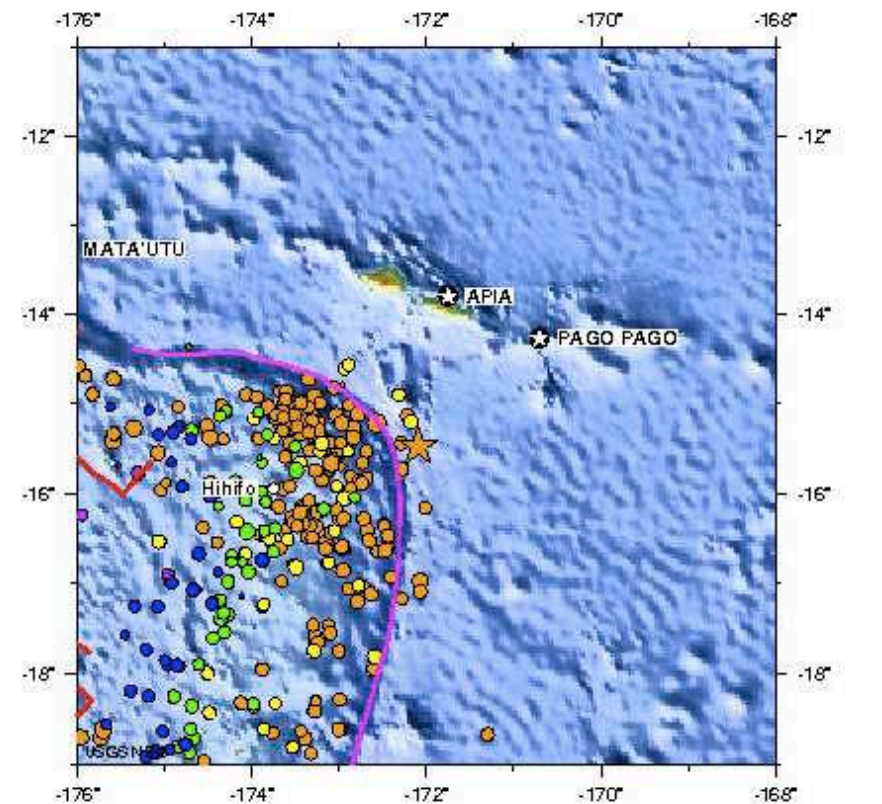
### SAMOA ISLANDS REGION

2009 09 29 17:48:10 UTC 15.48S 172.09W Depth: 18 km, Magnitude: 8.1

Seismicity 1990 to Present



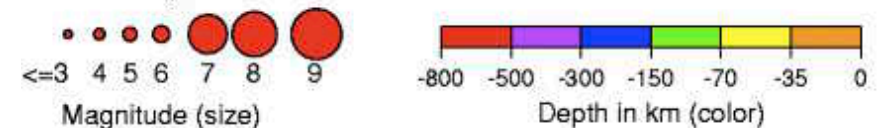
Major Tectonic Boundaries: Subduction Zones -purple, Ridges -red and Transform Faults -green



### SAMOA ISLANDS REGION

2009 09 29 17:48:10 UTC 15.48S 172.09W Depth: 18 km, Magnitude: 8.1

Seismicity in 2009



# Aktuell: Samoa Island, 29. 9. 2009

## 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

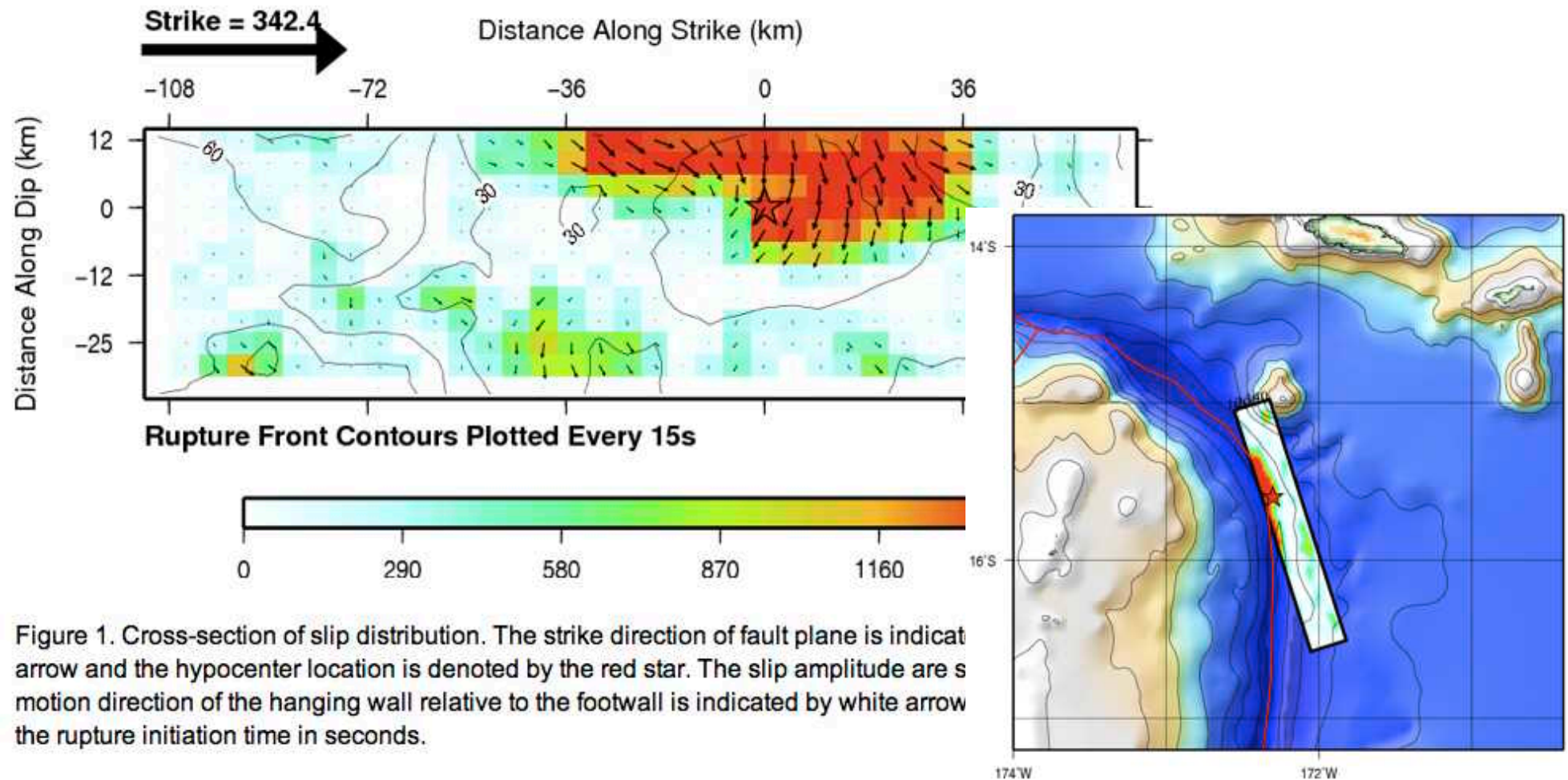
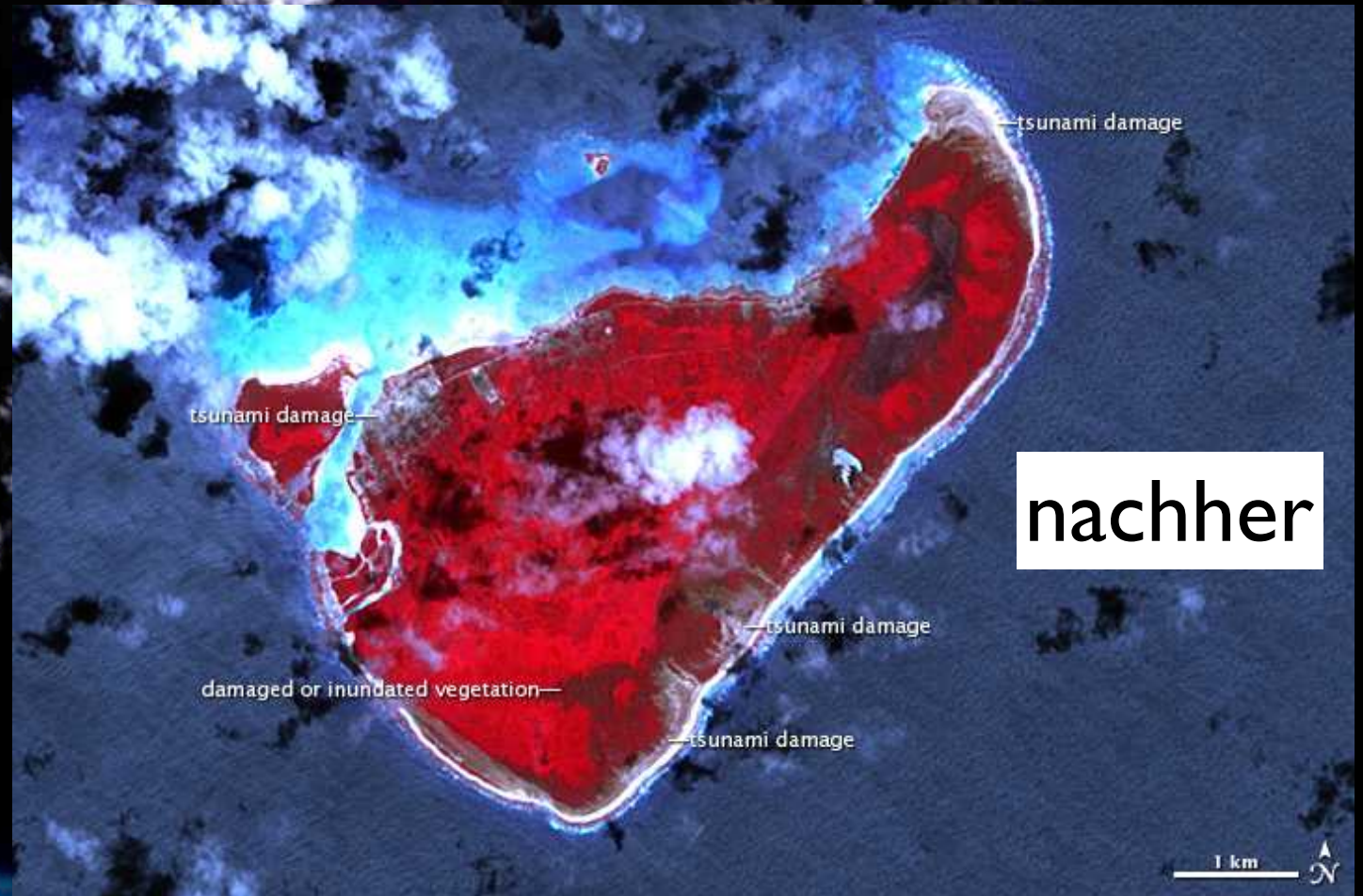


Figure 1. Cross-section of slip distribution. The strike direction of fault plane is indicated by arrow and the hypocenter location is denoted by the red star. The slip amplitude and the motion direction of the hanging wall relative to the footwall are indicated by white arrows. The rupture initiation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

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.

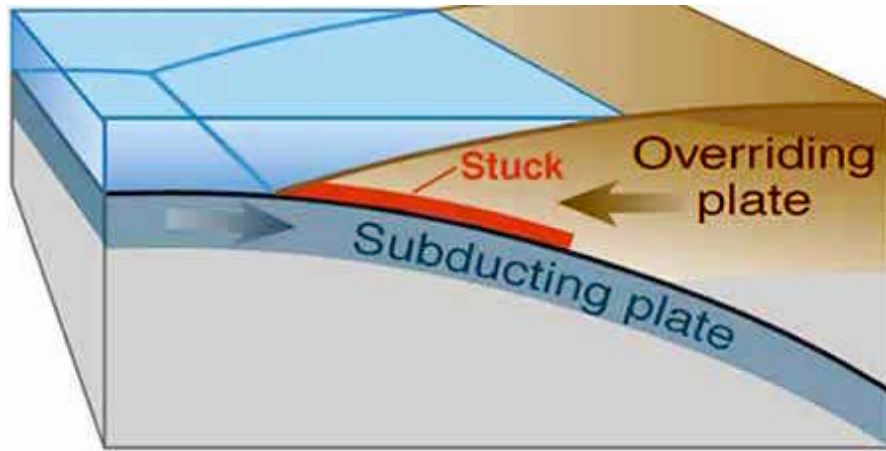


nachher

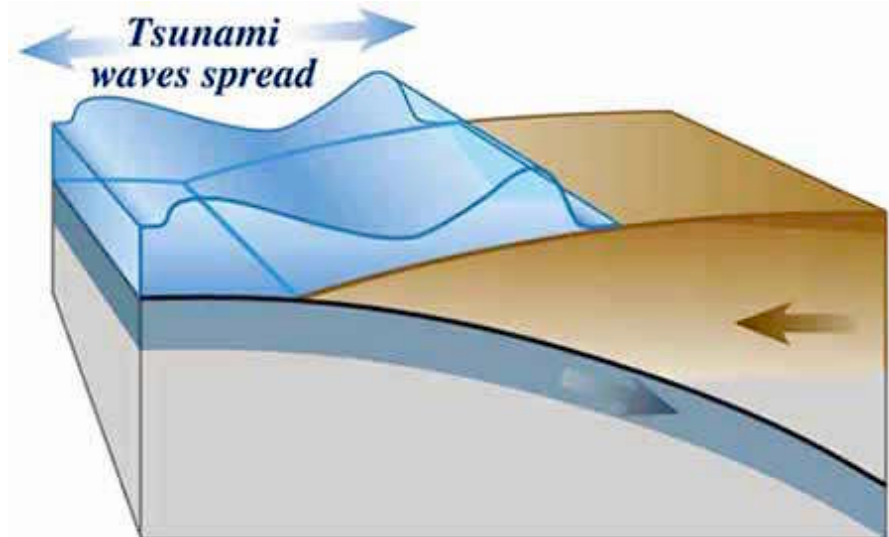
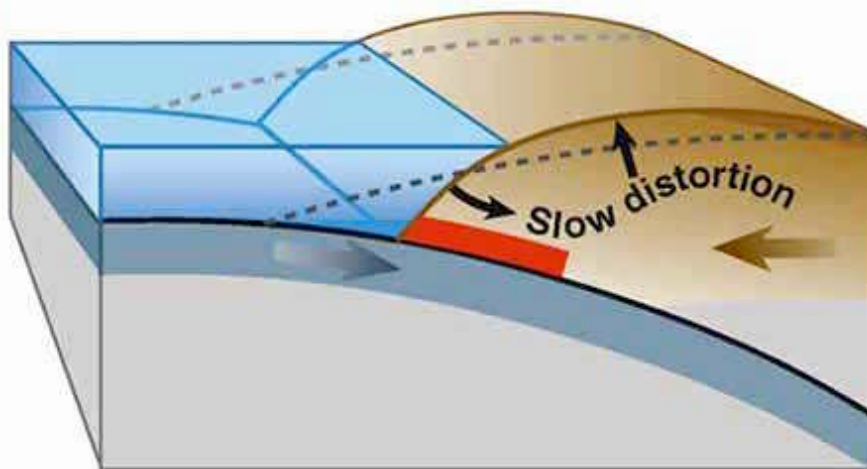
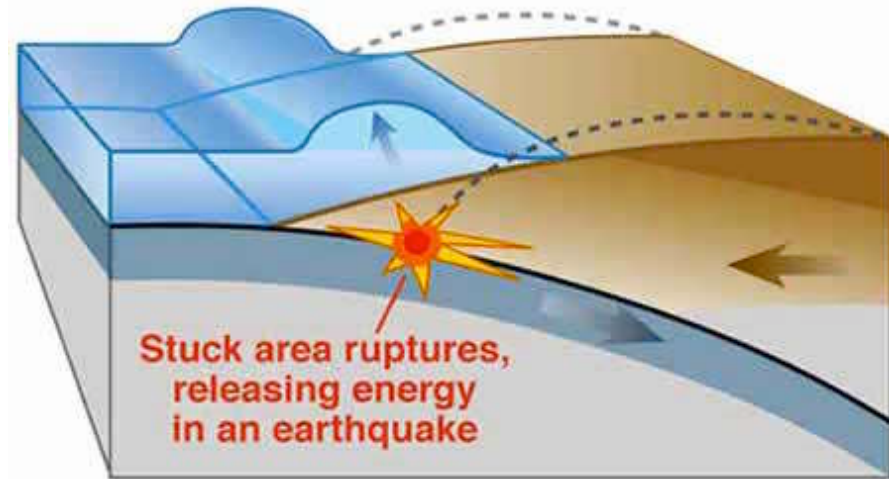


vorher

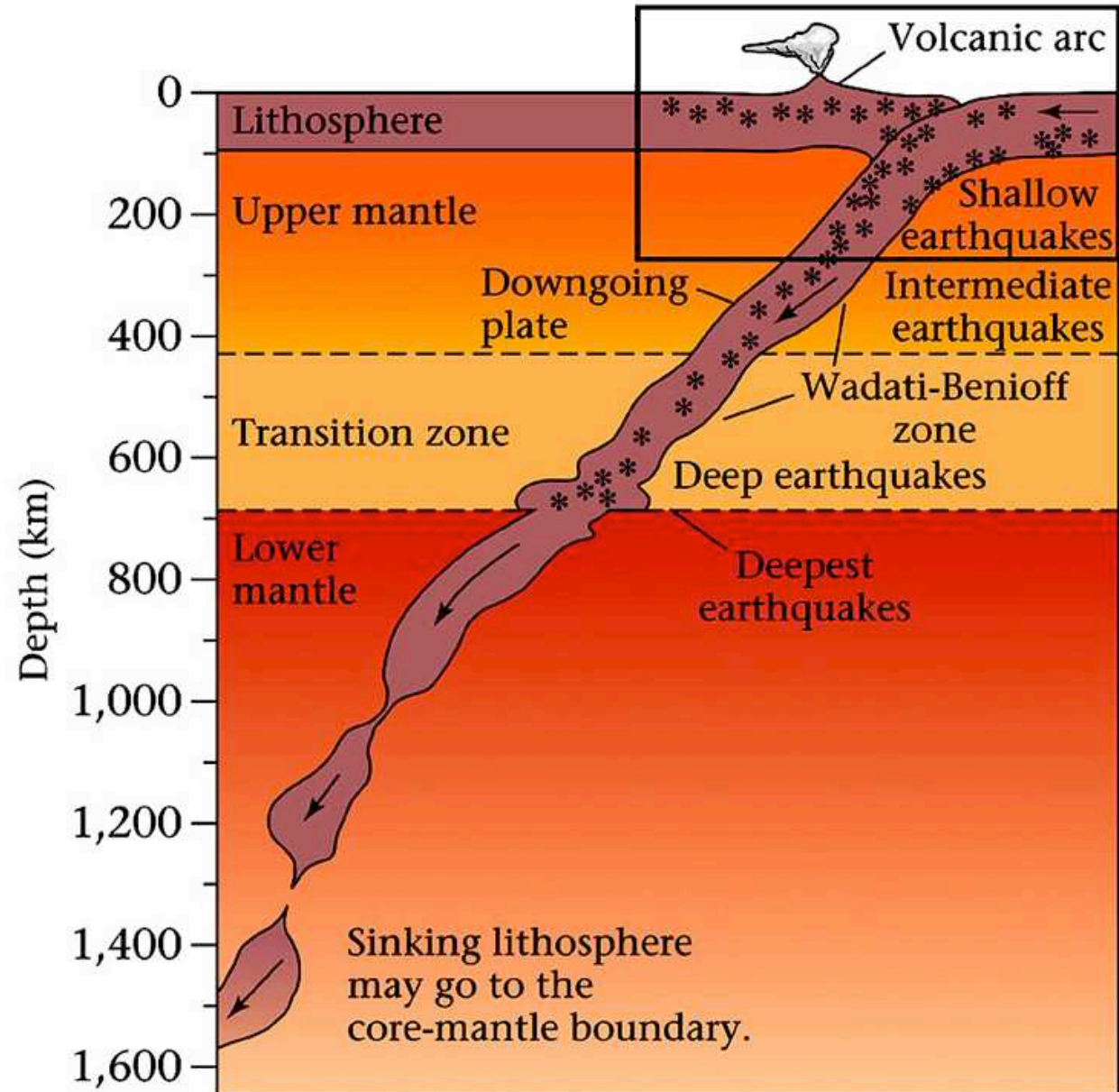
# Tsunami



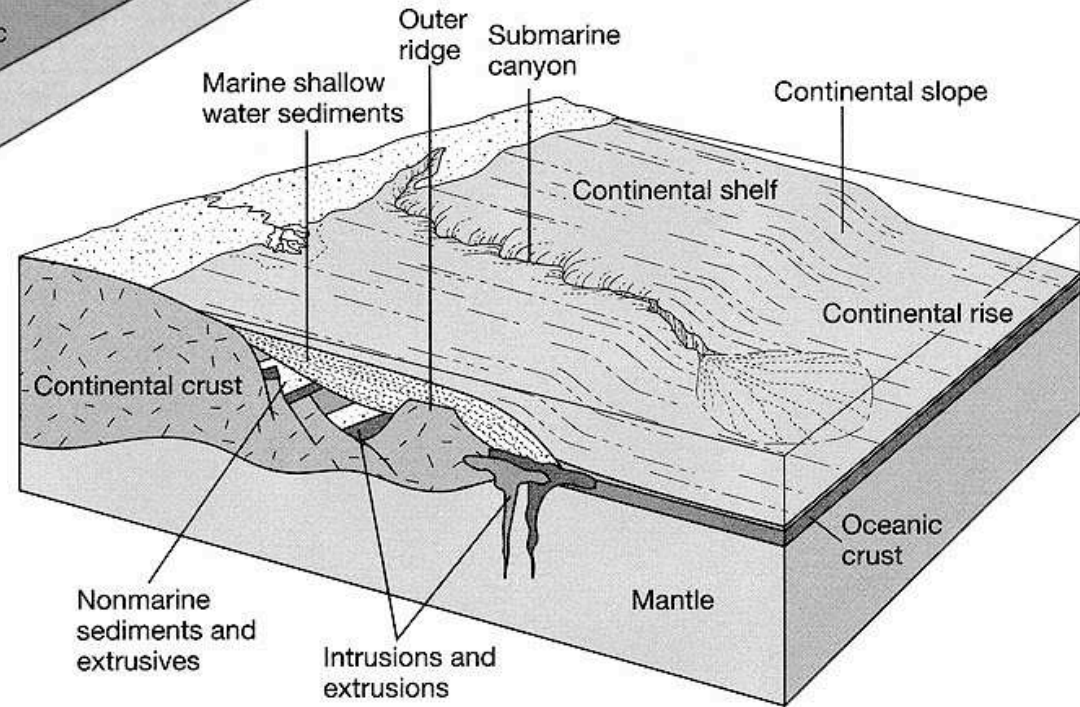
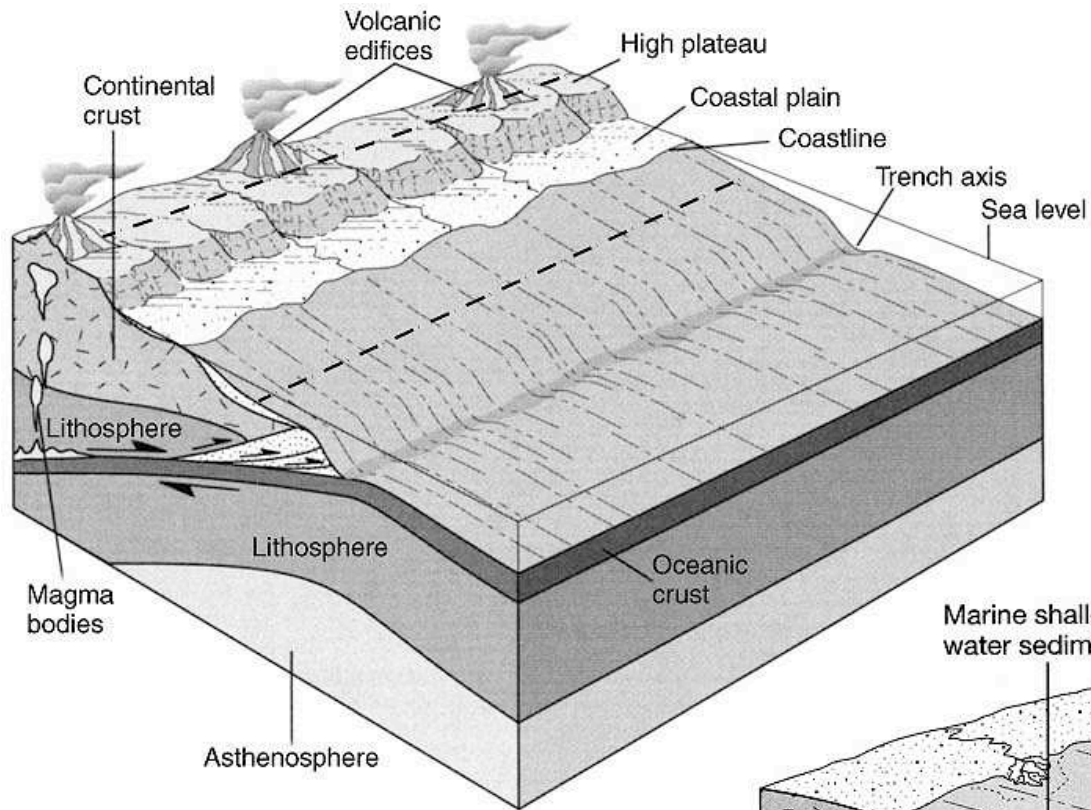
*Earthquake starts tsunami*



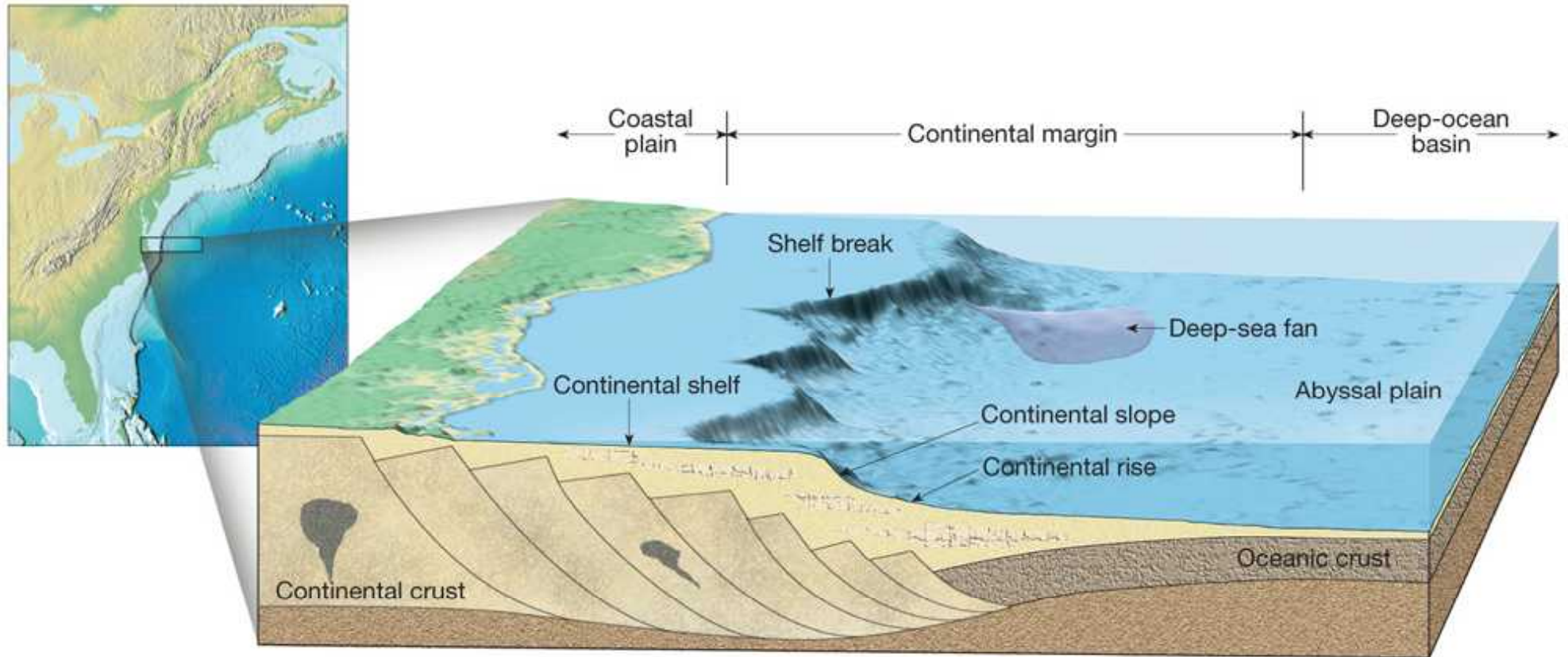
# Subduktionszone



# Aktiver vs. passiver Kontinentalrand



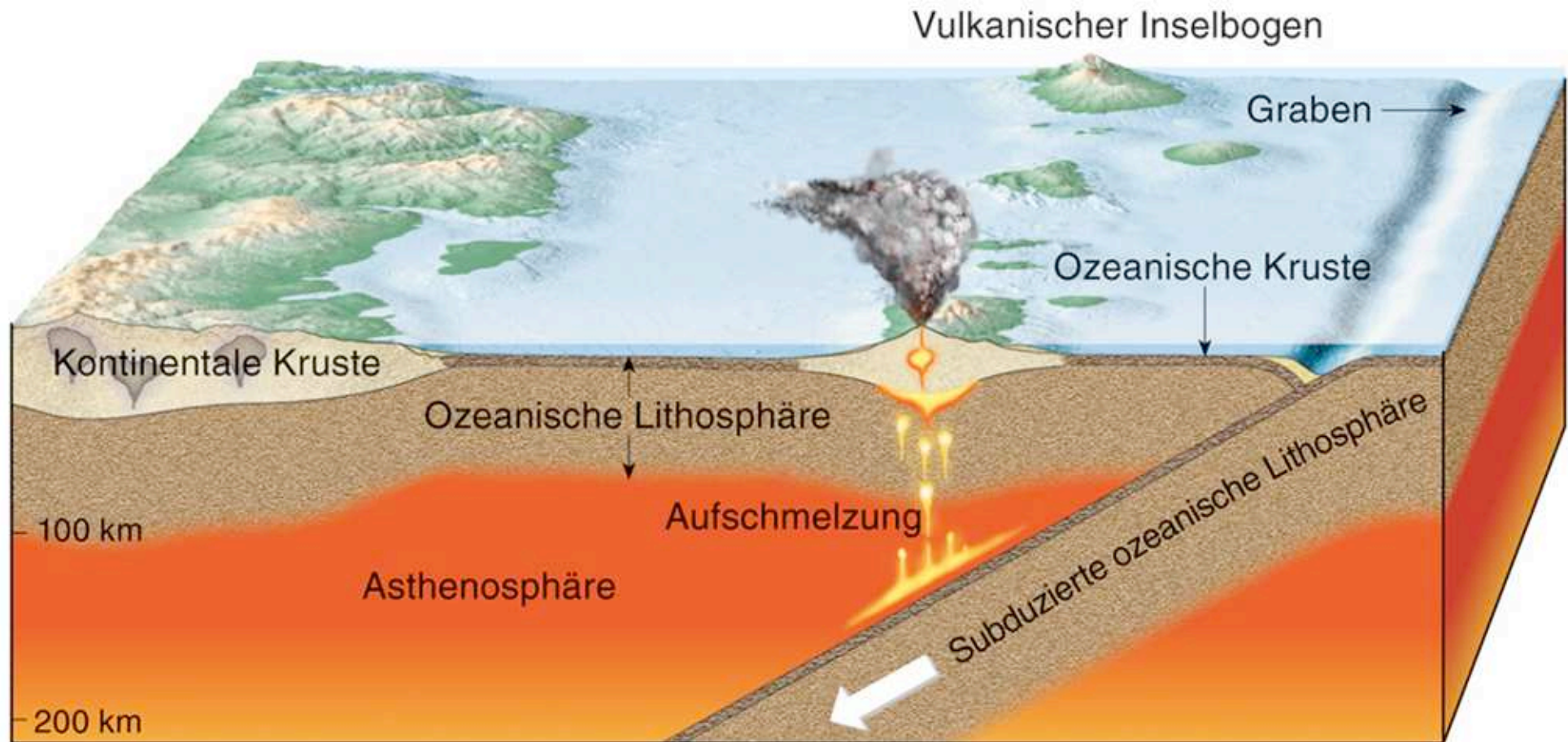
# Passive continental margin



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# Ozean - Ozean

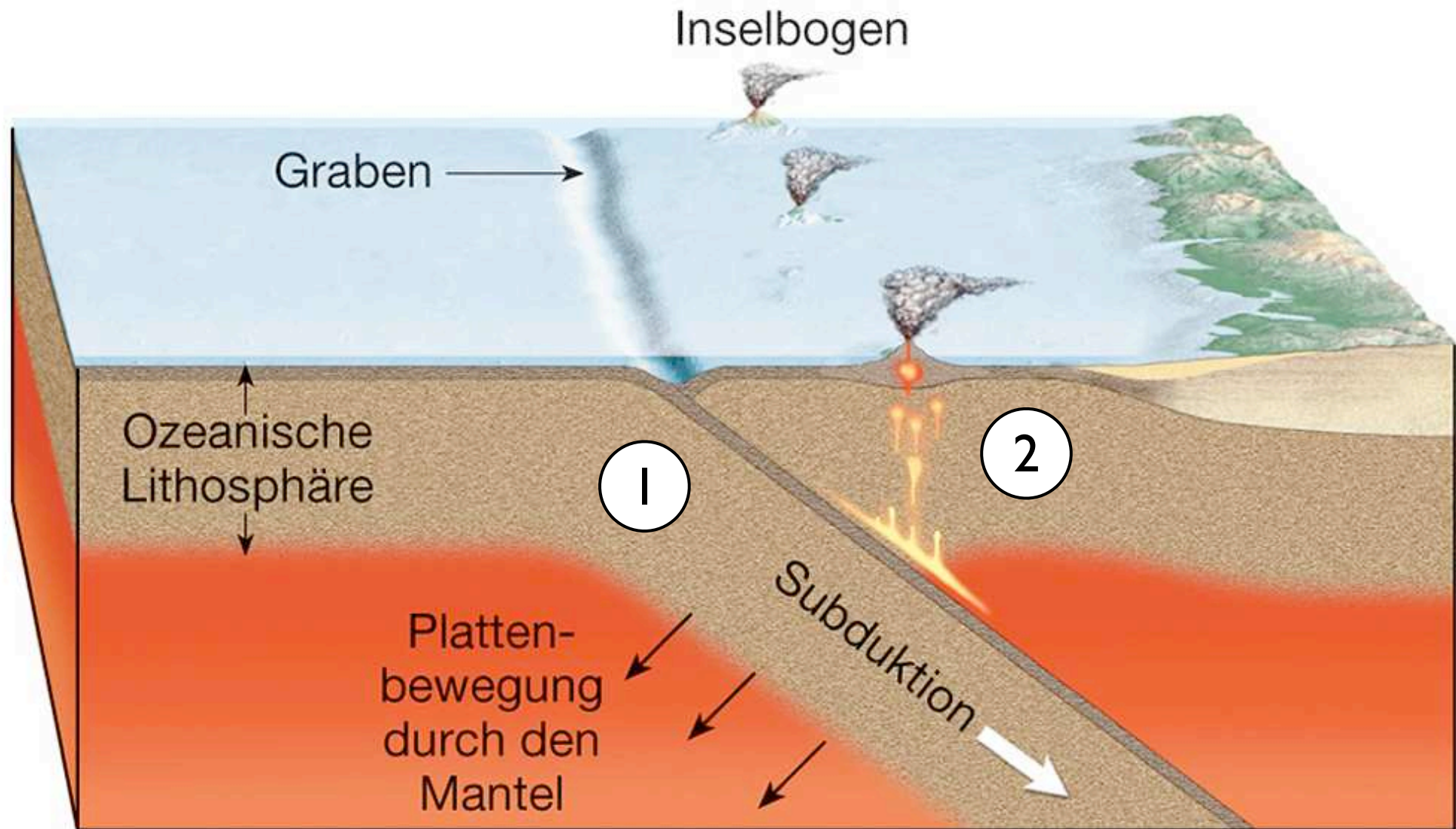


dichtere Platte sinkt hinunter

Vulkanismus am Ozeanboden

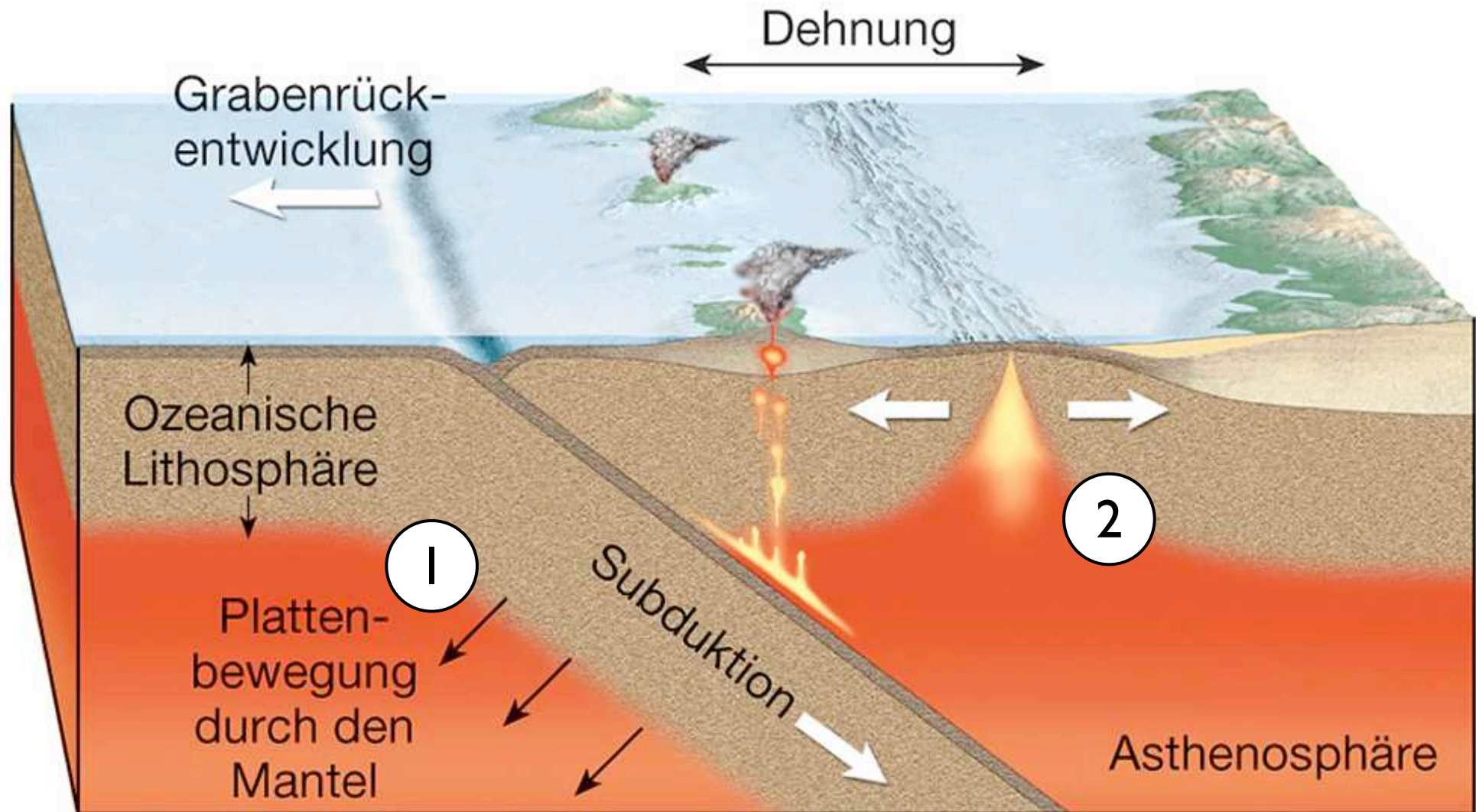
Vulkanische Inselbögen: Japan, Aleuten, Tonga

# Vulkanischer Inselbogen



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

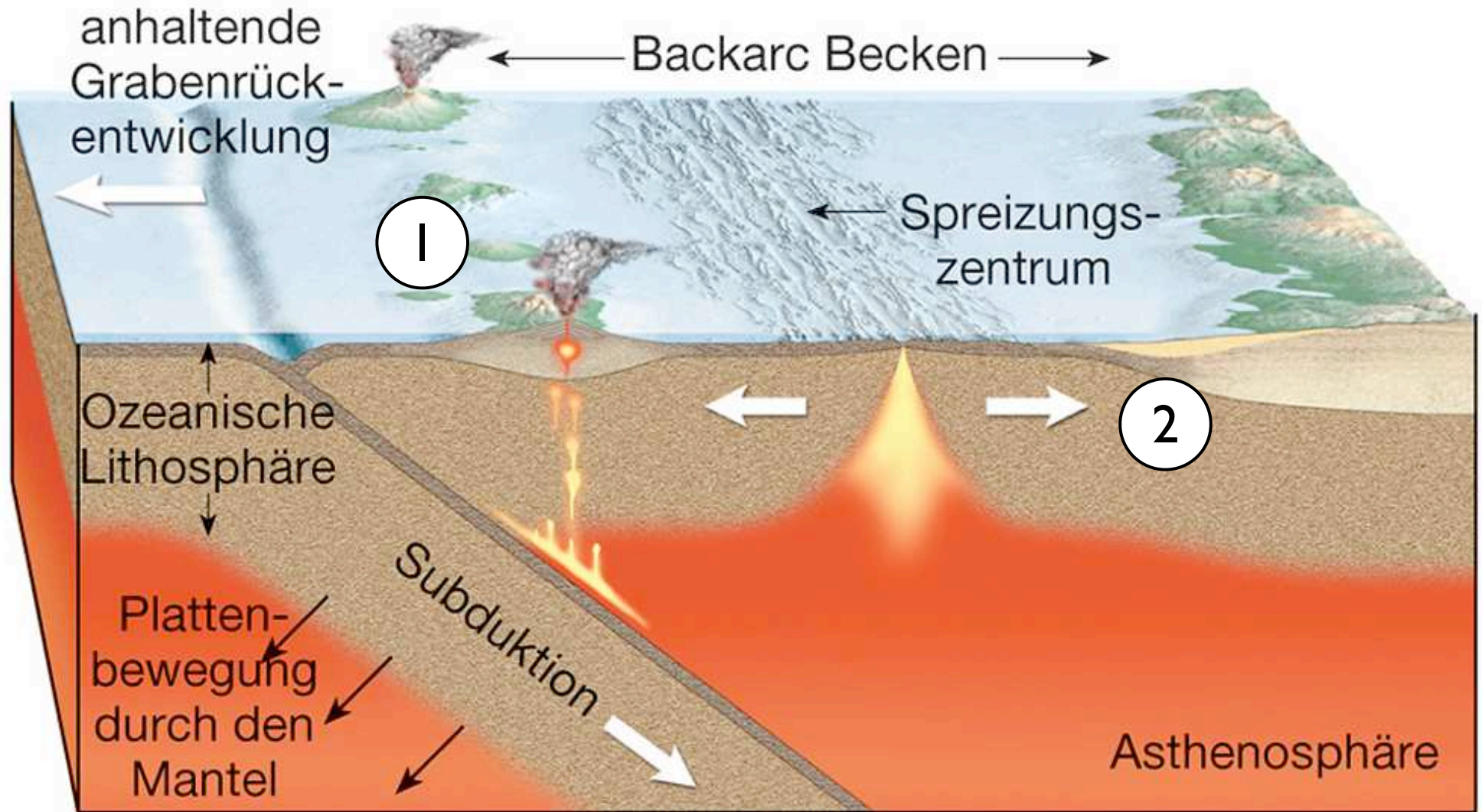
# Vulkanischer Inselbogen



1 Subduzierte Platte sinkt ab: roll-back

2 Leichtes (heisses) Magma steigt auf, Kruste dehnt sich

# Vulkanischer Inselbogen



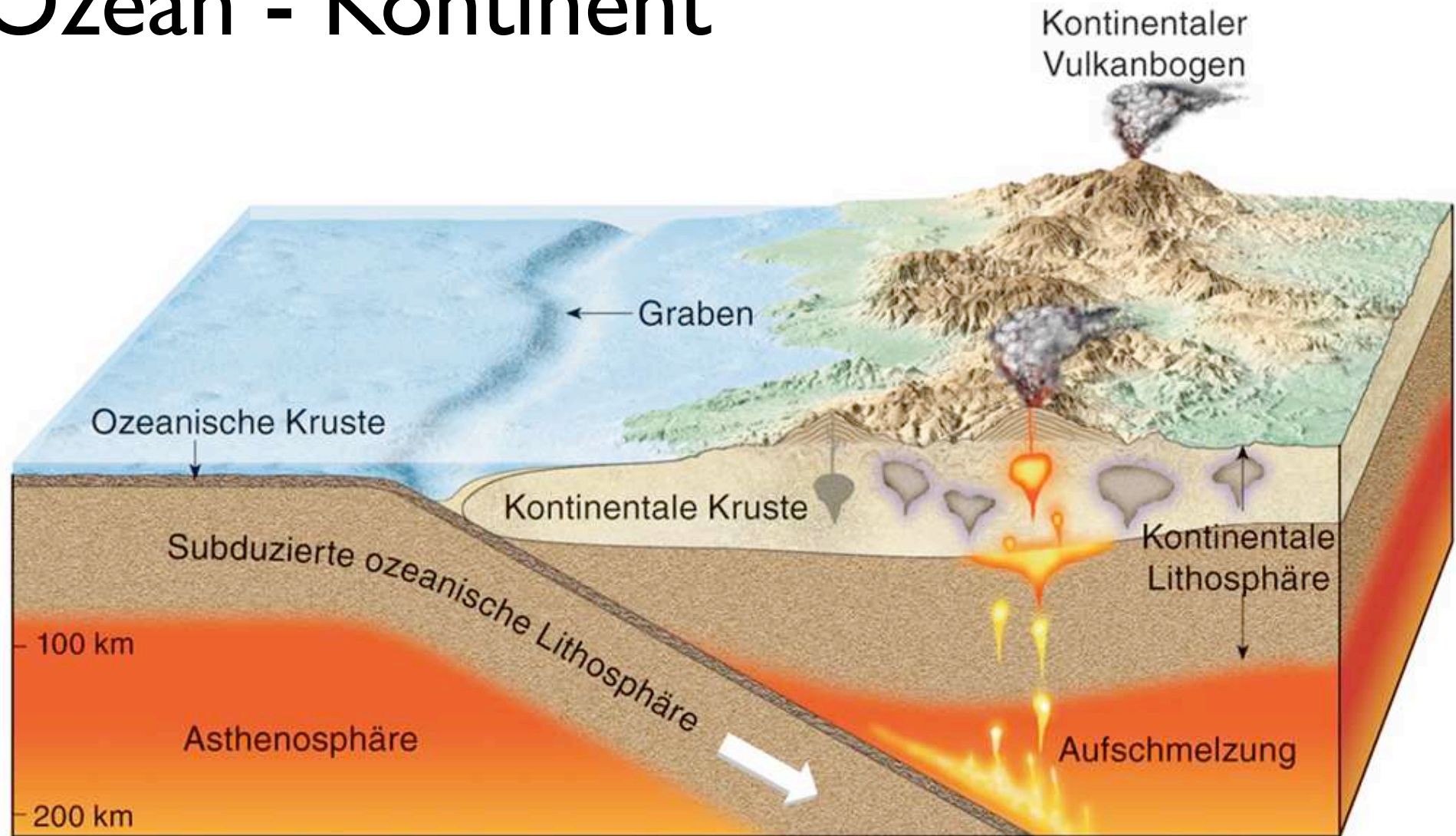
1 Vulkanismus führt zu Inseln

2 Ozeanbodenspreizung in obduzierter Platte: back arc spreading

# Beispiel: Aleutian

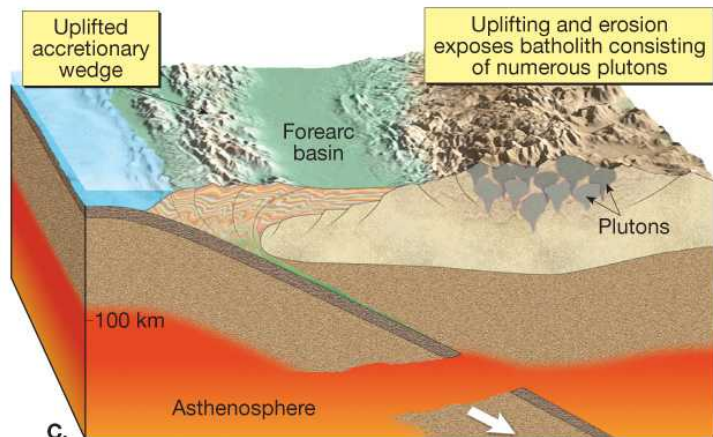
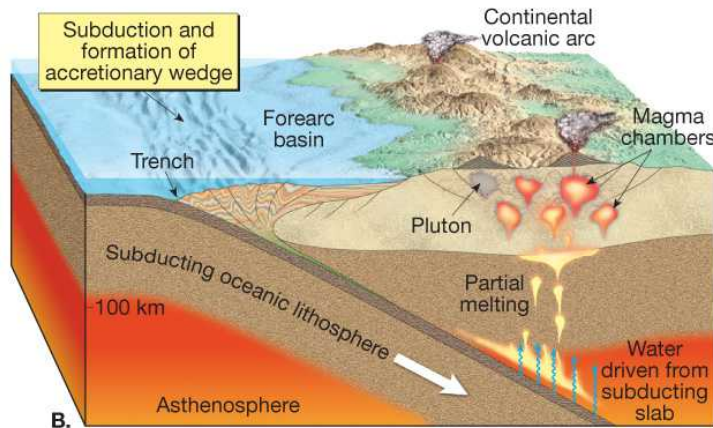
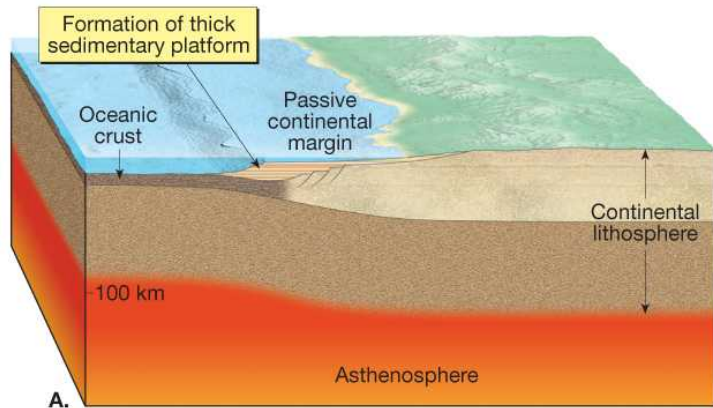


# Ozean - Kontinent



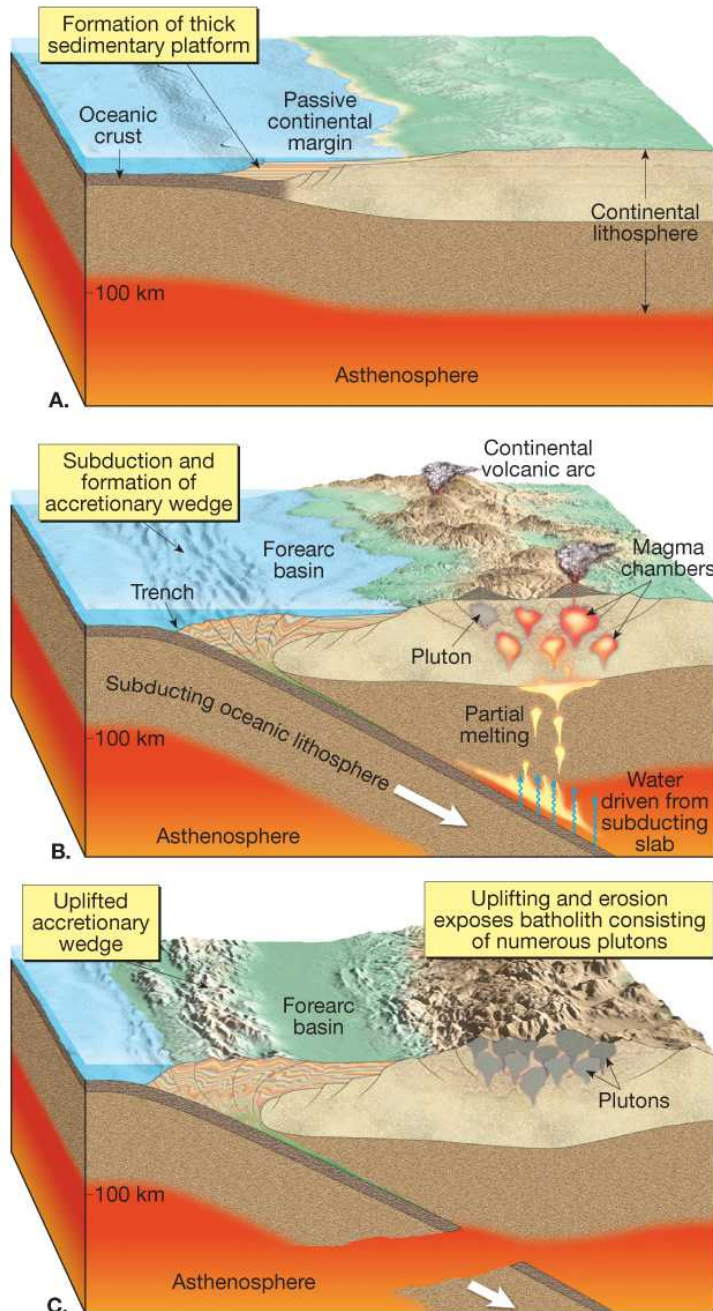
dichtere Platte (= ozeanische) sinkt hinunter  
Aufschmelzung in überschobener Platte  
Kontinentale Vulkanbögen: Anden, Cascades (USA)

# 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

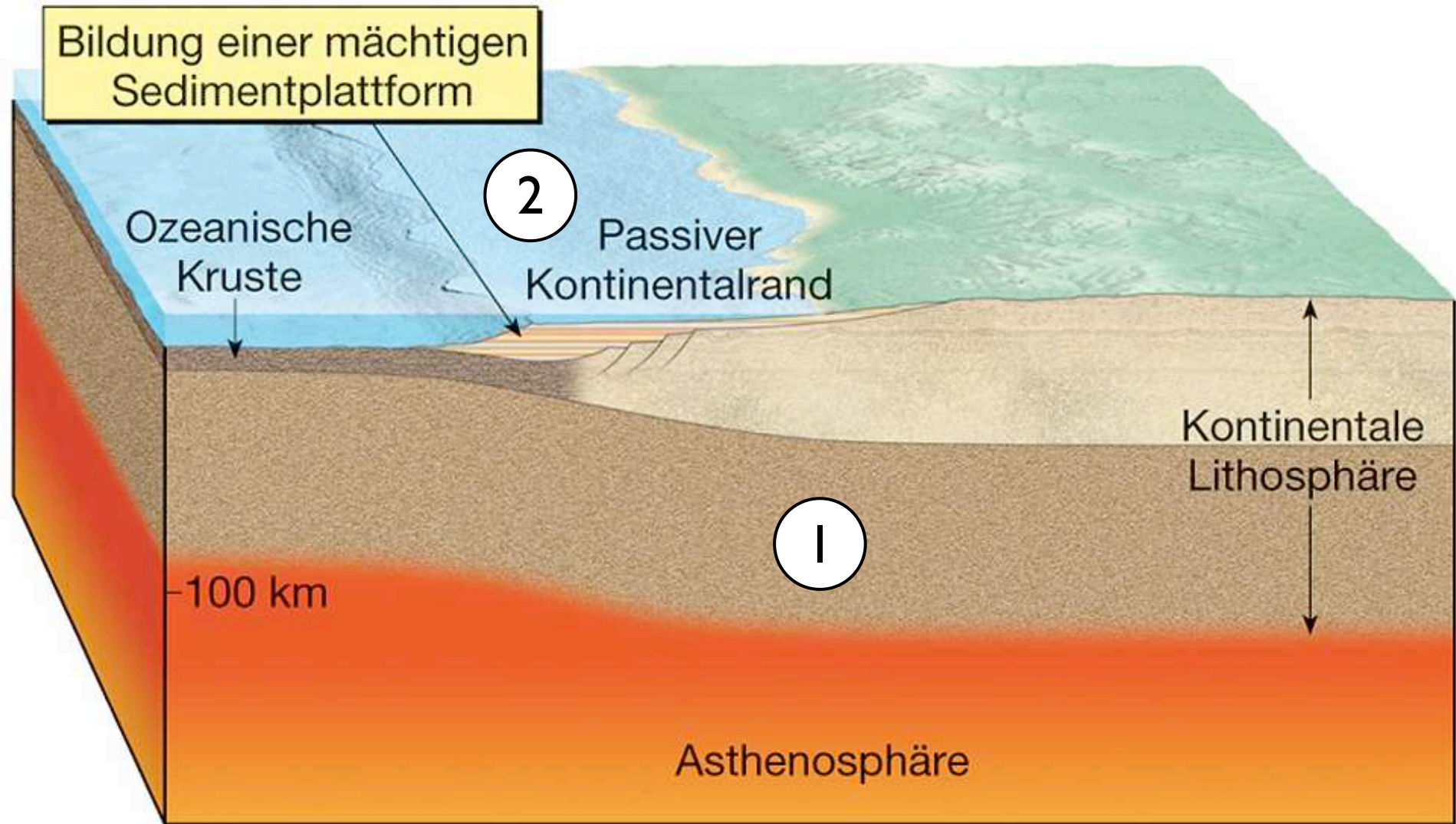
# Andean-type mountain building



- 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

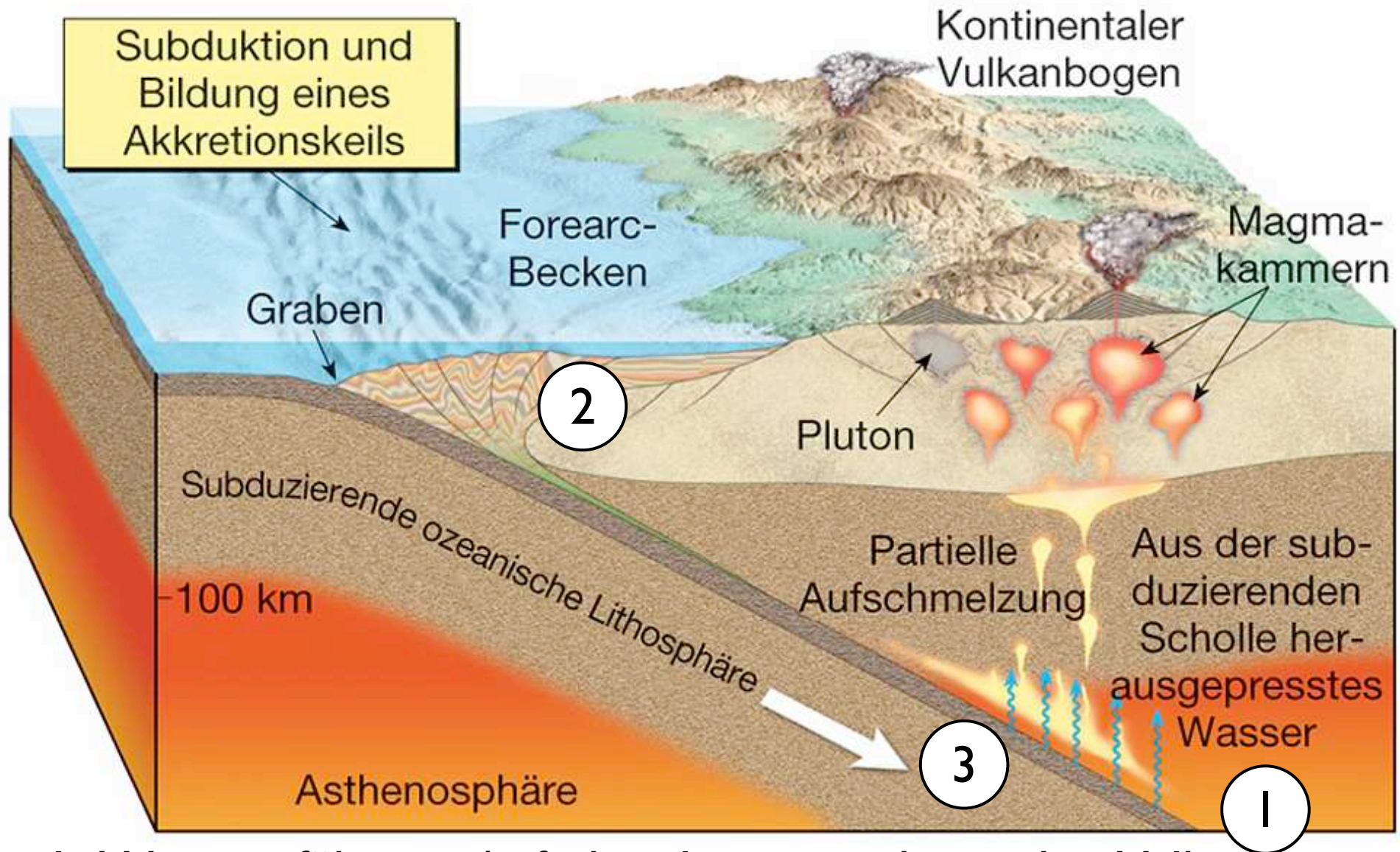


# Orogenese an Subduktionszone



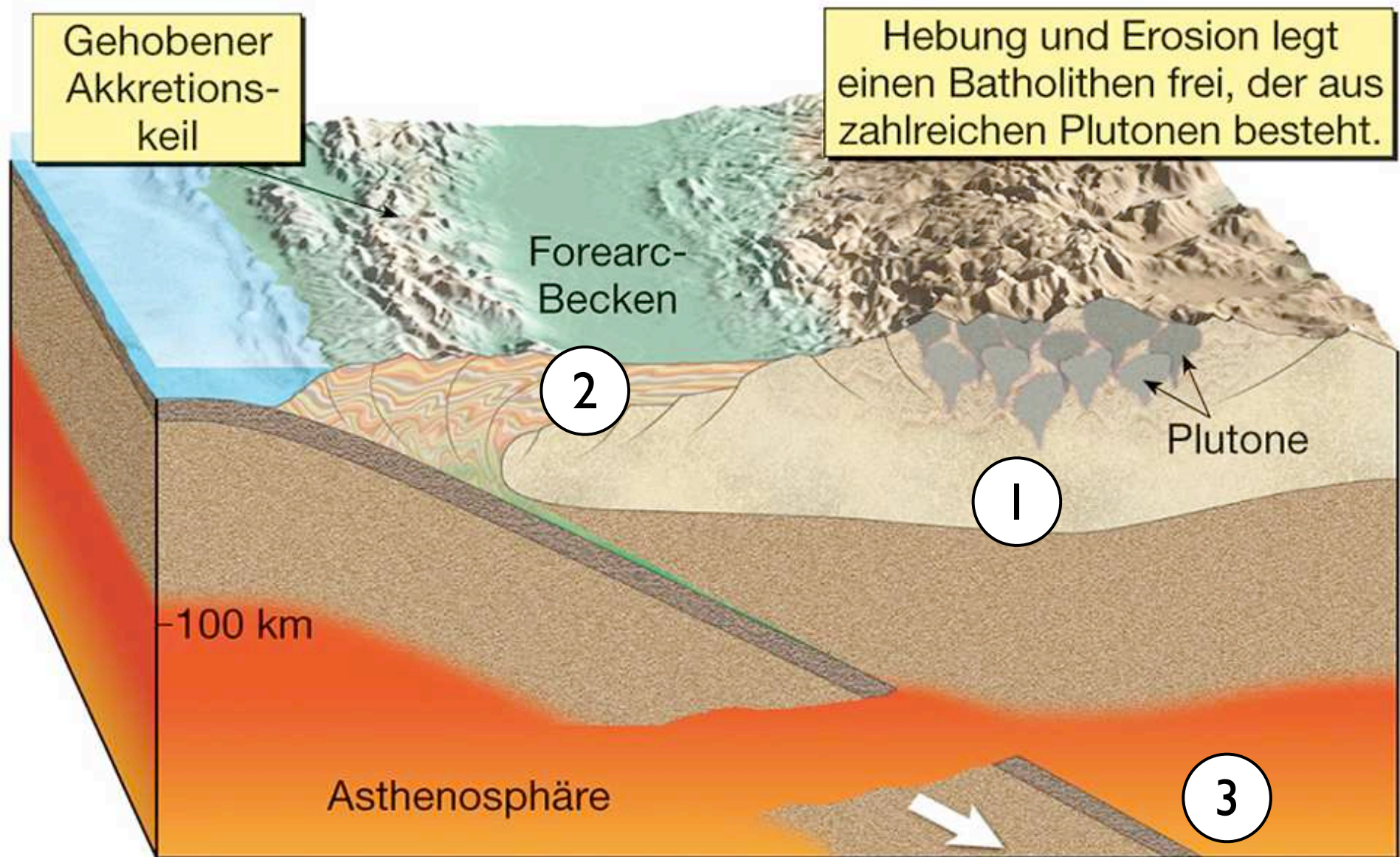
- 1 Konvergenz: Ozeanische Platte - Platte mit Kontinentalrand
- 2 Bildung einer mächtigen Sedimentplattform

# Orogenese an Subduktionszone



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

# Orogenese an Subduktionszone

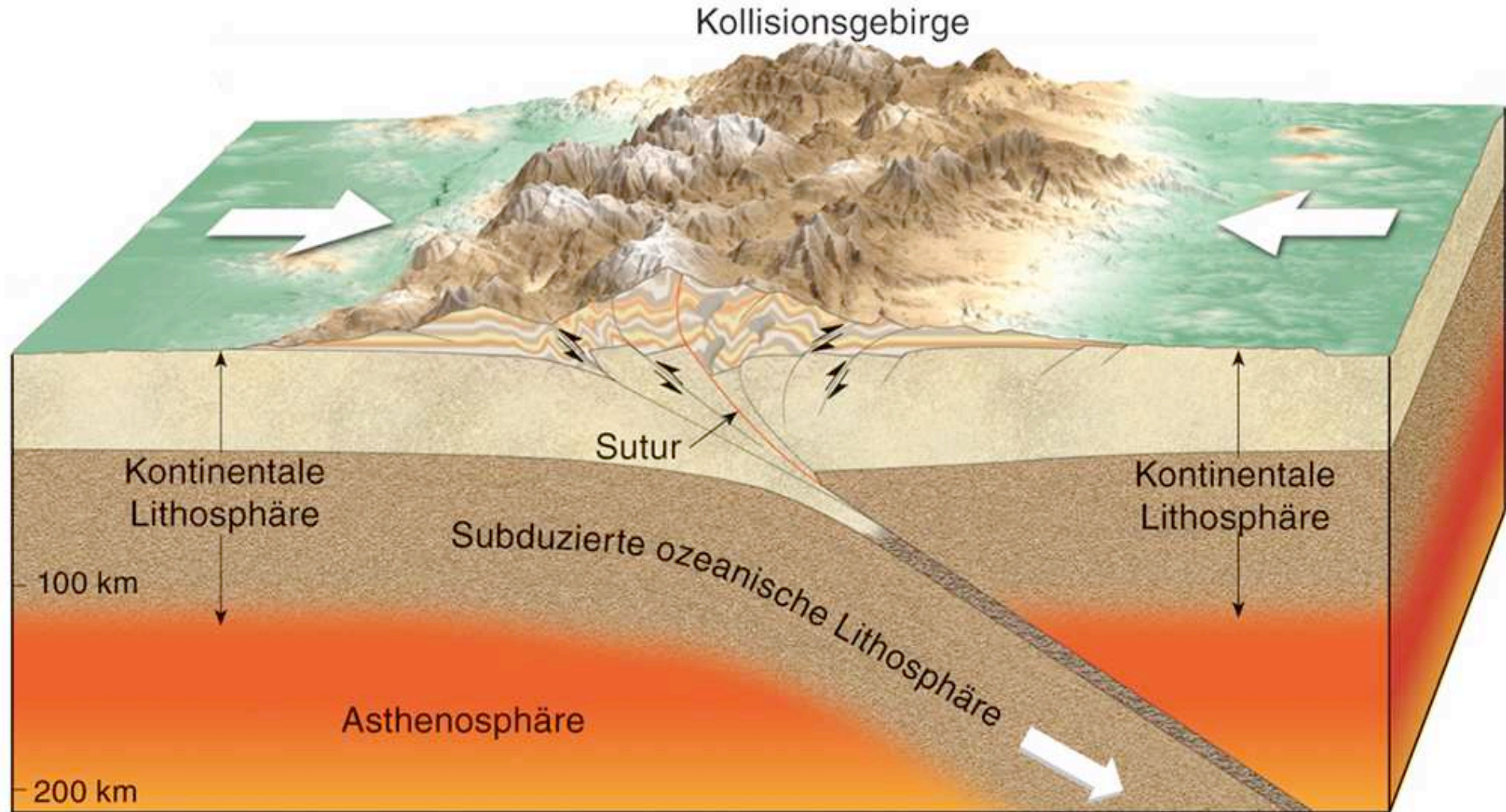


1 Plutone (Batholite) - Metamorphismus

2 Forearc Becken

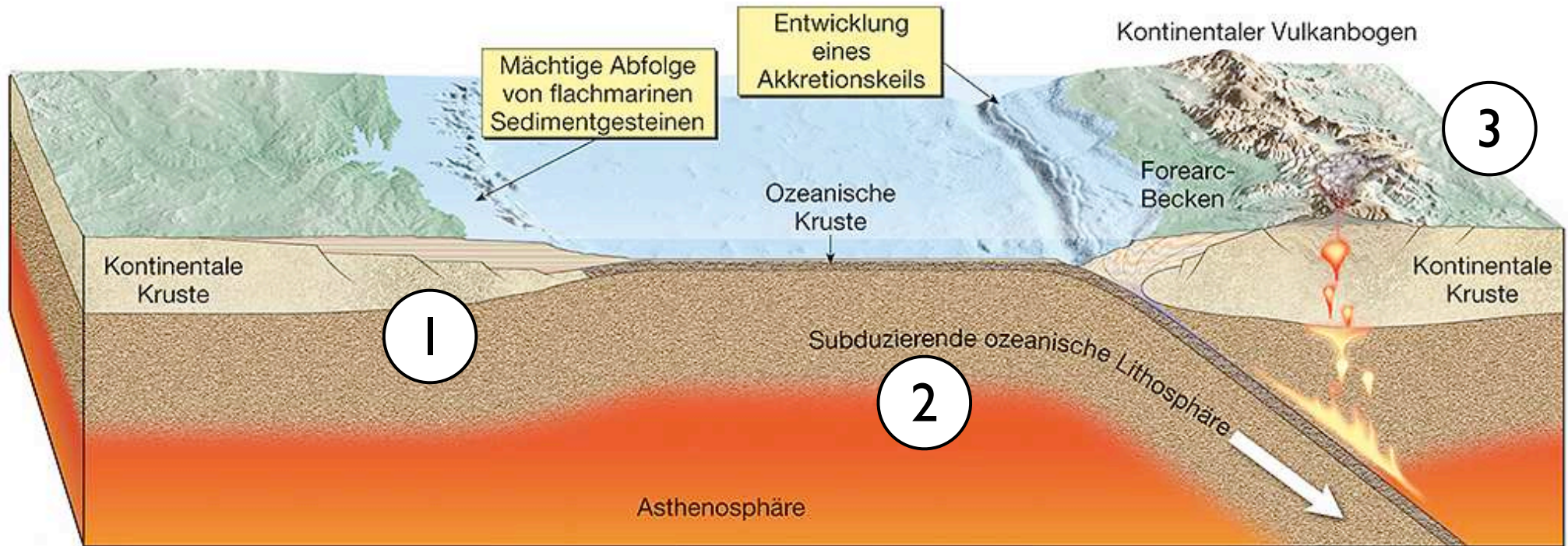
3 Slab break-off

# Kontinent - Kontinent



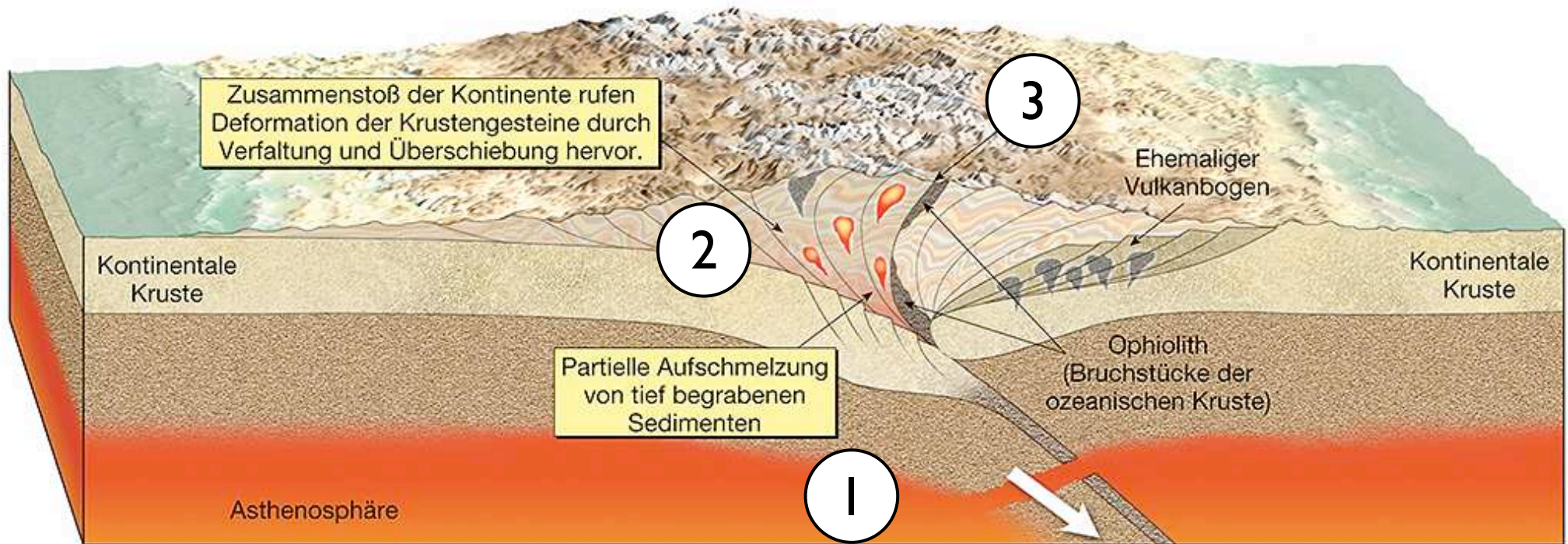
Fortgesetzte Subduktion → kontinentale Kollision  
dichtere Platte wird subduziert  
Kollisionsgebirge: Himalaya, Alpen, Appalachen

# Gebirgsbildung



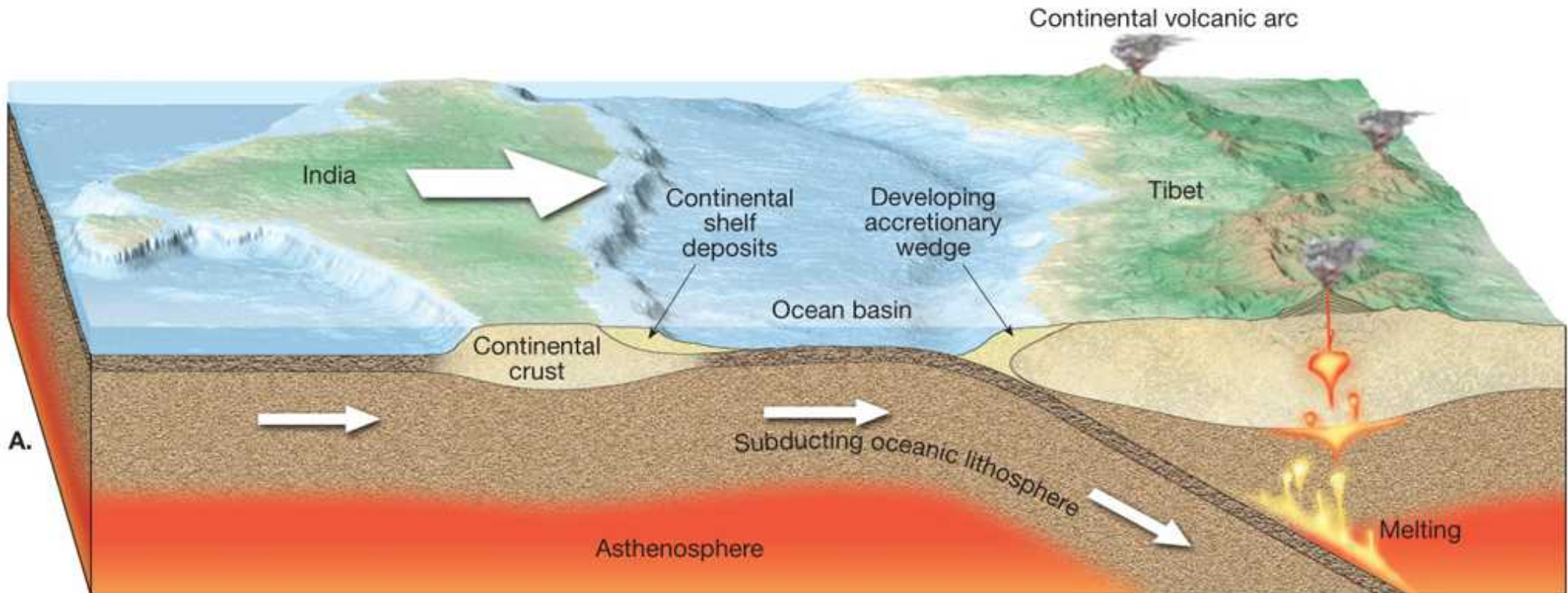
- 1 Öffnung eines Ozeans, Sedimente am passiven Kontinentalrand
- 2 Konvergenz: Schliessung des Ozeans
- 3 Kontinentaler Vulkanbogen

# Kontinentale Kollision



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

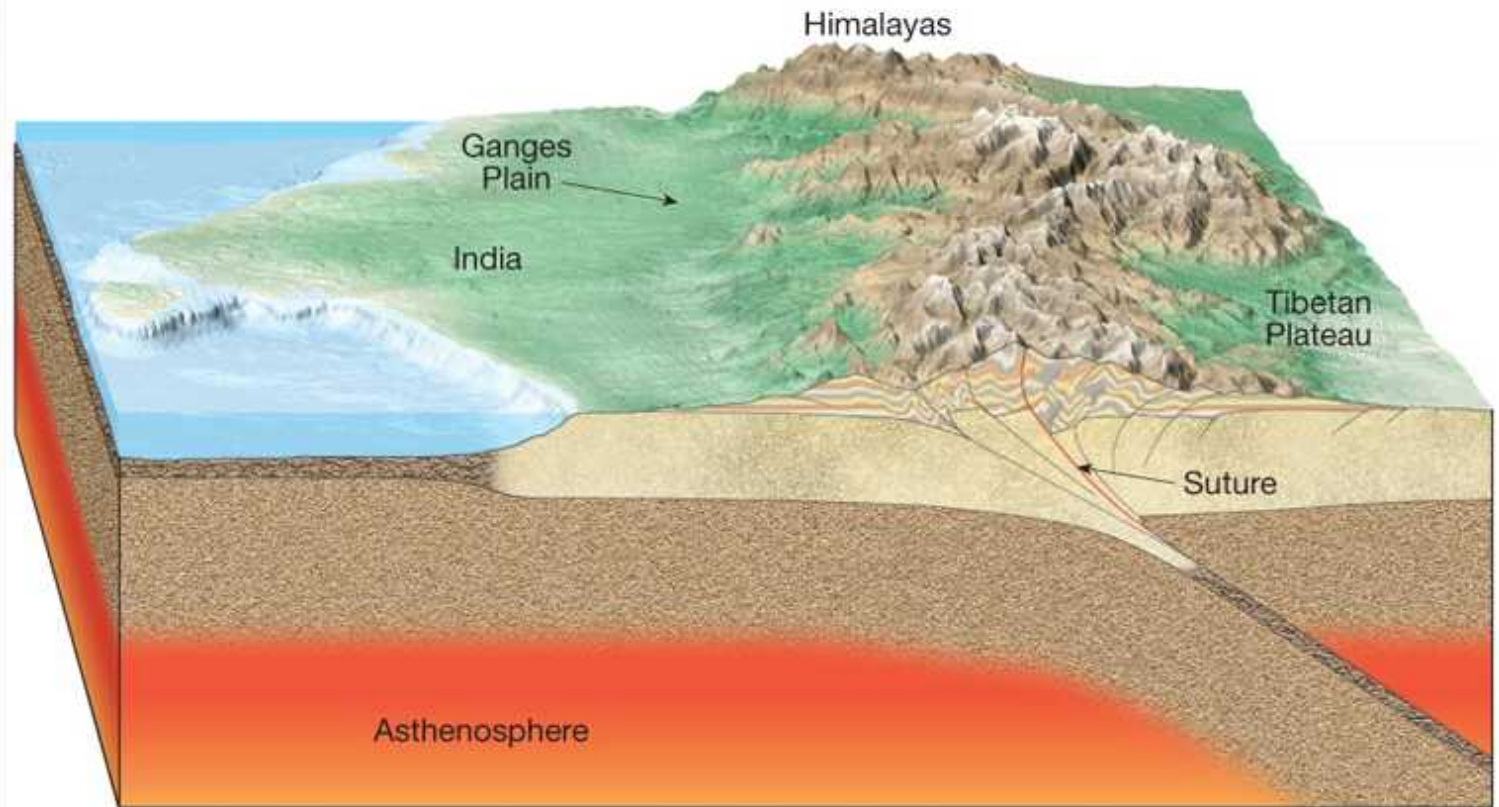
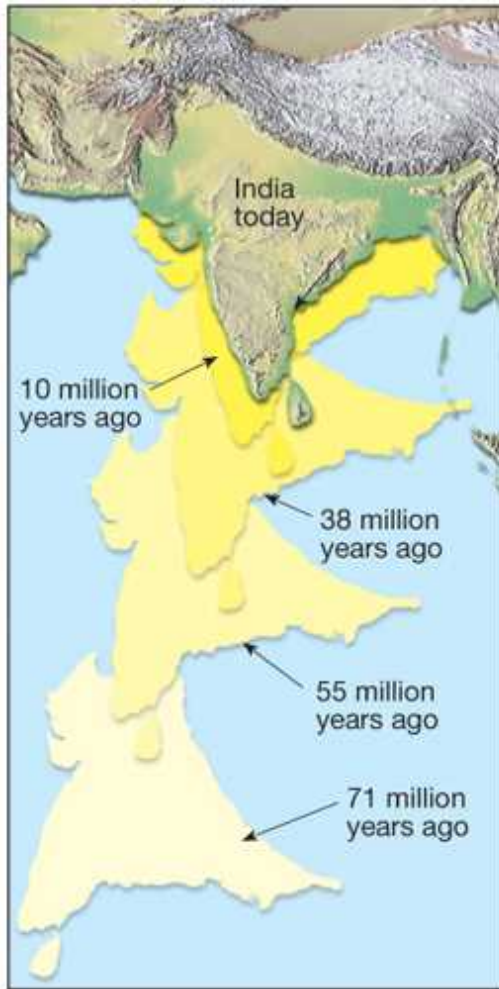
# Beispiel: Himalaya



Kollision vor 45 Ma

Kollision Indische - Eurasische Platte

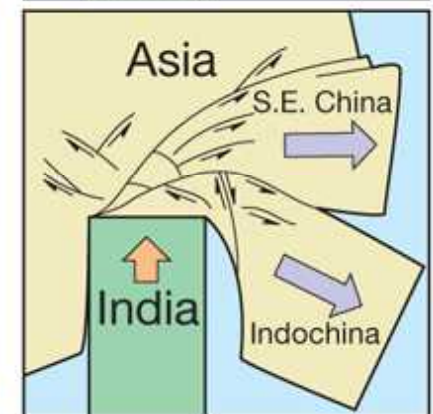
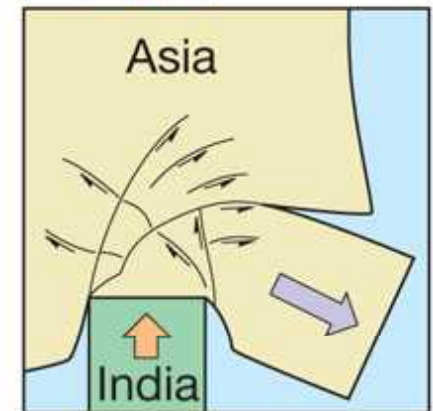
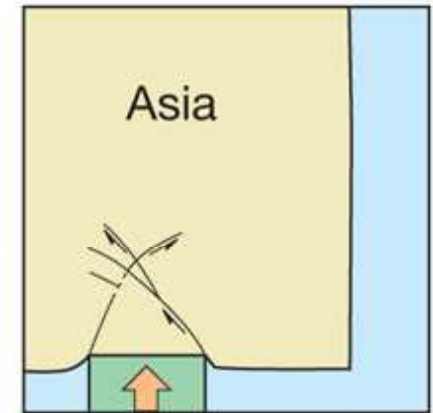
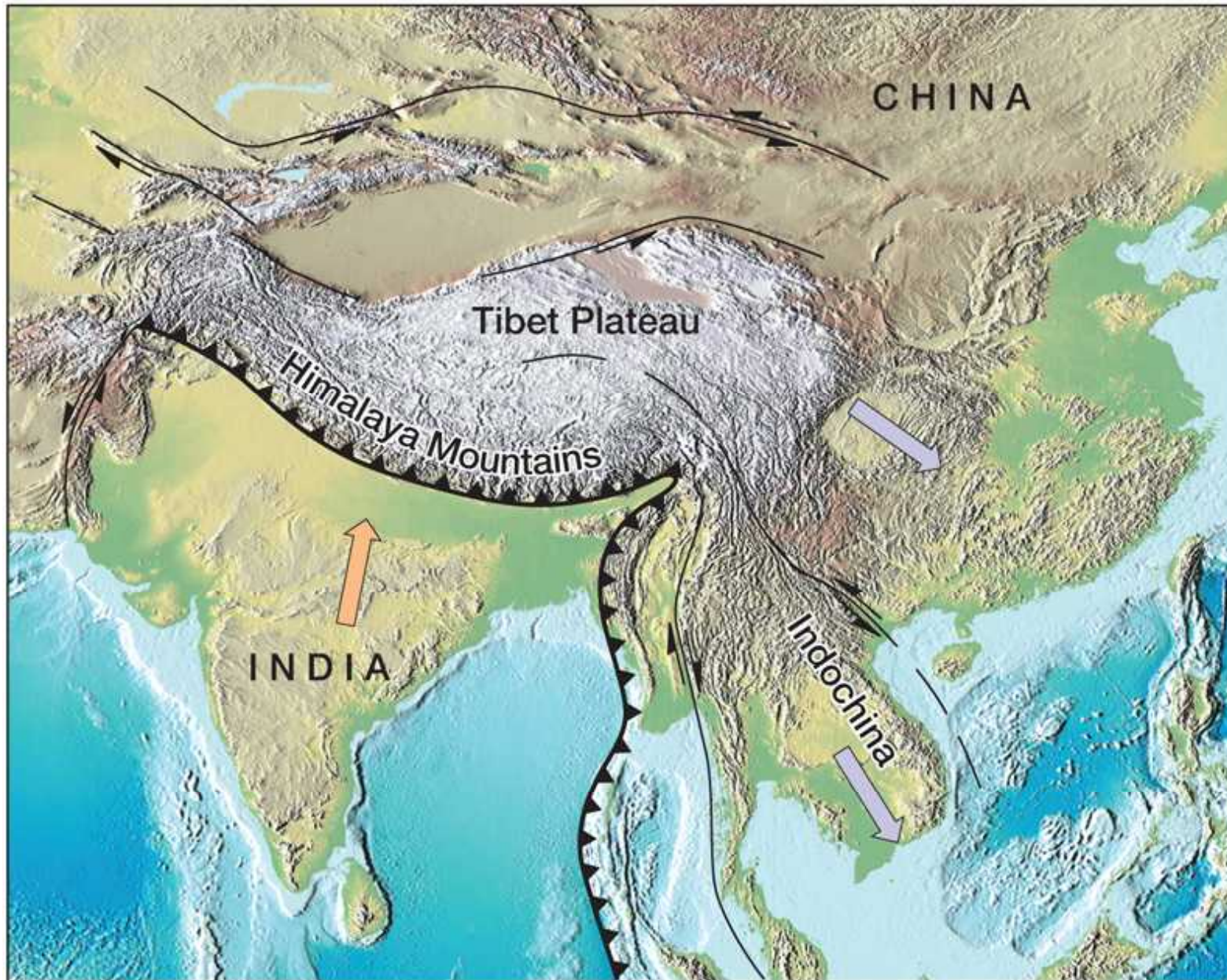
# Beispiel: Himalaya



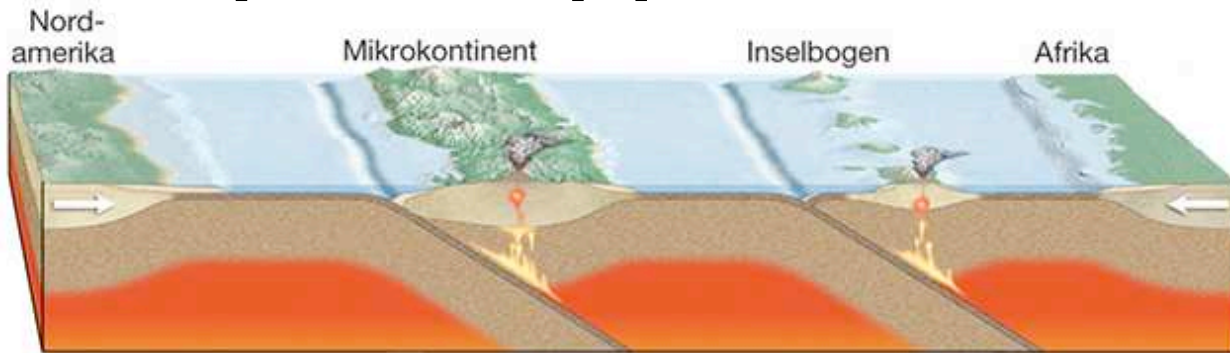
C.



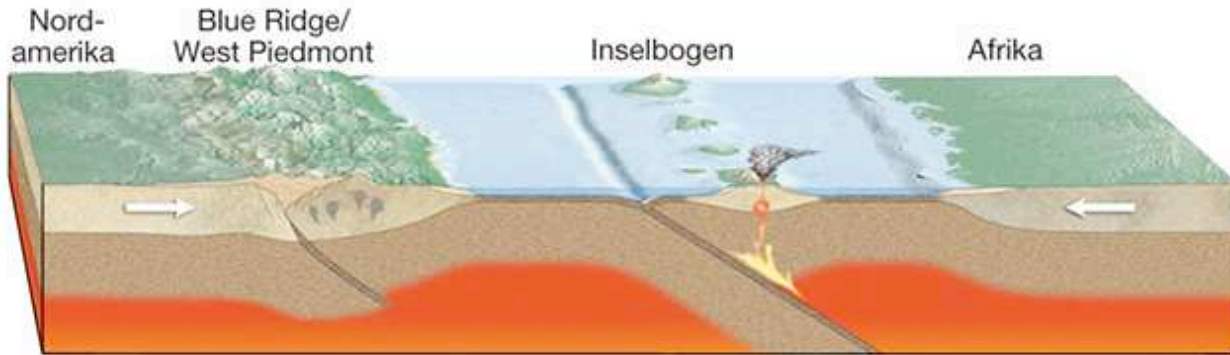
# Beispiel: Himalaya



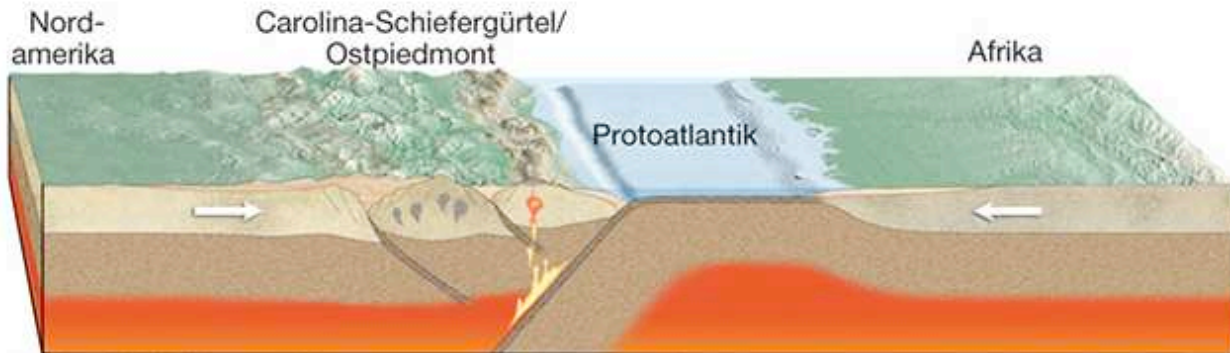
# Beispiel: Appalachen



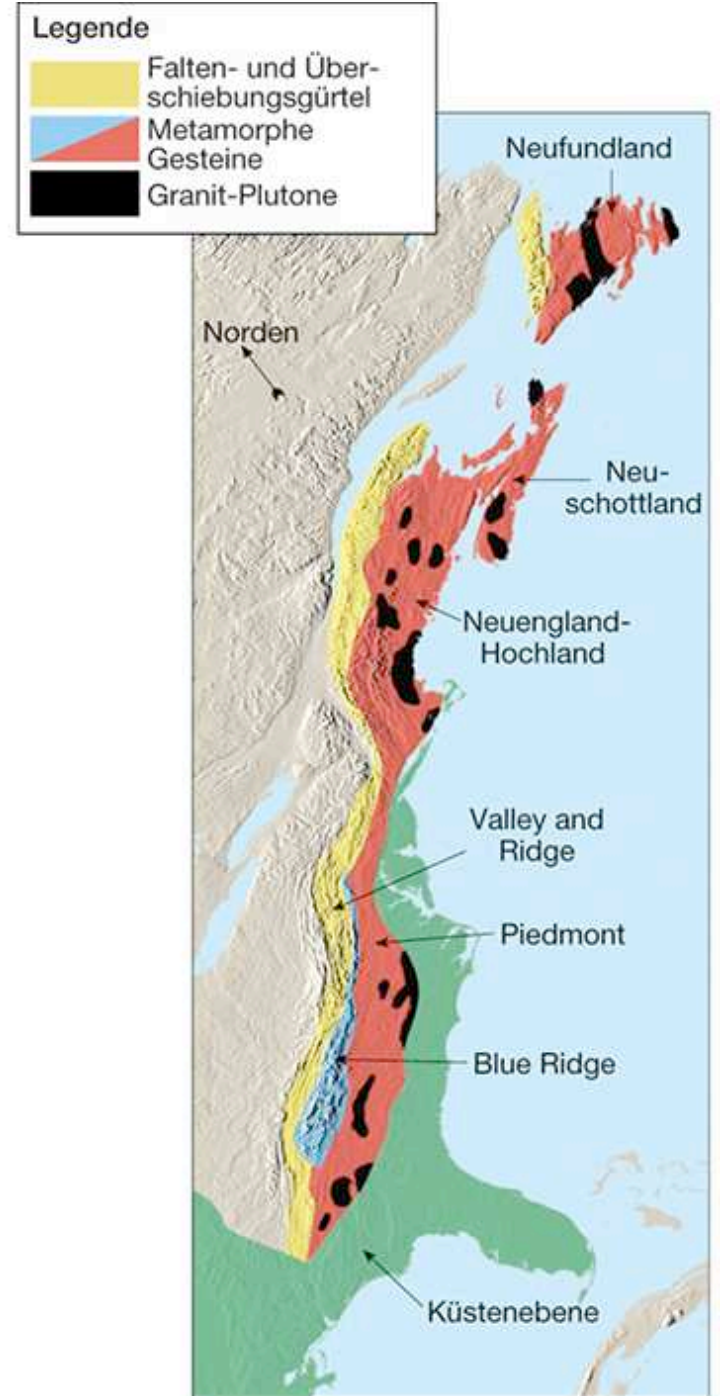
600 Ma



450 - 500 Ma

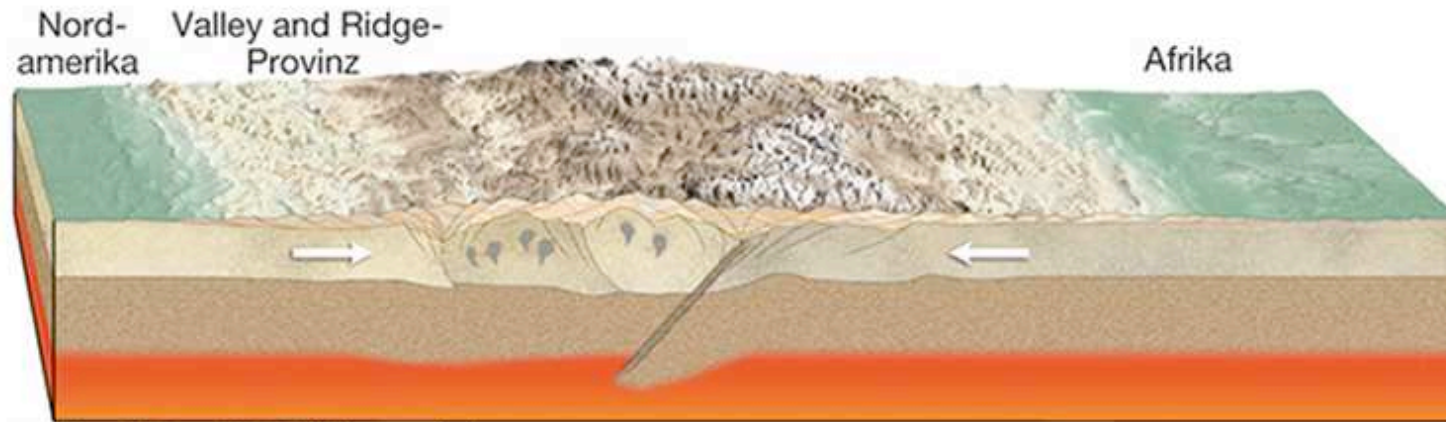


400 Ma

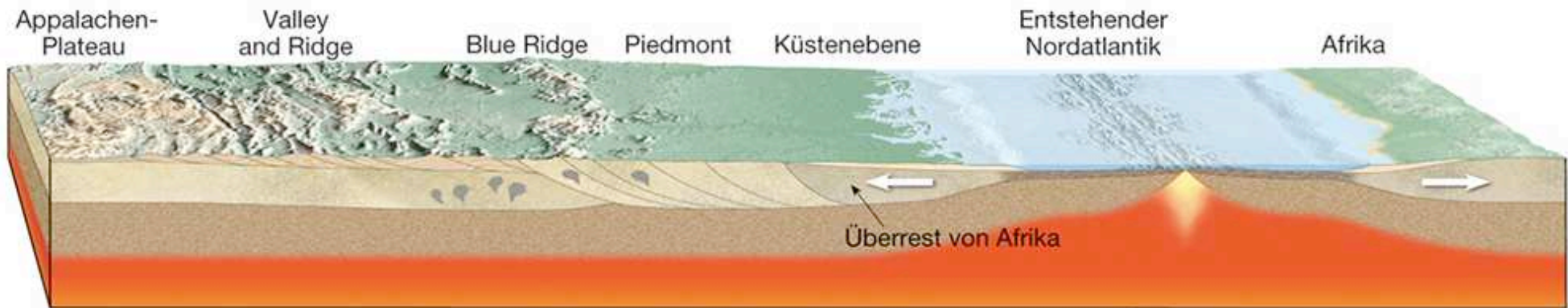


Hauptstrukturen der Appalachen

# Beispiel: Appalachen

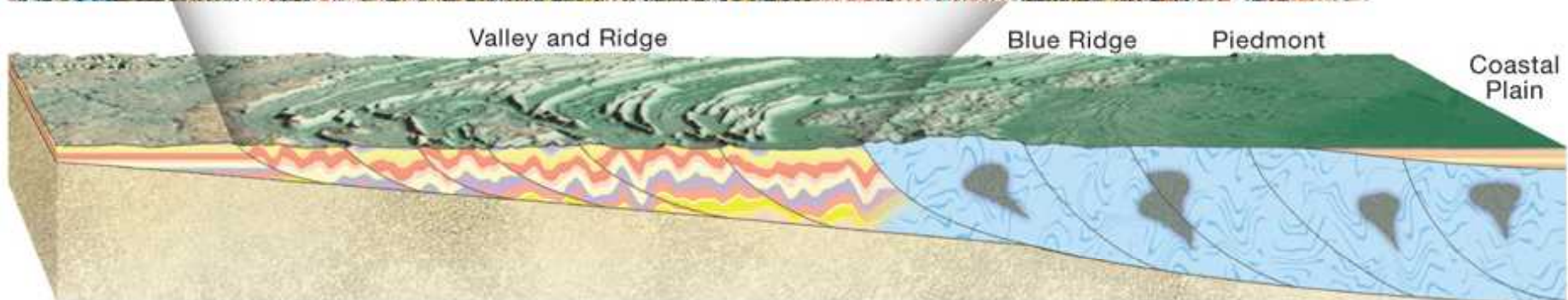
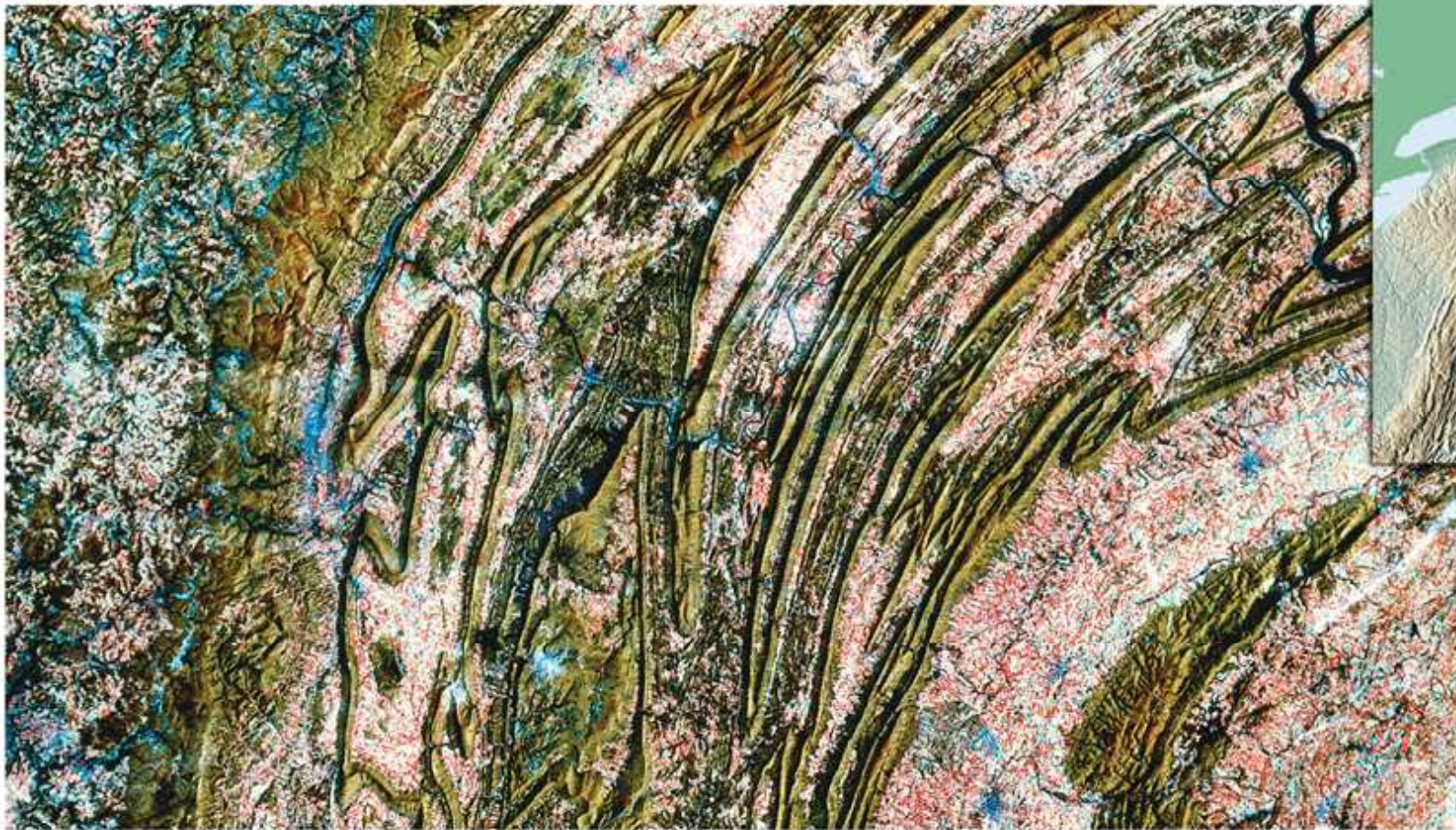


250 - 300 Ma

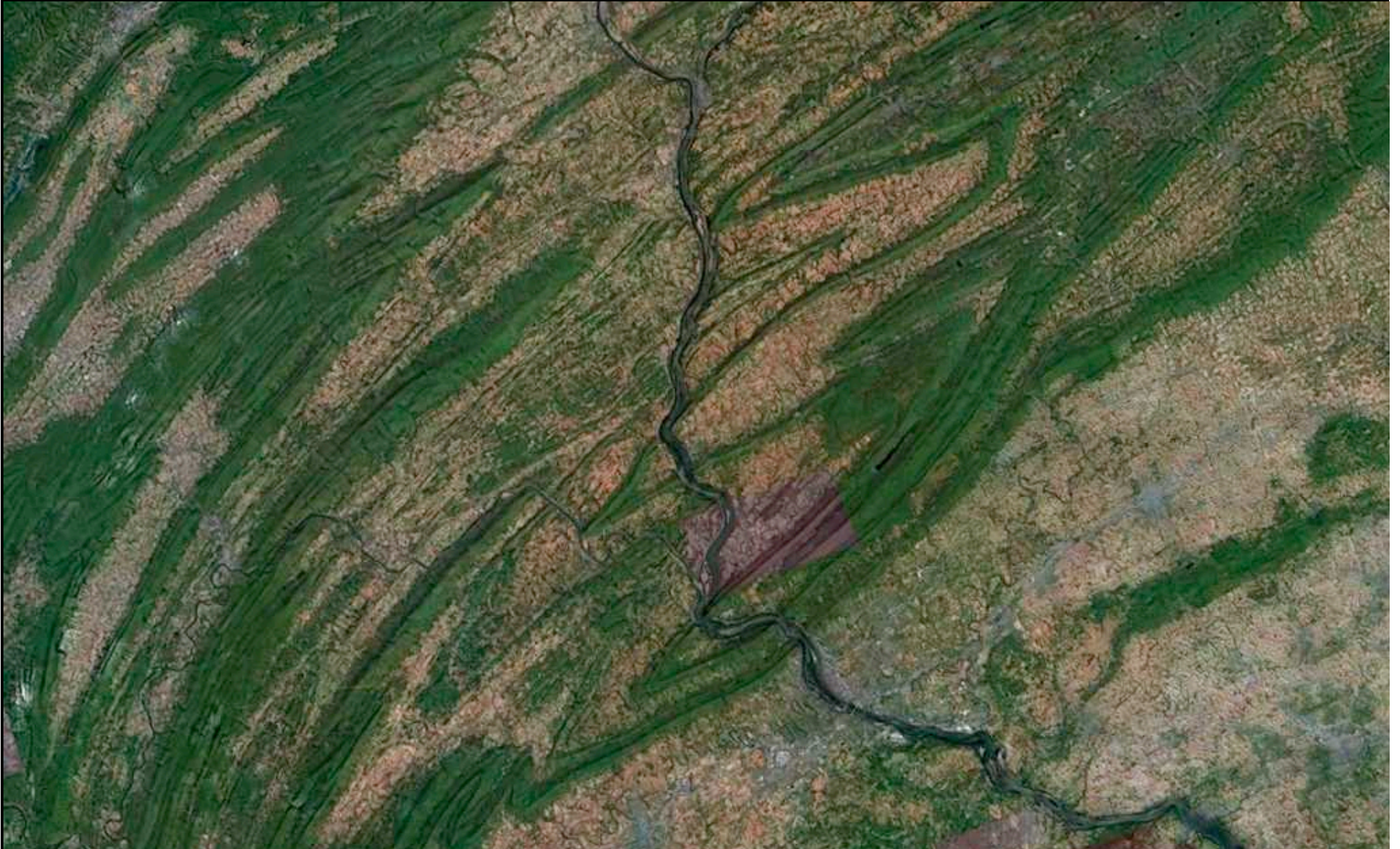


150 Ma

# Beispiel: Appalachen



# Phanerozoikum: Appalachen



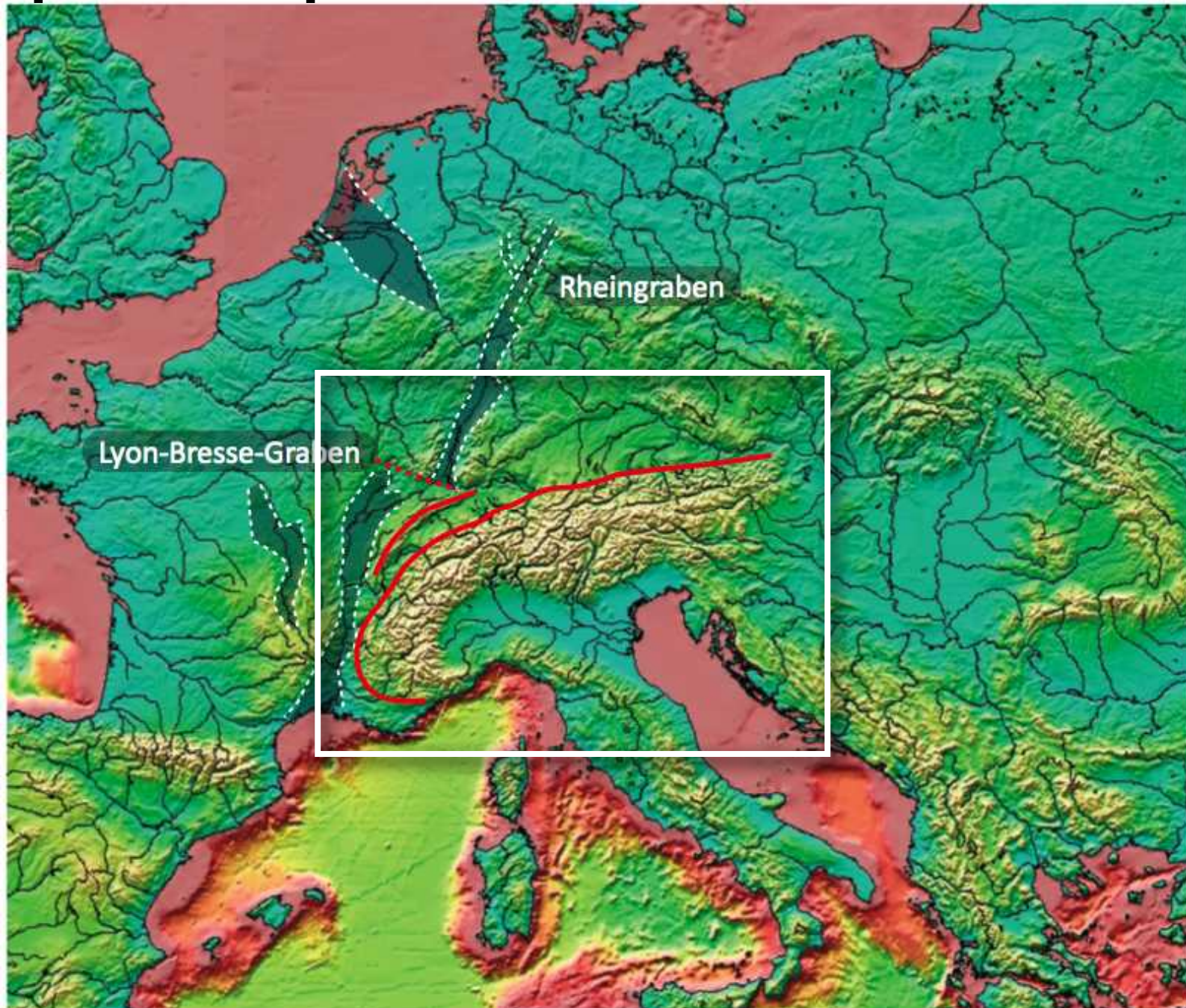
Late Paleozoic Alleghenian orogeny

# Phanerozoikum: Appalachen

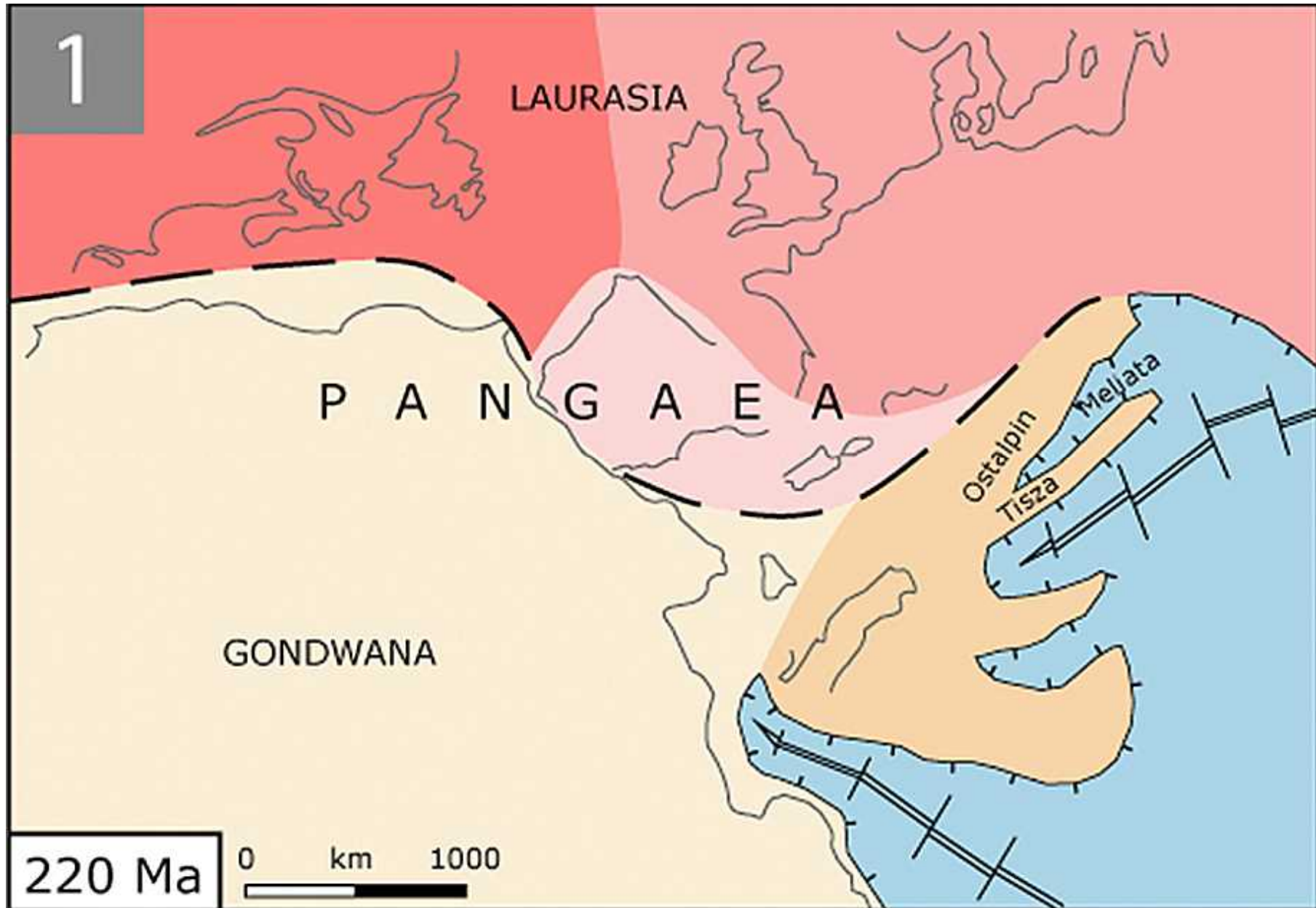


Late Paleozoic Alleghenian orogeny

# Beispiel: Alpen



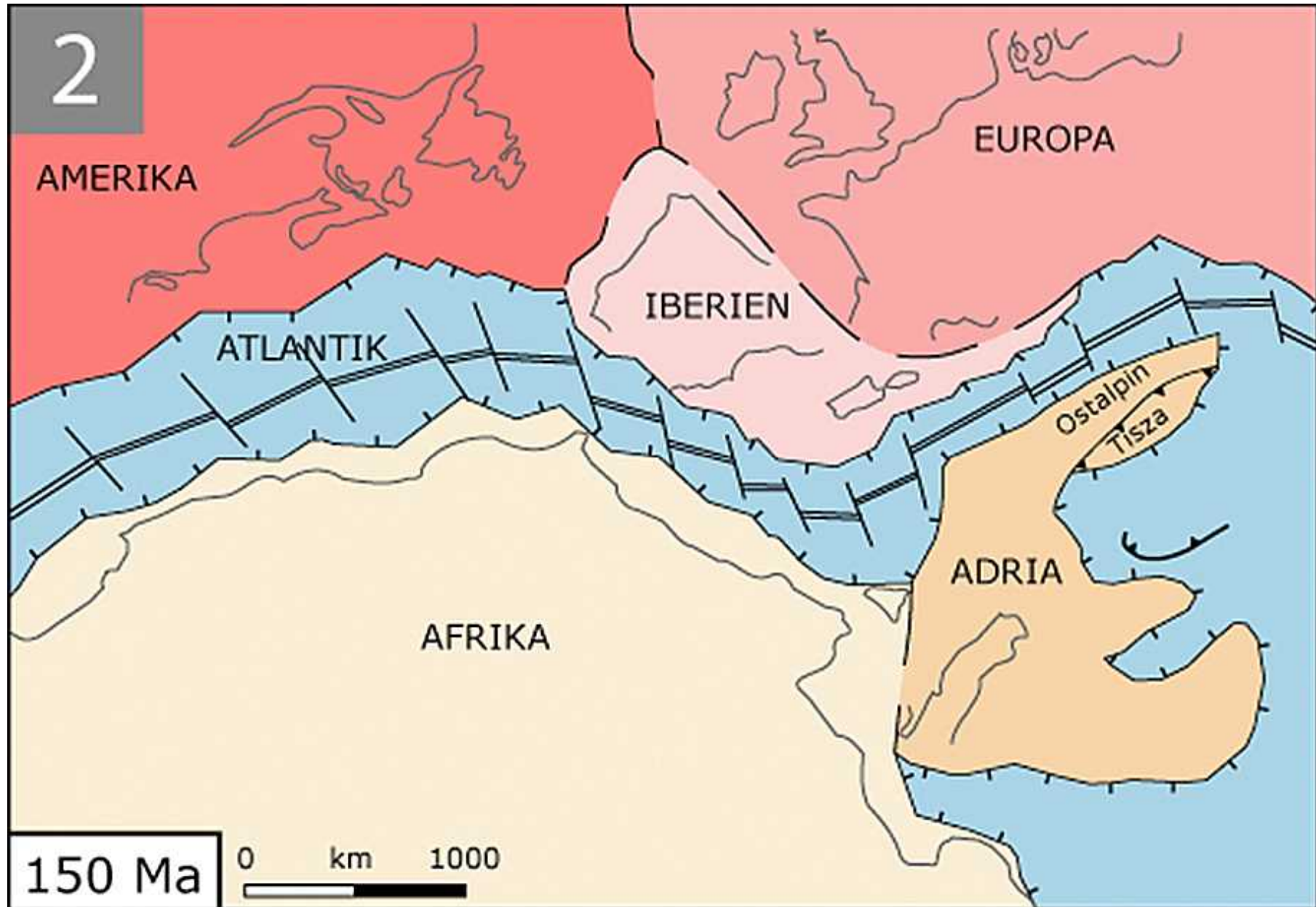
# Phase I: Neuer Raum wird geschaffen ("Rifting Phase")



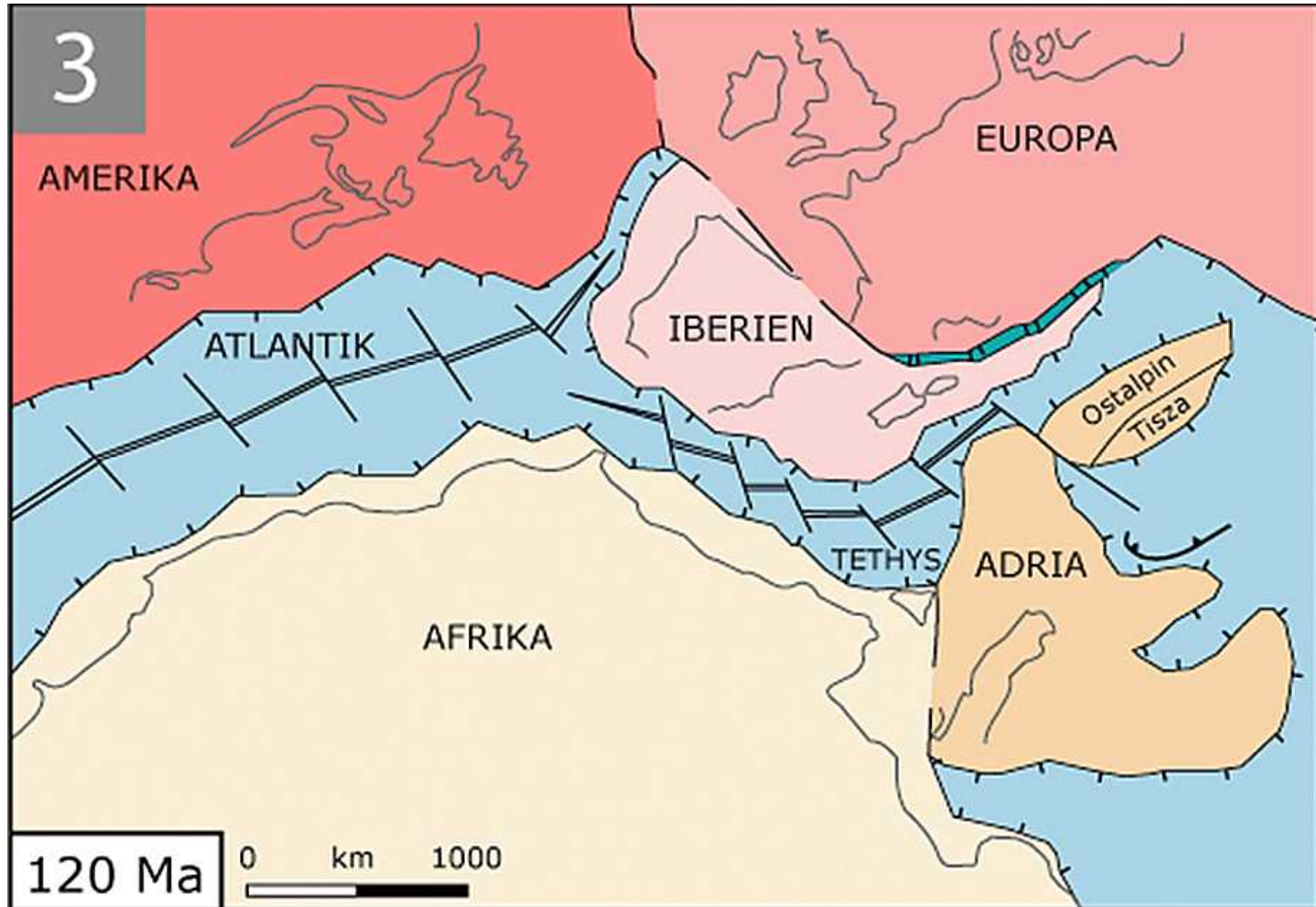


Phase 2:

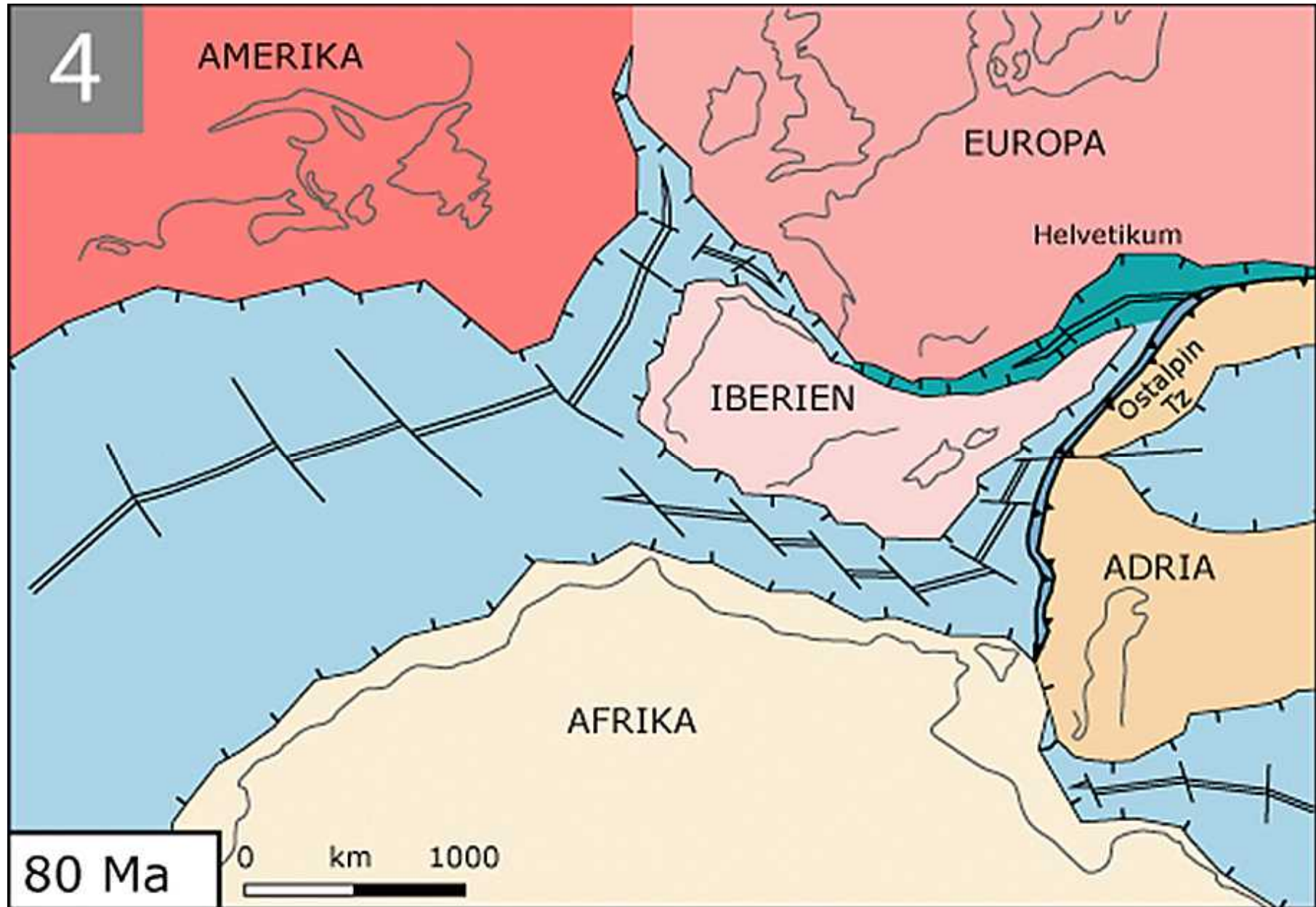
Neue ozean. Kruste wird gebildet ("Drifting Phase")



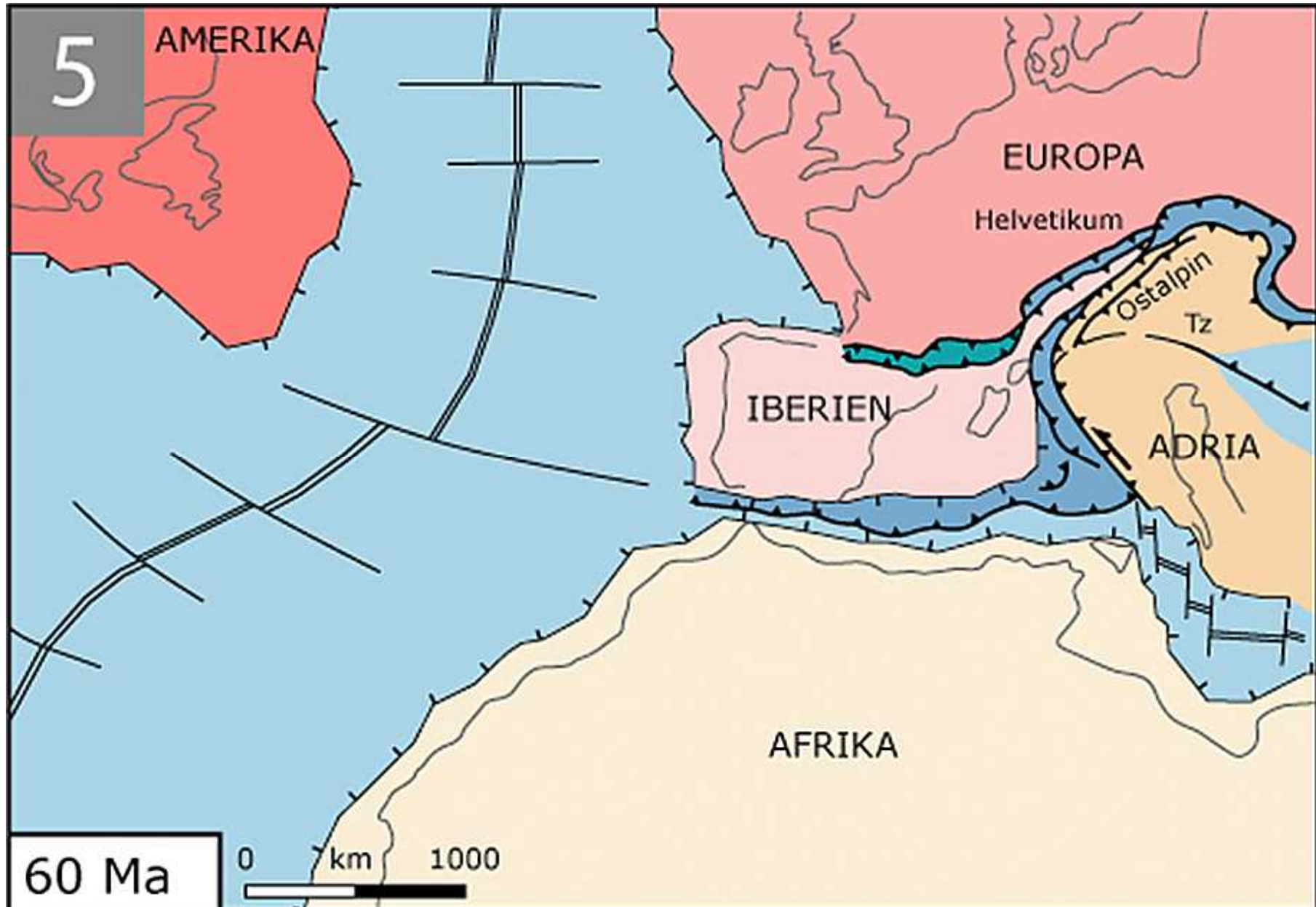
# Phase 3: Ozeanische Kruste und Transform-Brüche



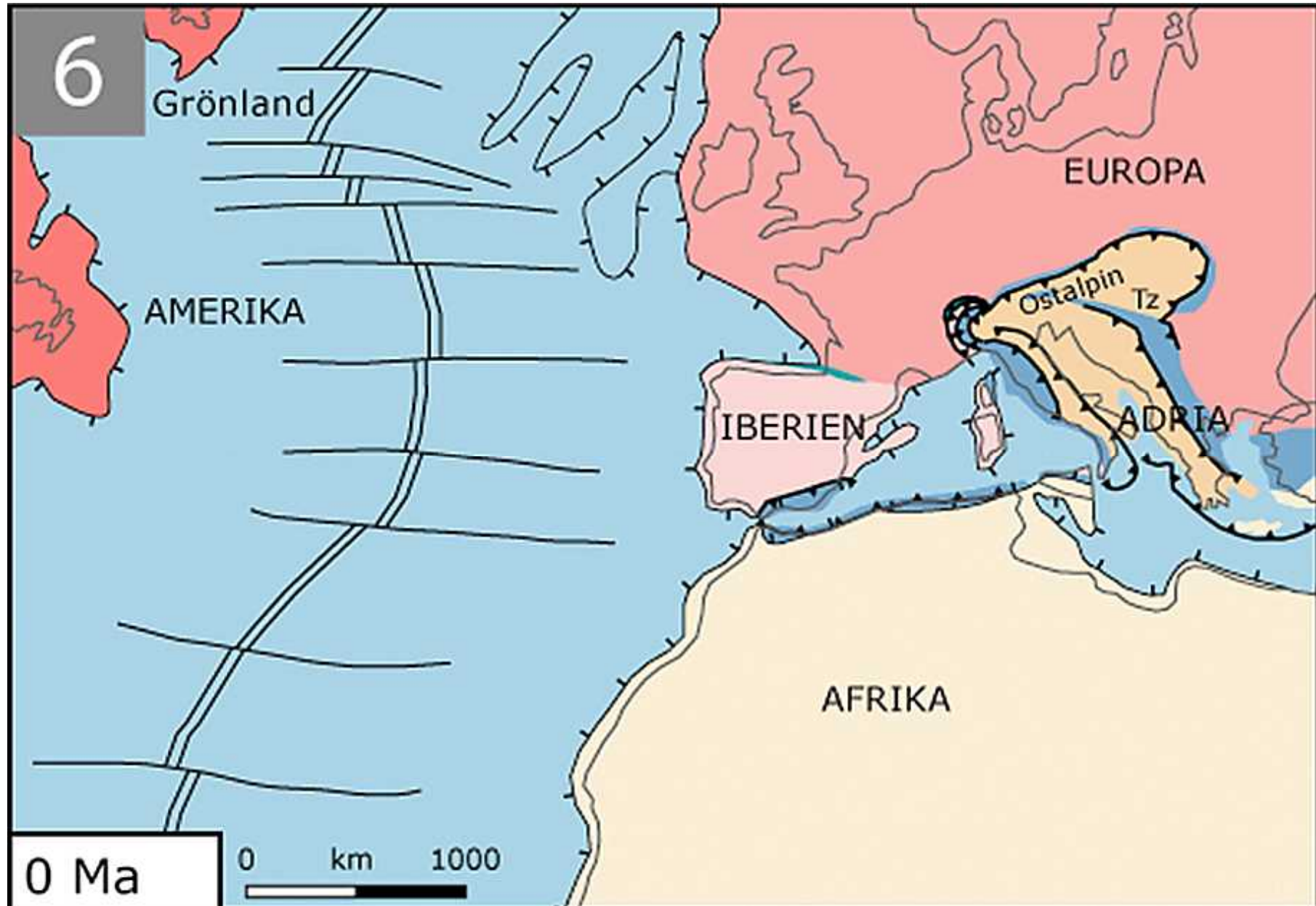
# Phase 4: Subduktion



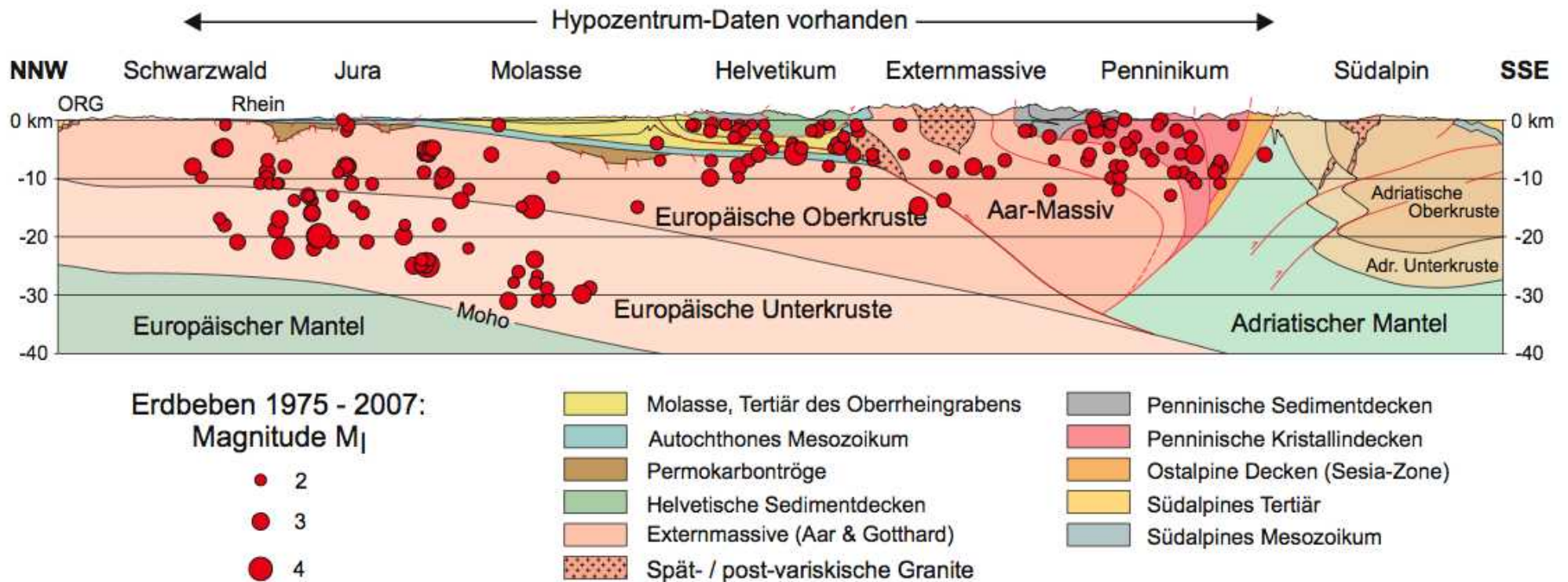
# Phase 5: Kollision der Kontinente

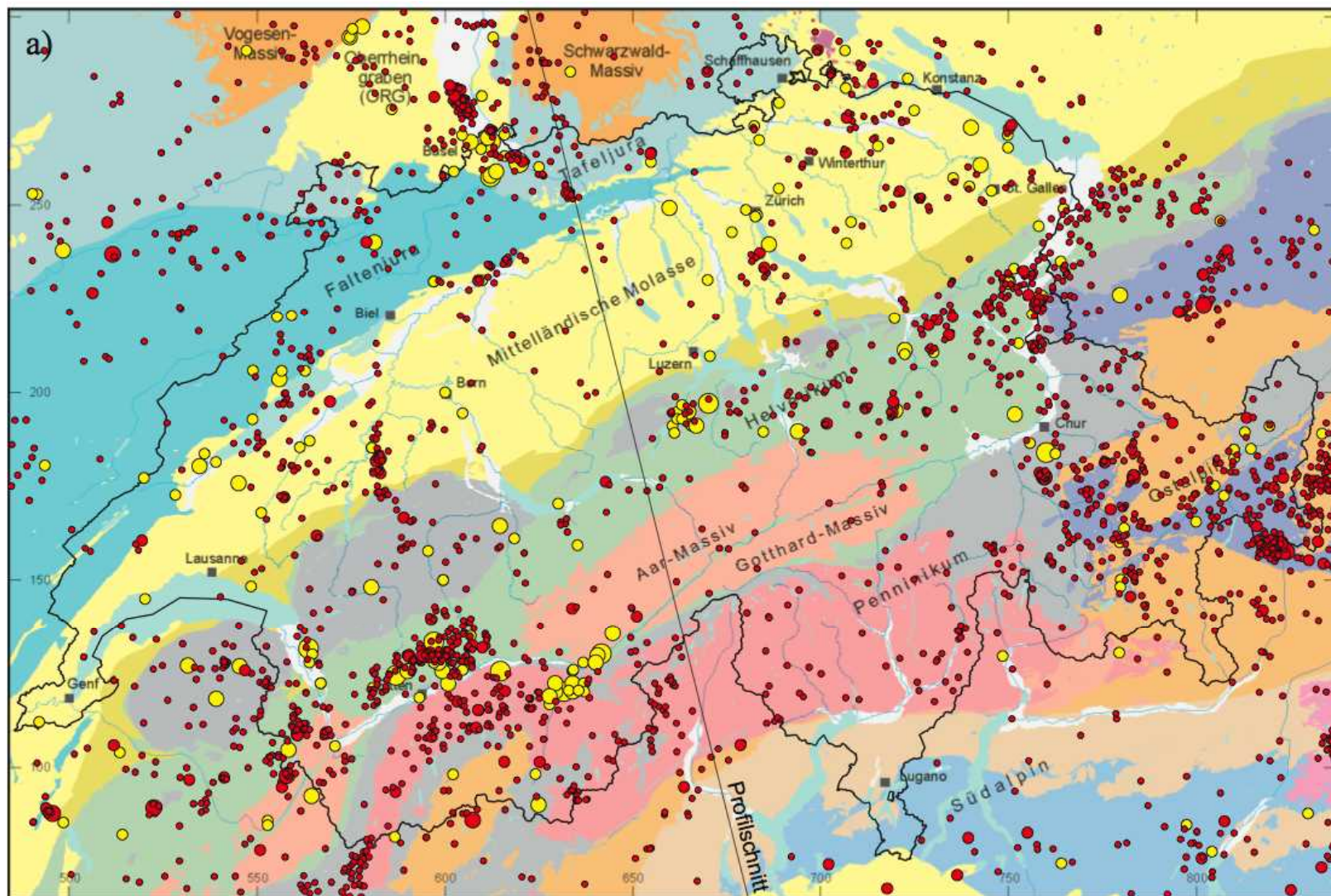


# Phase 6: Die Alpen heute



# Seismische Aktivität in den Alpen





### Erdbebenkatalog ECOS

ca. 1000 - 1974:  
Makroseismisch  
Magnitude  $M_W$

- 4 - 5
- 5 - 6
- 6 - 7

1975 - 2007:  
Instrumentell  
Magnitude  $M_W$

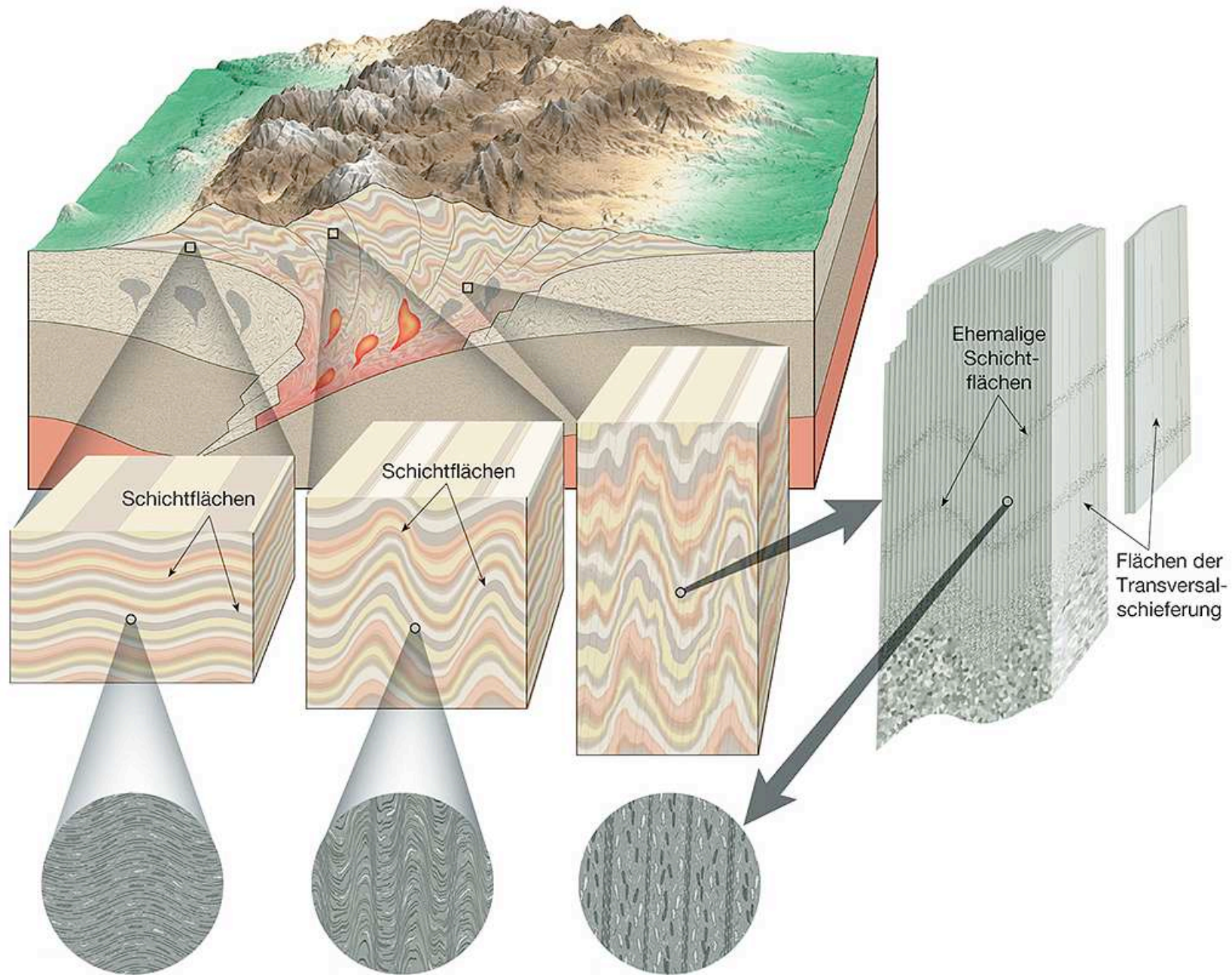
- 1.8 - 3
- 3 - 4
- 4 - 5

### 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

