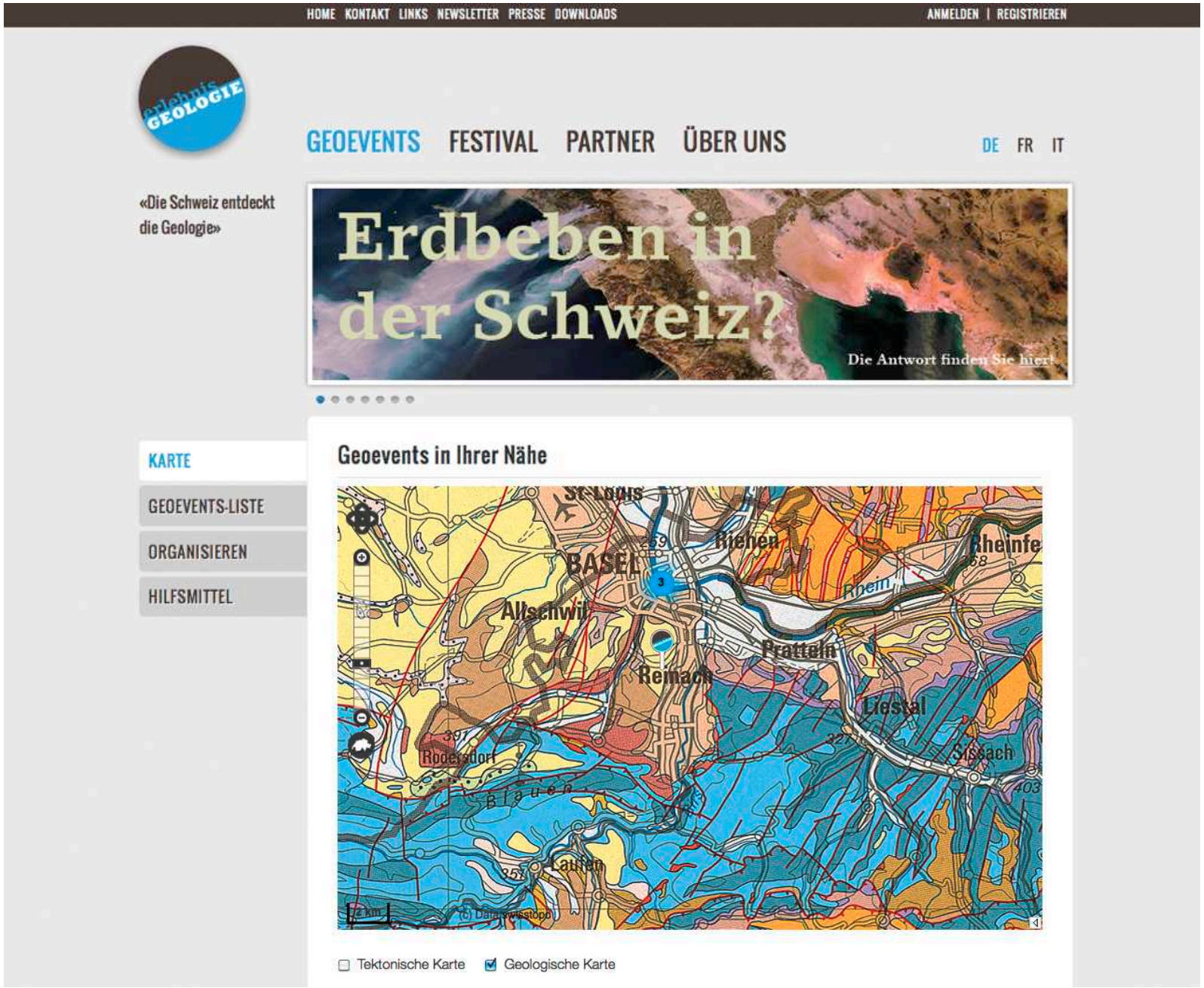
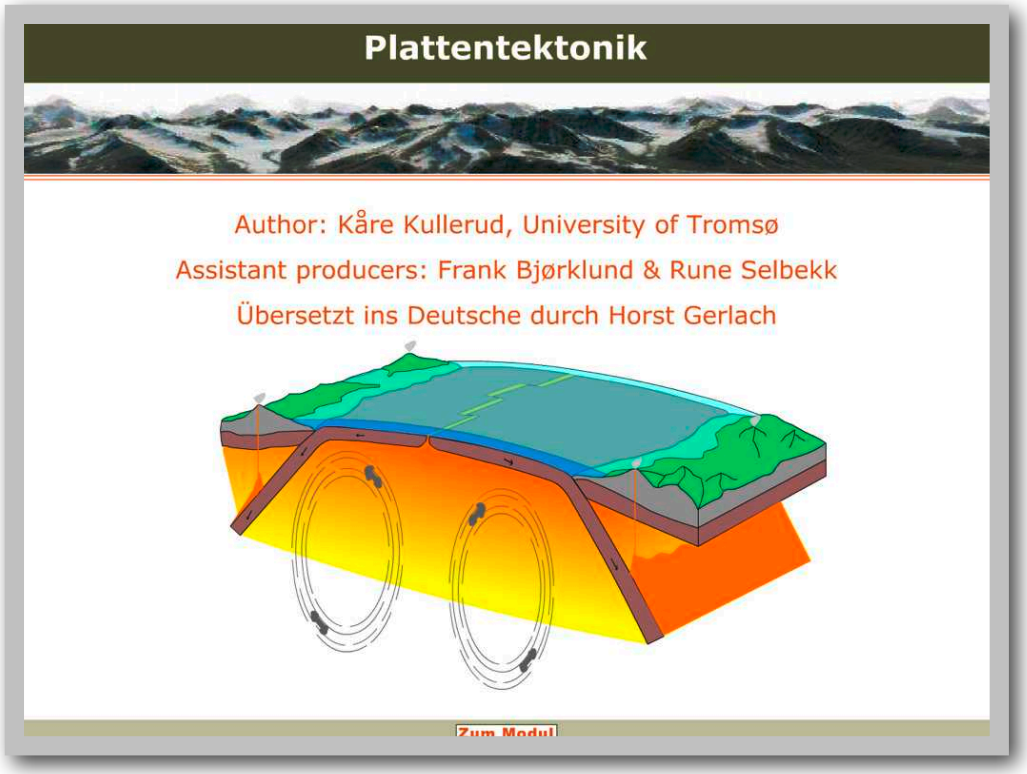
Tatort Plattengrenze
2
Der Schauplatz des Geschehens

Erlebnis Geologie



Web Module zum Einstieg



auf deutsch erhältlich:

- Gesteine (800 KB)
- Klastische Sedimente (1 MB)
- Klastische Sedimentite (1 MB)
- Biologische und chemische Sedimentite(1.7 MB)
- Geologie und Zeit - Relative Altersbestimmung (1.4 MB)
- Erdbeben (1 MB)
- Plattentektonik (1.3 MB)
- Gebirgsbildung (700 KB)

http://ansatte.uit.no/kare.kullerud/webgeology/
http://ansatte.uit.no/webgeology/webgeology_files/deutsch/plattentektonik.html

Plattentektonik revisited

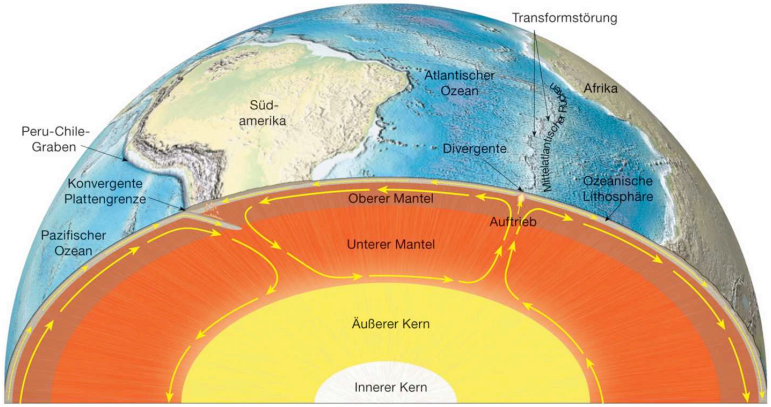
Was wir schon wissen ...

... und was wir noch nicht so gut wissen:

Subduktion

Platte taucht in den Mantel zurück

Erdoberfläche wird vernichtet



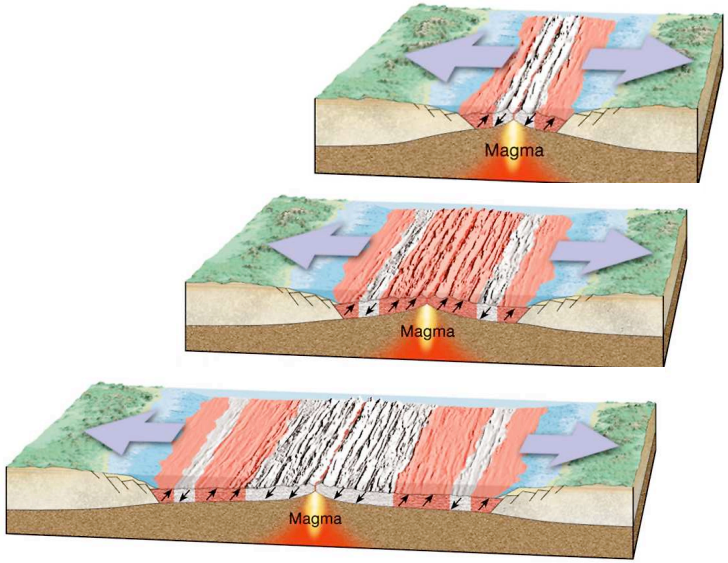
Seafloor Spreading

Mantelmaterial wird an die Platten angefügt

Neue Erdoberfläche entsteht

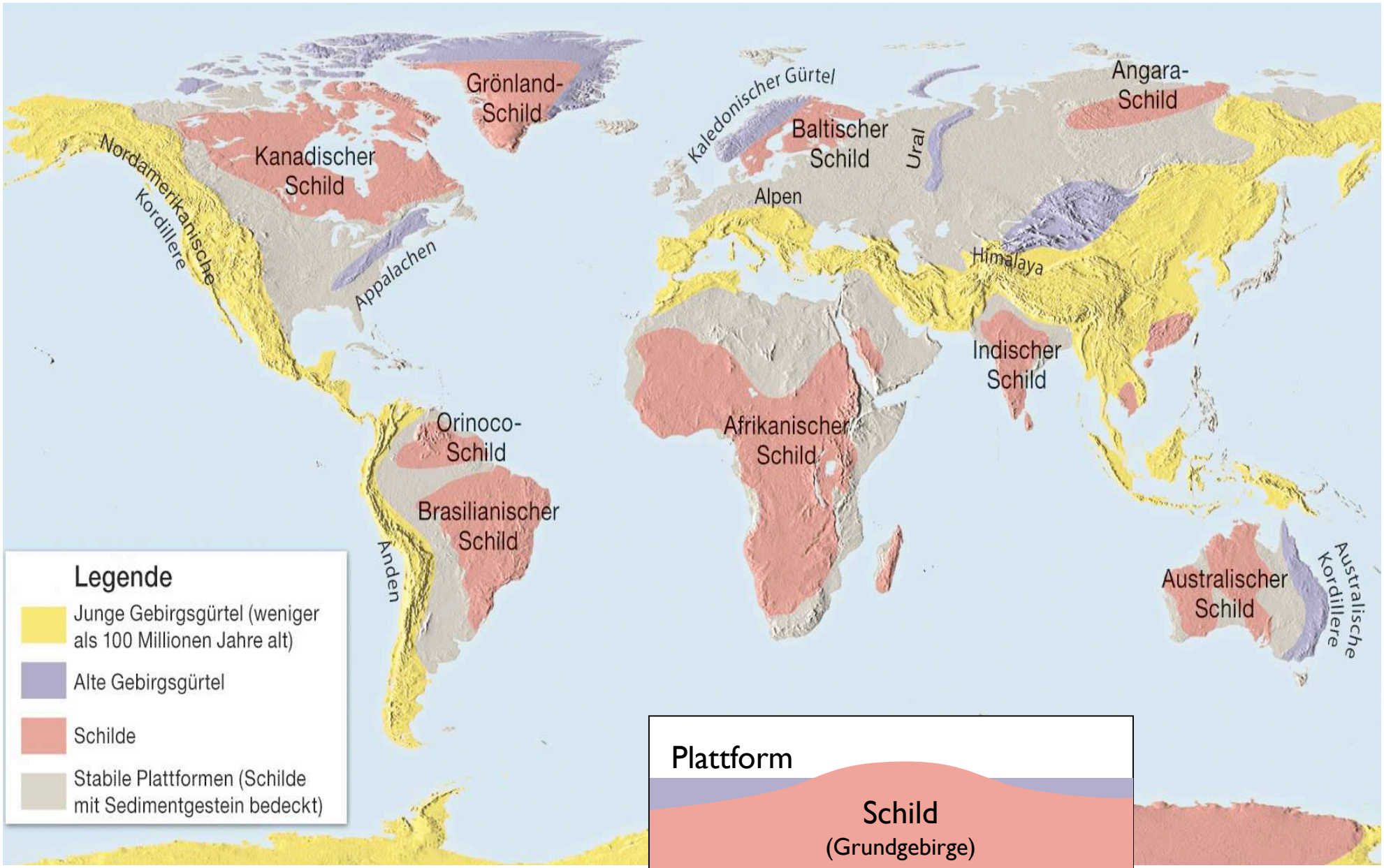
Schalenbau
Lithosphärenplatten
Re-Cycling
Mantelkonvektion

Plattengrenzen:
- Seafloor Spreading
- Subduktionszonen
- Transformstörungen



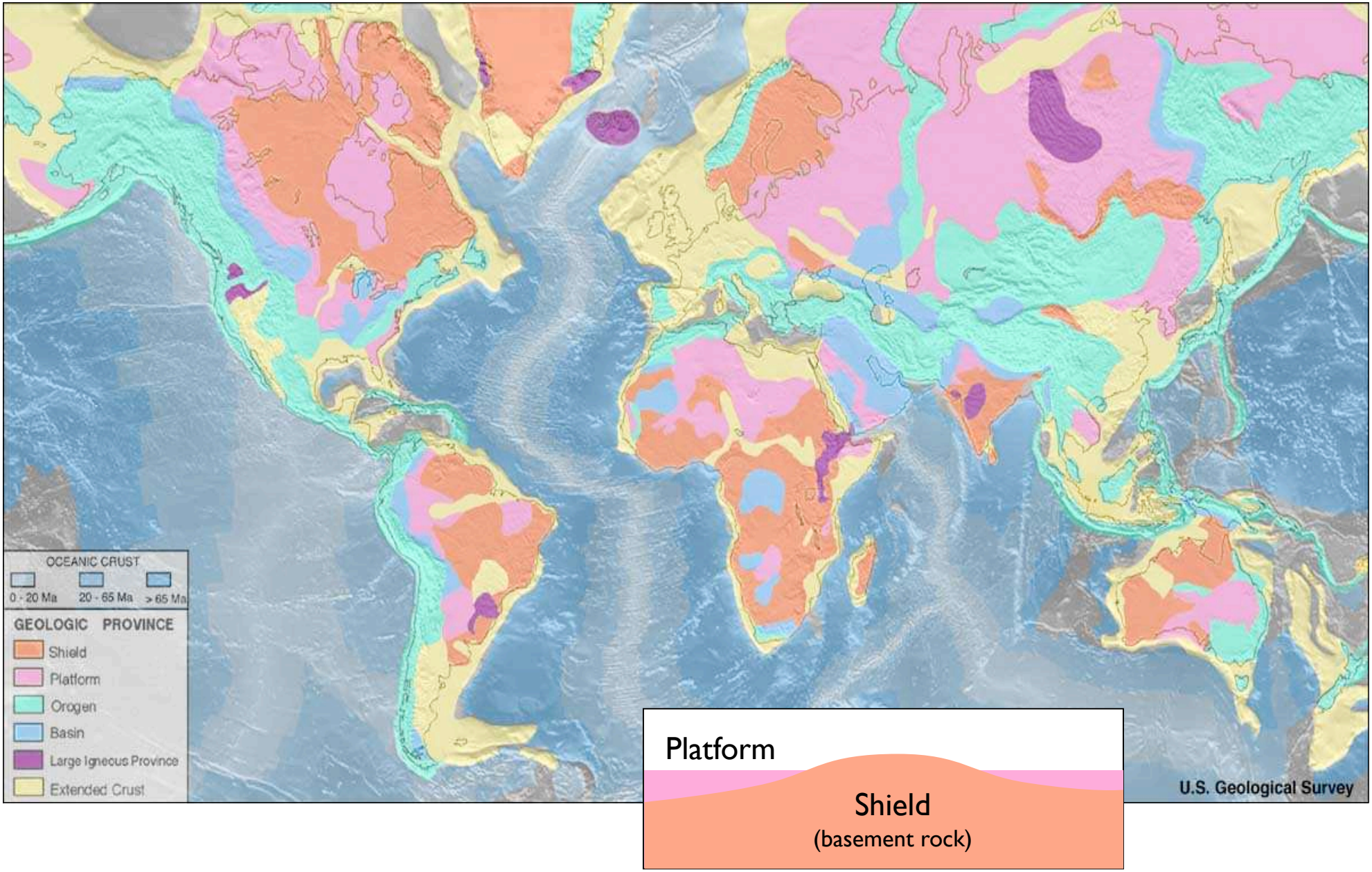
... die 1. Plattengrenze: Seafloor Spreading

Bekannte Kontinente - unbekannte Ozeane



Tarbuck & Lutgens, Allgemeine Geologie, 2009

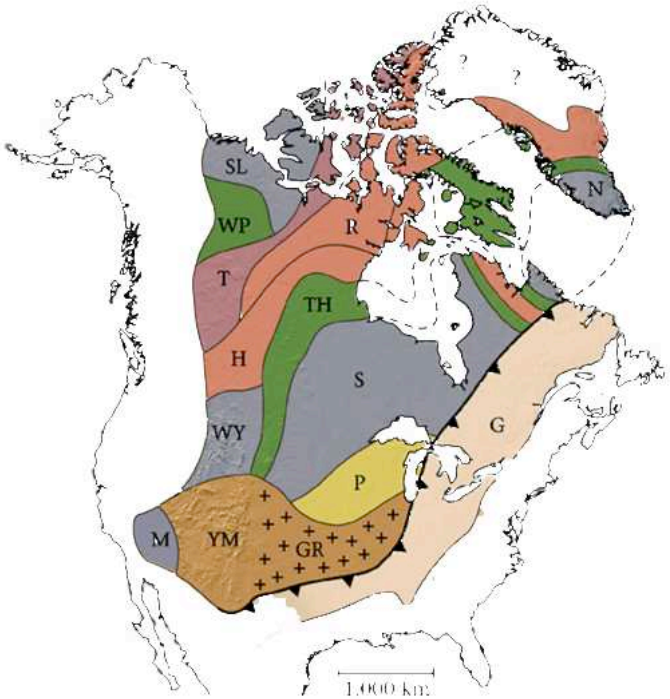
Geologische Provinzen

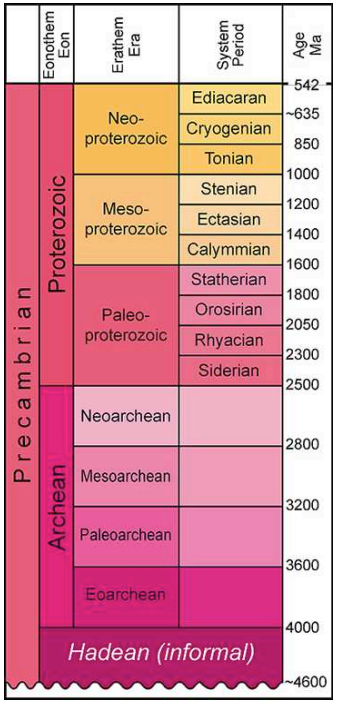


http://earthquake.usgs.gov/research/structure/crust/type.html

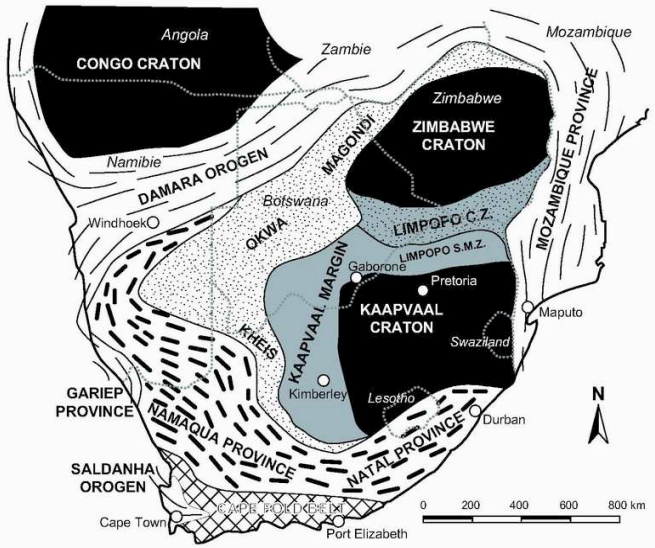
Präkambrische Schilde

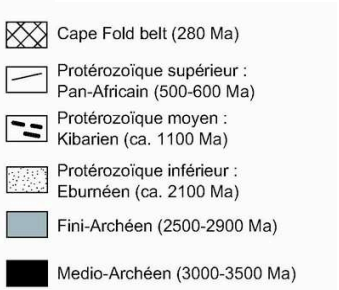
Nordamerikanischer Schild





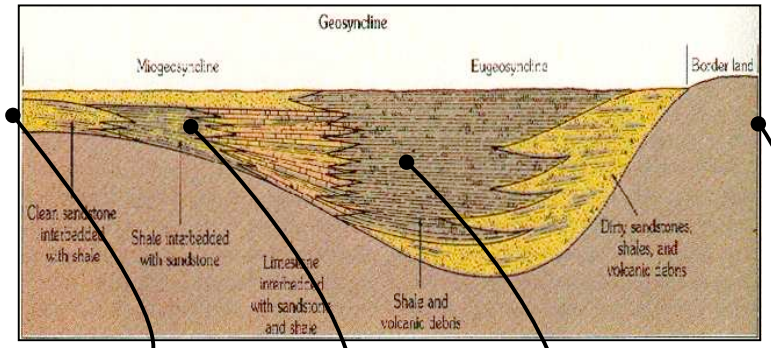
Afrikanischer Schild

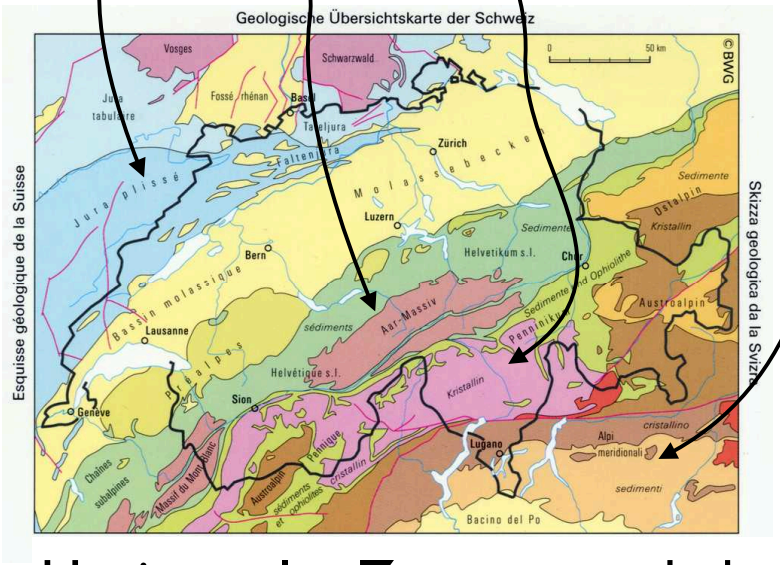




Theorien zur Gebirgsbildung

Geosynklinale: Becken senkt sich ein





Horizontaler Zusammenschub:

- leichtes Material hinauf
- schweres Material hinunter

Kontraktionstheorie

Leichte und schwere Gesteine

leichte Gesteine

Kontinentale Kruste: Si Al

Granodiorit

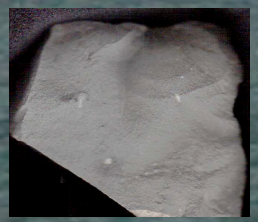
Granit

Verfalteter Gneis

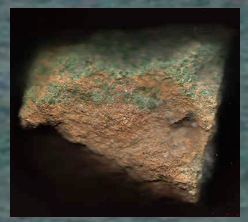
schwere Gesteine

Ozeanische Kruste... ... und Mantel: Fe Mg

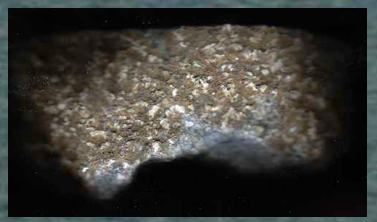
Gabbro



Basalt



Peridotit

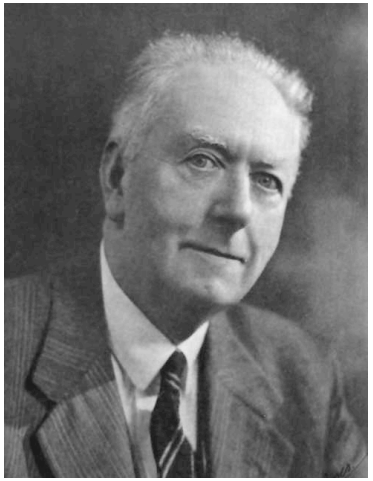


Kimberlit

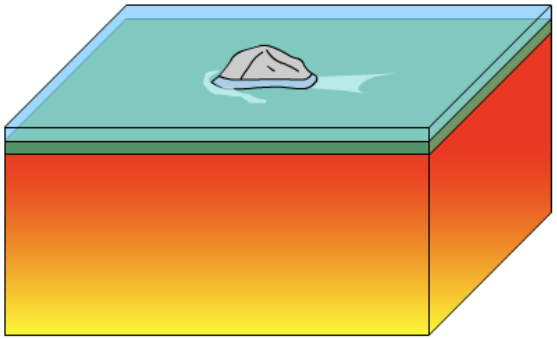
Wie bewegt man Kontinente durch Ozeane ?

Alfred Wegener
(1880 - 1930)

Otto Ampferer
(1875 - 1947)

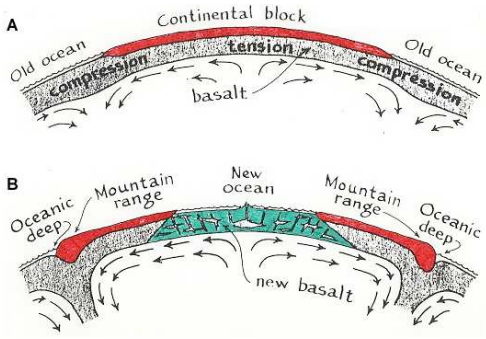


Arthur Holmes
(1890 - 1965)



Mondflut ?

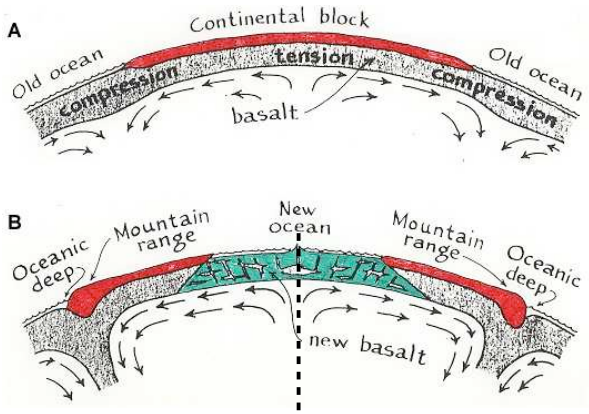
nachgiebige Schicht auf Schmelze ?
("wie Haut auf gekochter Milch")



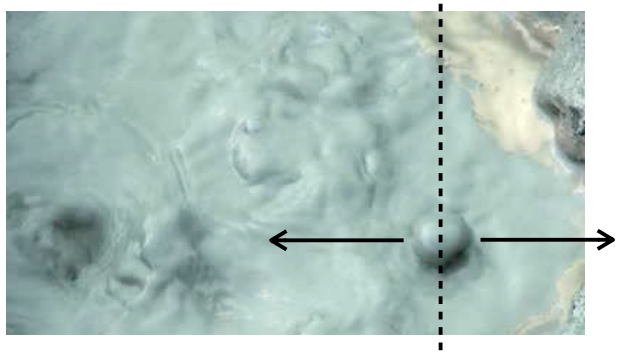
Mantelkonvektion ?

Konvektion ja - aber wo ist da eine "Platte" ?

Im Profil



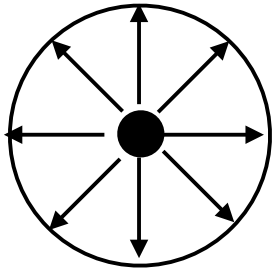
von oben ?



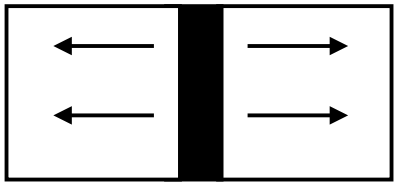
http://footage.shutterstock.com
Underground volcanic spring

in der Ebene

?

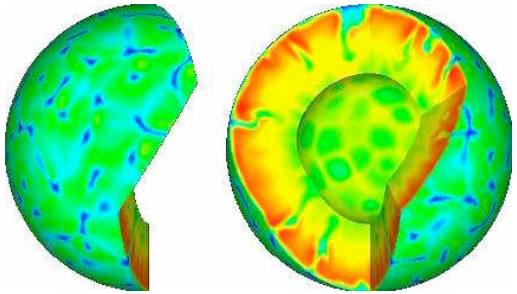


radiale
Konvektionszelle



orthogonale
Konvektionszelle

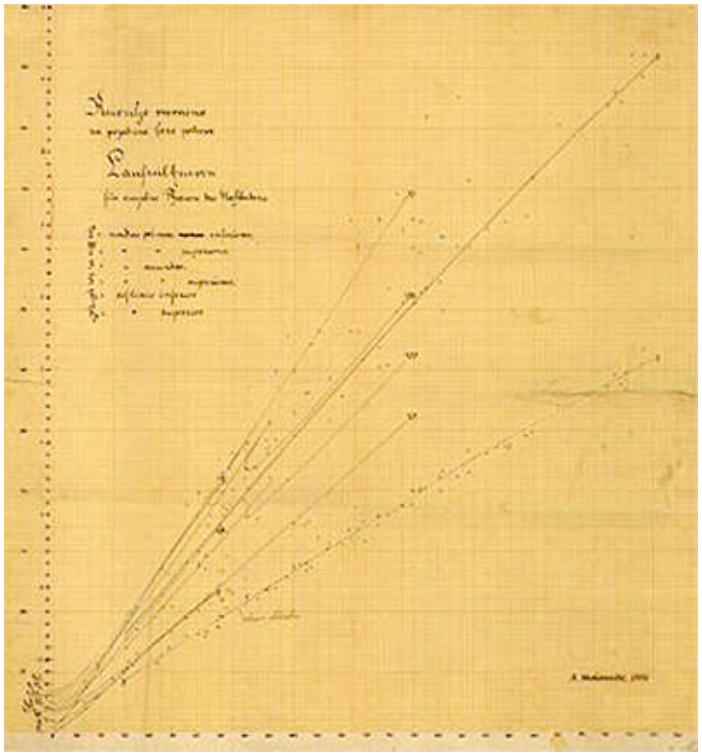
auf der Kugel



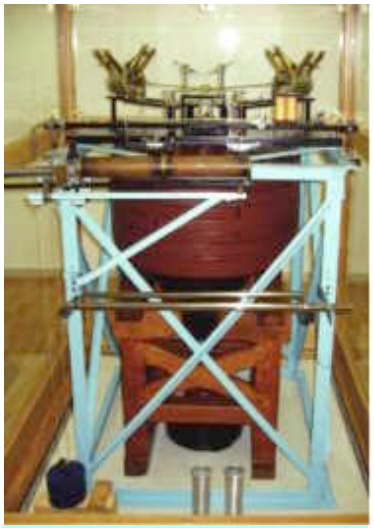
http://www.geophysik.uni-muenchen.de/
research/geodynamics

Geophysikalische Erkenntnisse

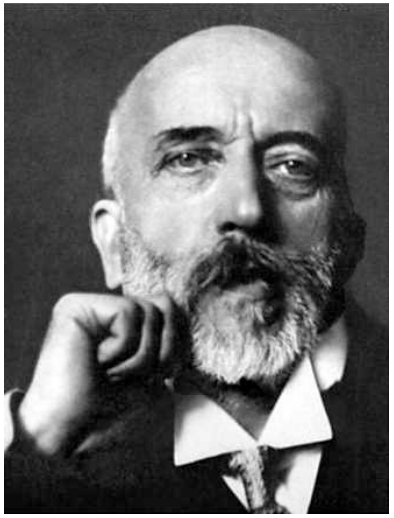
Blick ins Erdinnere



Laufzeitenkurven, lokale und regionale Distanzen (Andrija Mohorovičić, 1910).



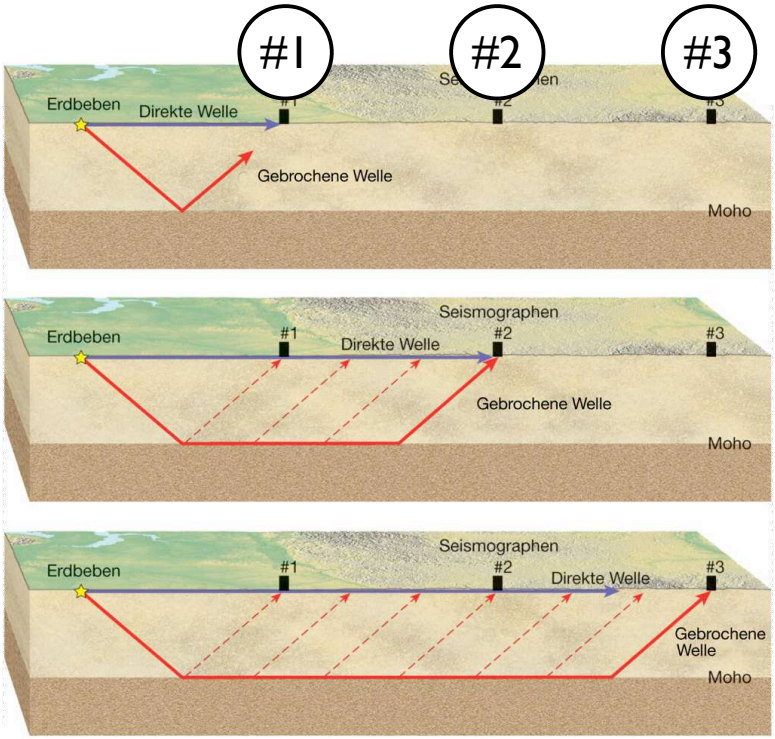
Wiechert Horizontal Seismograph installed by Mohorovicic in 1909.



Andrija Mohorovičić (1857 - 1936)

"The goal of seismology is to study the interior of the Earth, and to continue where the geologist stops; it has in modern seismographs a sort of binoculars that enables us to look into the largest of depths."

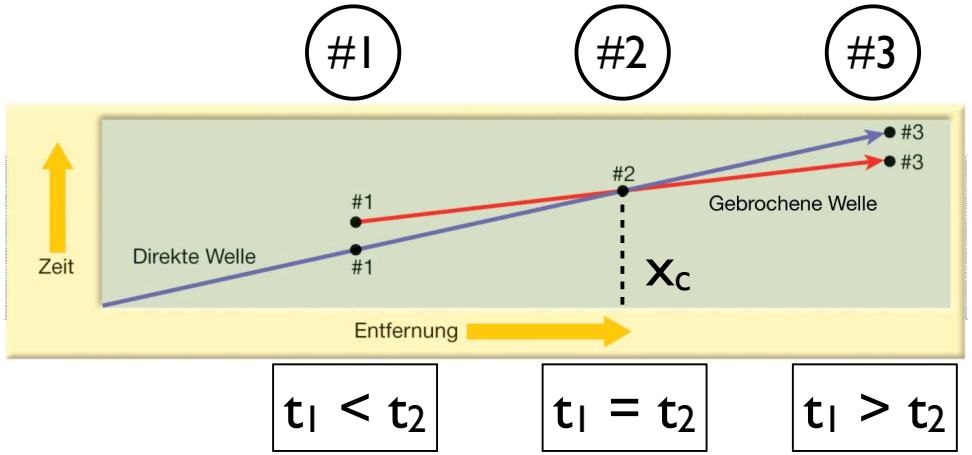
Die seismische Moho (Mohorovičić - Diskontinuität)



obere Schicht: v_1 = langsamer
untere Schicht: v_2 = schneller

Aus v_1, v_2 und x_c kann die Schichtdicke h berechnet werden

$$h = \frac{x_c}{2}\sqrt{\frac{v_2 - v_1}{v_2 + v_1}}$$

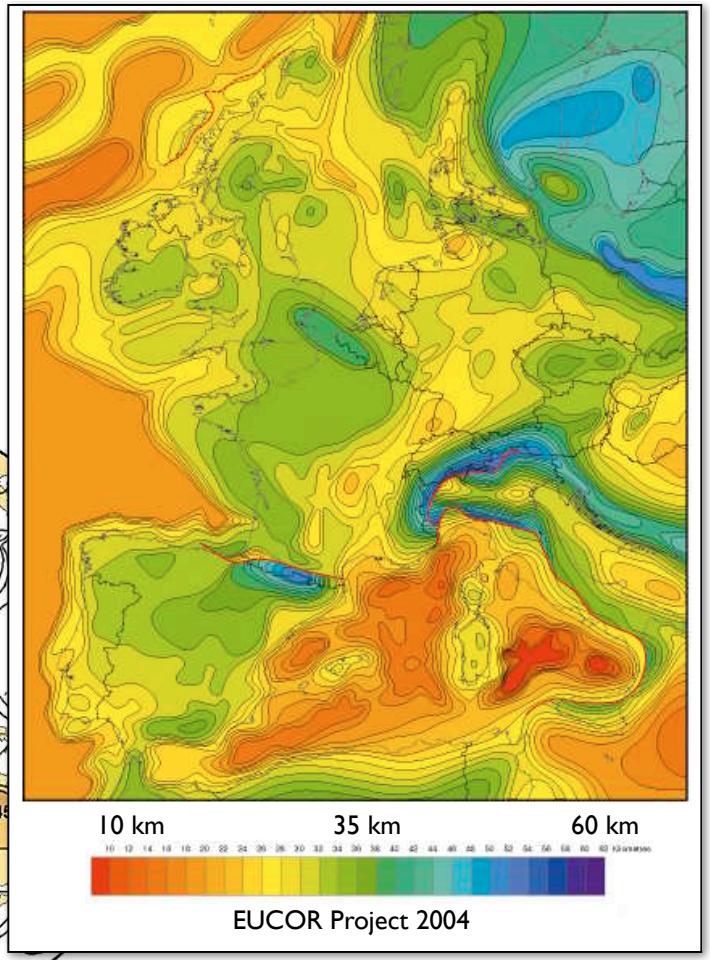


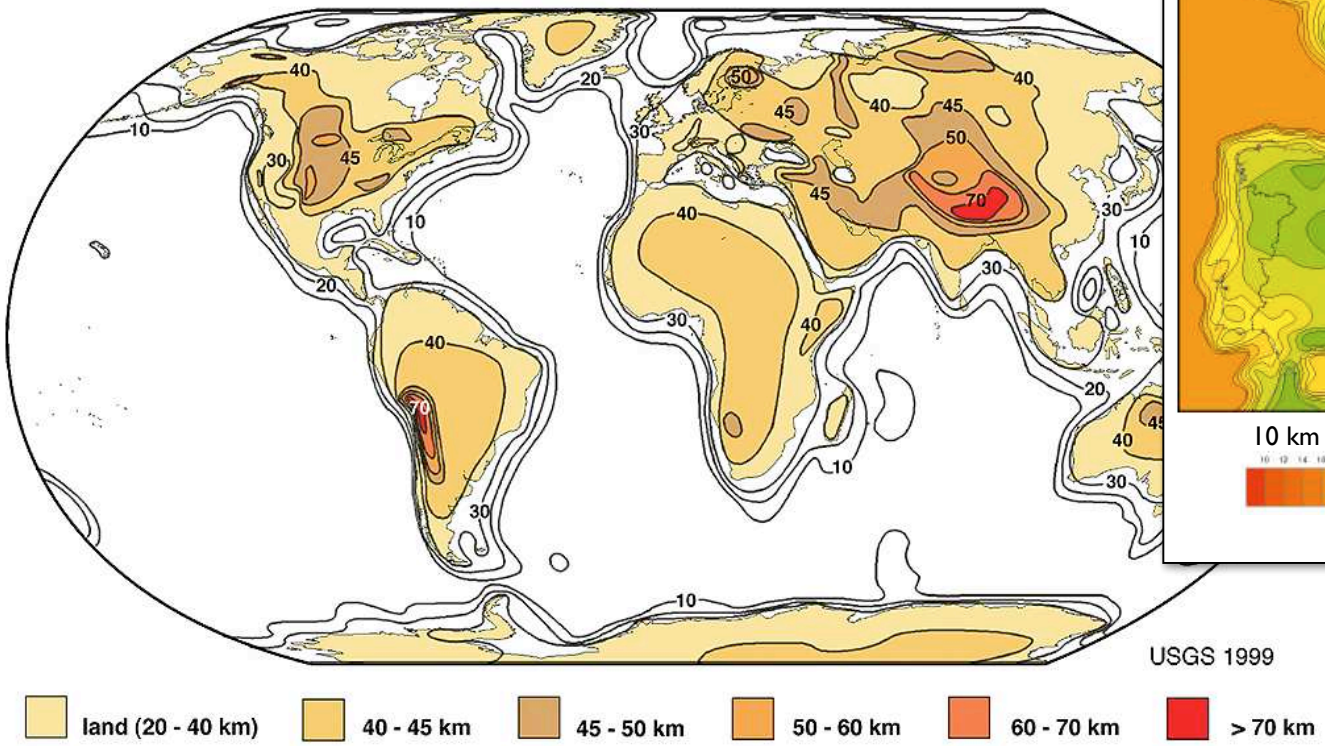
$t_1 < t_2$ $t_1 = t_2$ $t_1 > t_2$

t_1 Ankunftszeit Welle 1
t_2 Ankunftszeit Welle 2

Krustendicke

Kruste ≠ Tektonische Platte



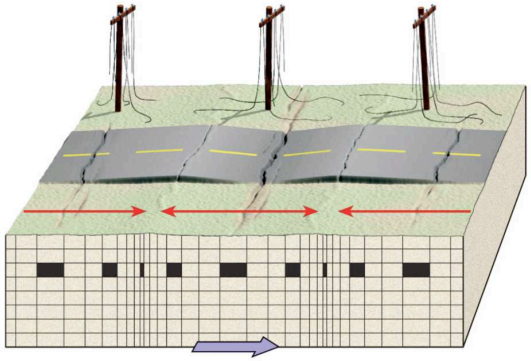


http://earthquake.usgs.gov/research/structure/crust/images/robinson.eps

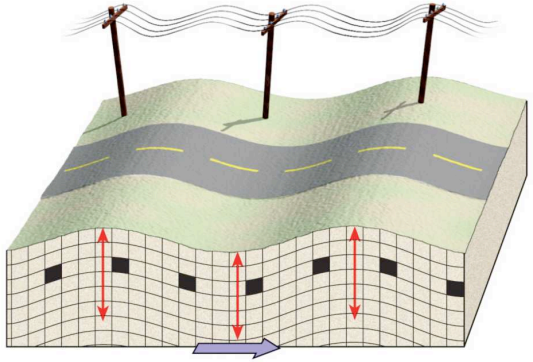
Seismische Wellen

Körperwellen

P-Wellen

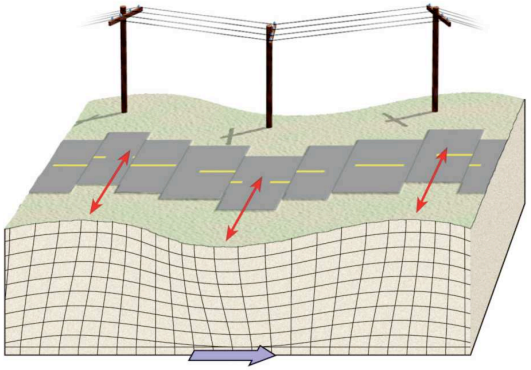


S-Wellen

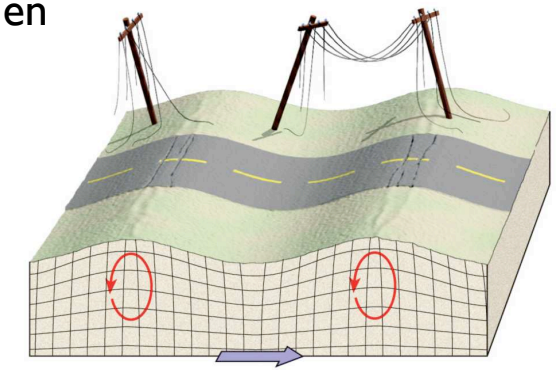


Oberflächenwellen

Love-Wellen



Raleigh-Wellen

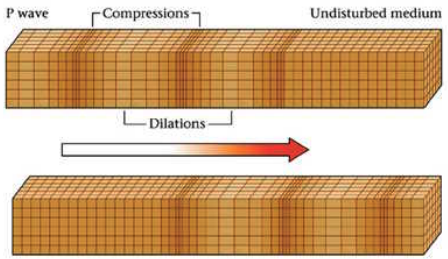


Fortpflanzungsrichtung der Welle

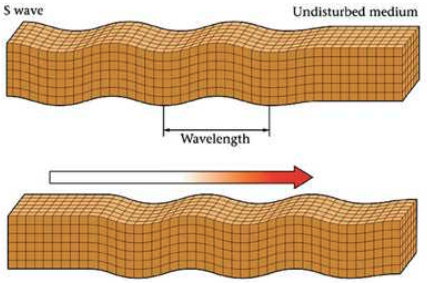
Bewegungsrichtung der Teilchen im Körper

P- und S- Wellen

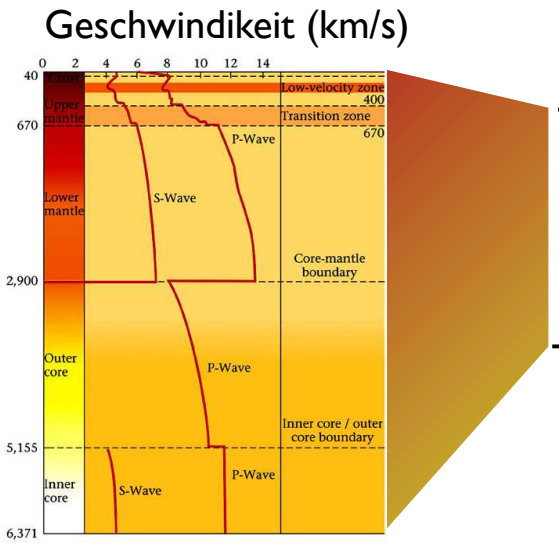
Beno Gutenberg
(1889 - 1960)

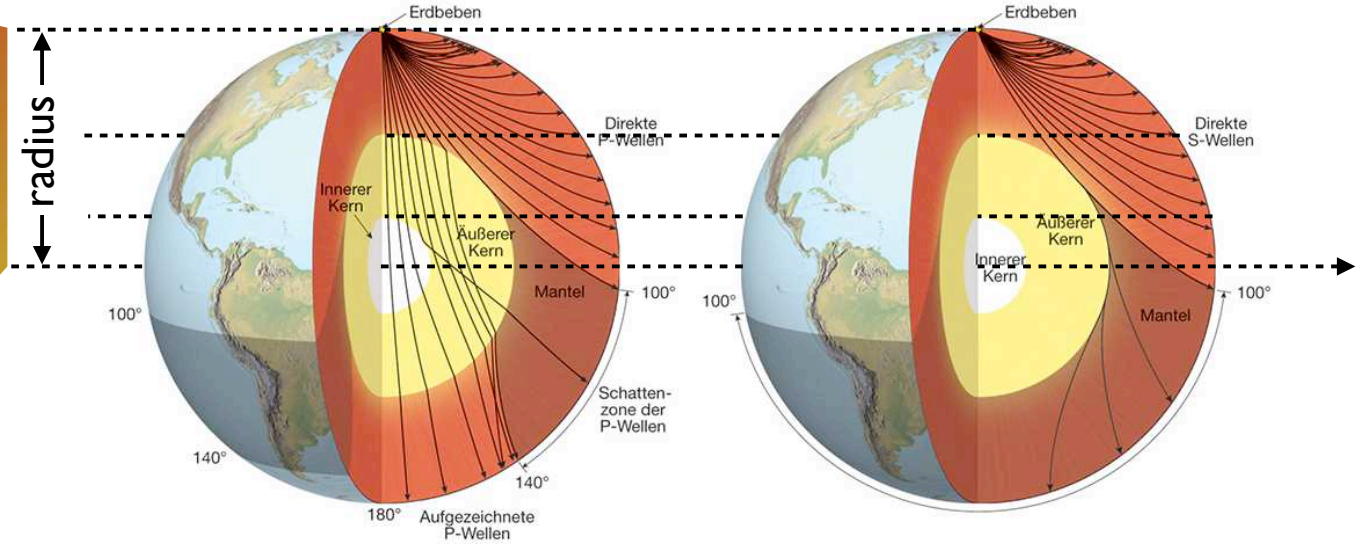


P- Wellen
durch fest
durch flüssig



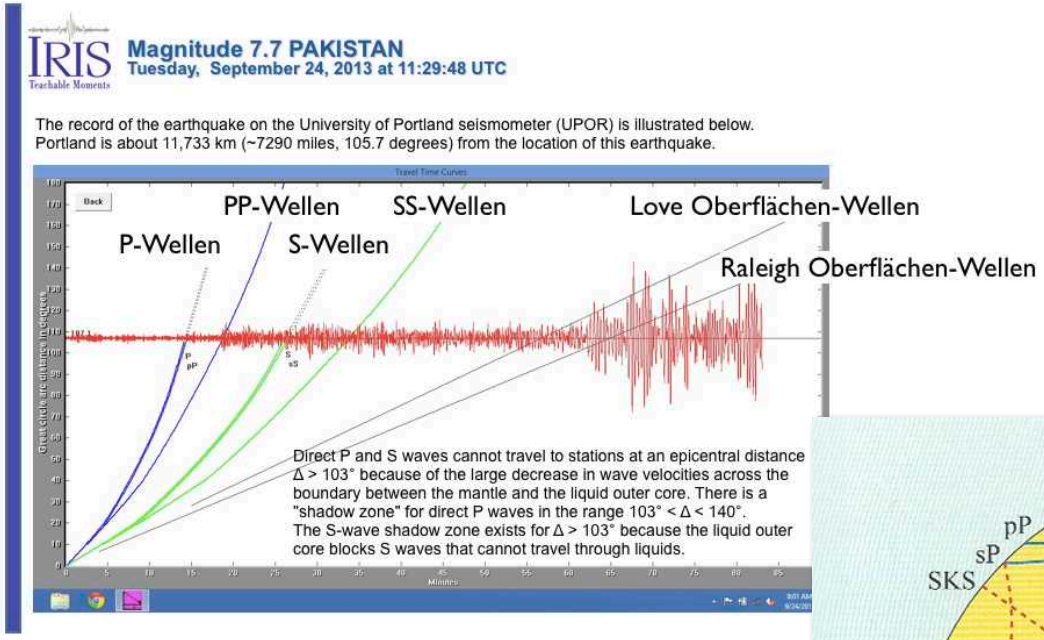
S- Wellen
nur durch fest
nicht durch flüssig



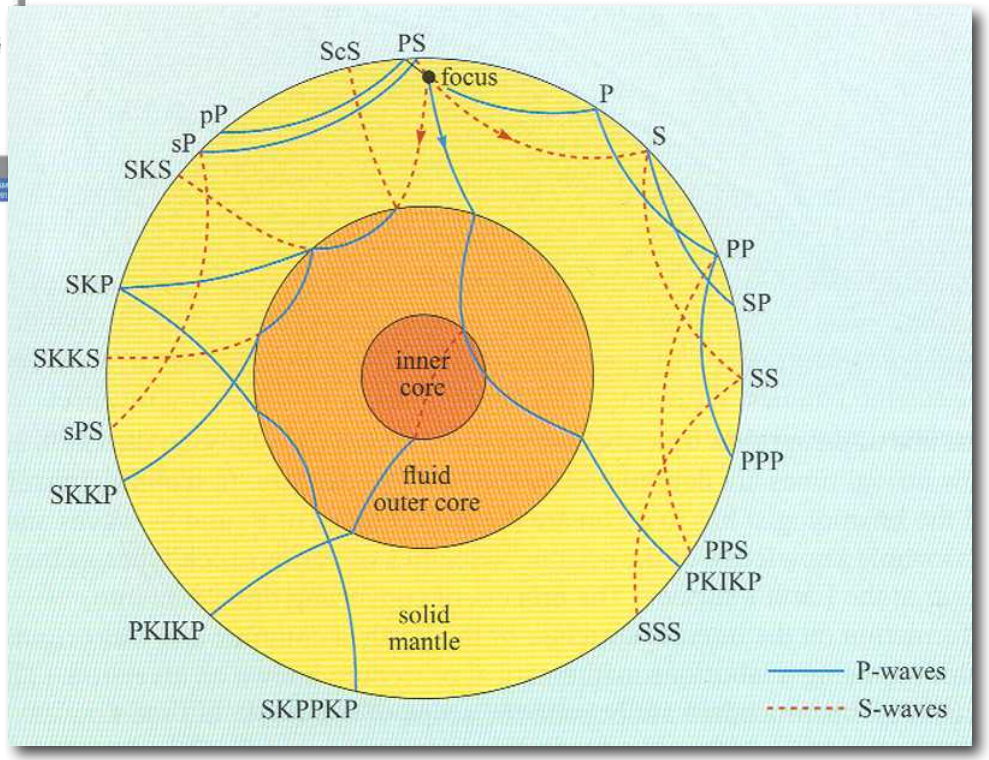


PP- und SS- Wellen ... and all the rest

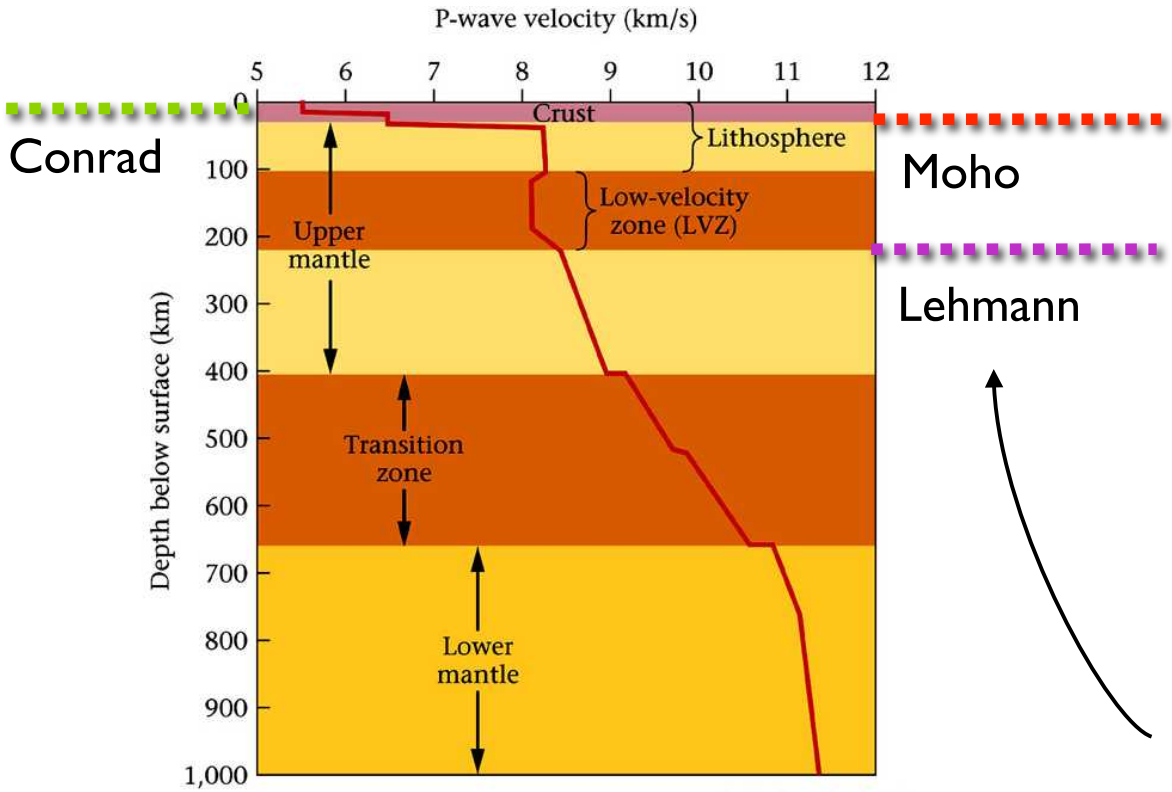
11

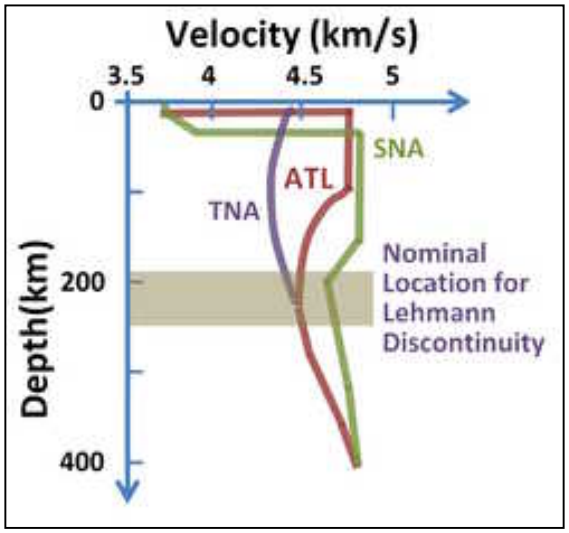


Inge Lehmann
(1888 - 1993)



Asthenosphäre - die weiche Unterlage

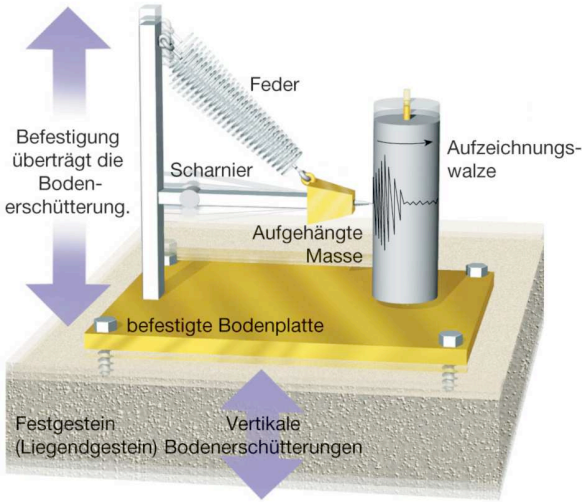




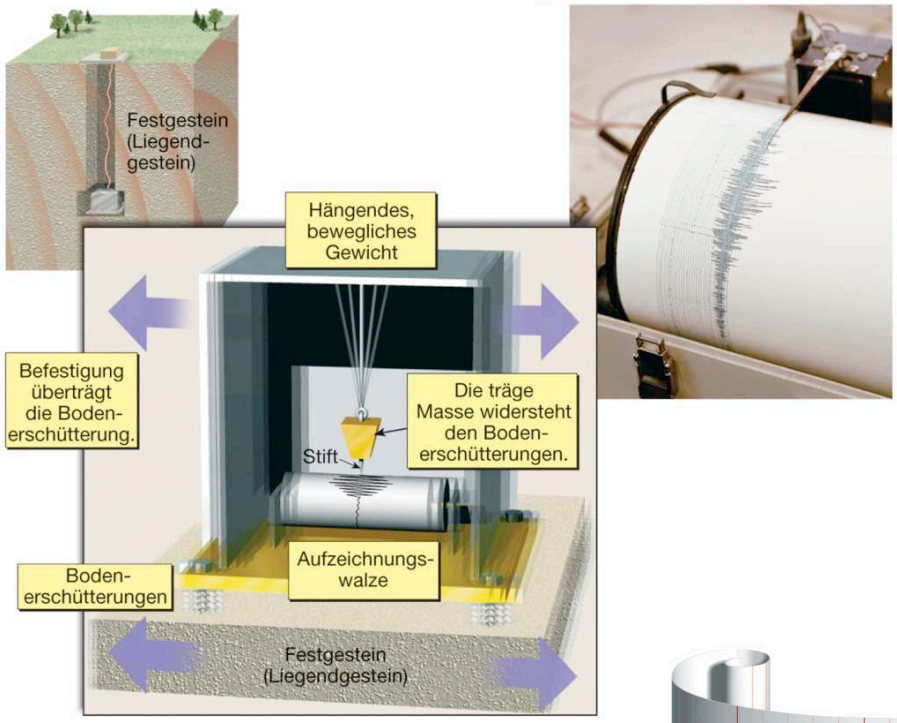
S-wave velocity for three tectonic provinces:
TNA= Tectonic North America
SNA= Shield North America
ATL = North Atlantic

... die 2. Plattengrenze: die Untergrenze

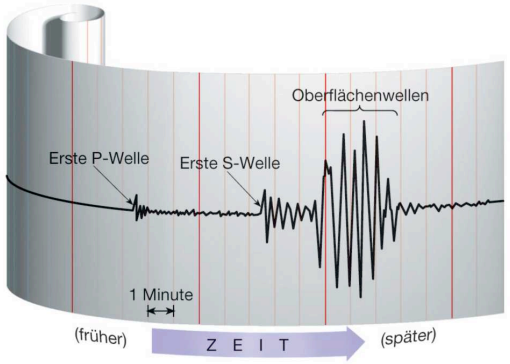
Auswertung von Erdbeben



Seismograph



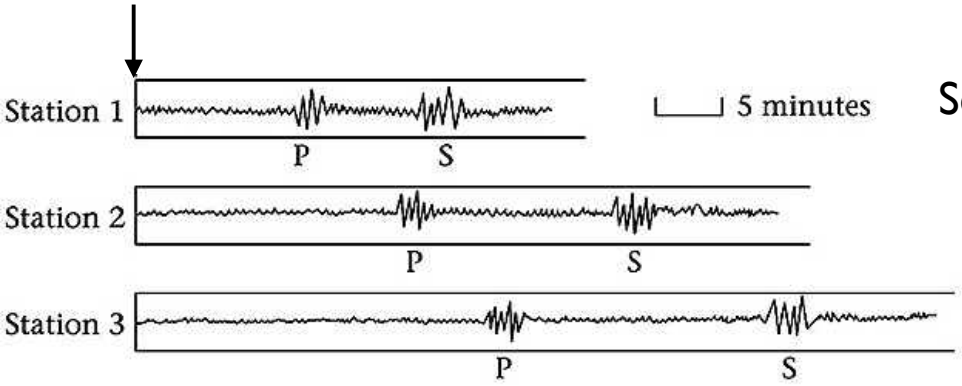
Seismograph



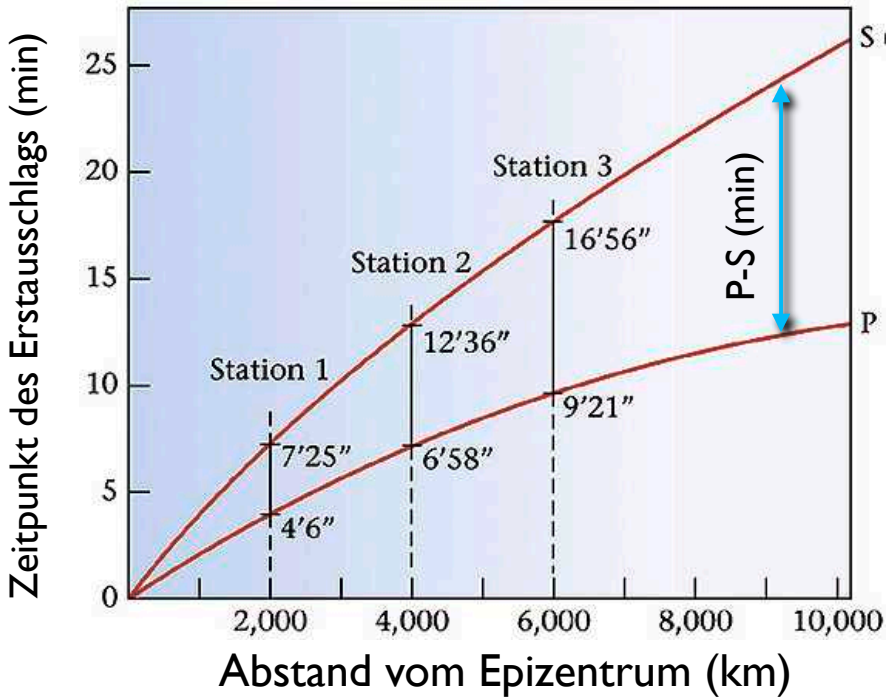
Seismogramm

Wo ist das Epizentrum ?

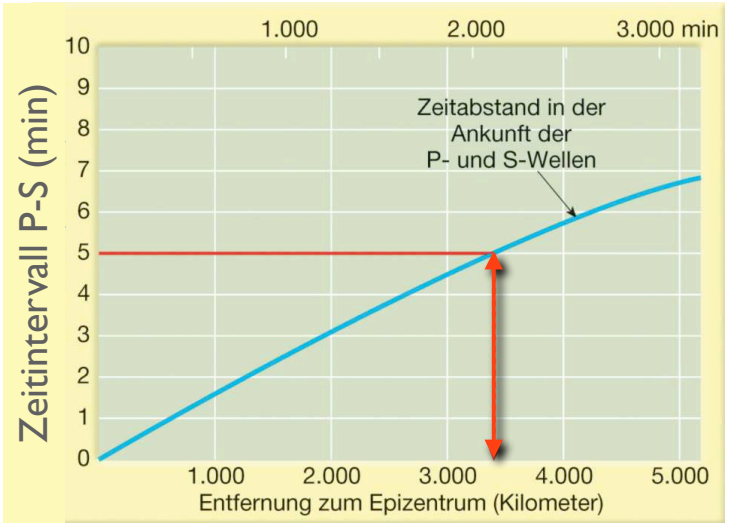
Zeitpunkt des Erdbebens



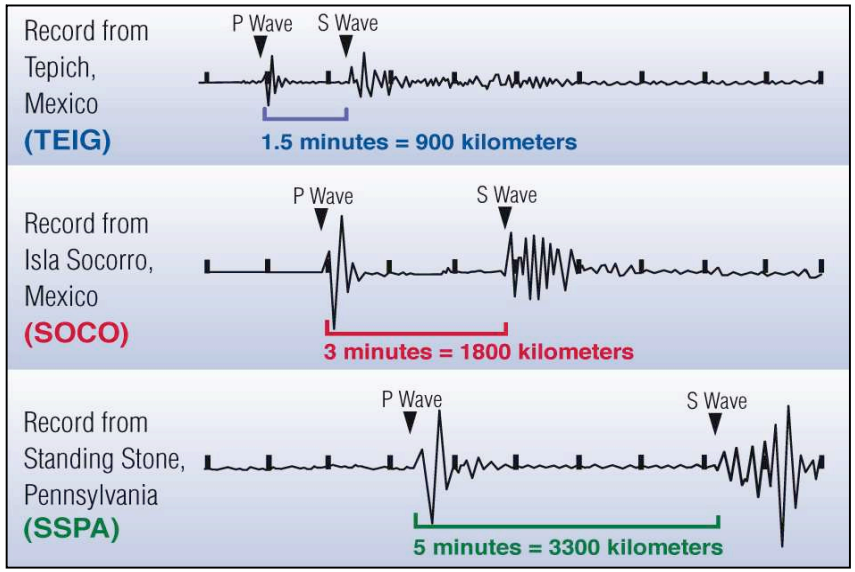
Seismogramme

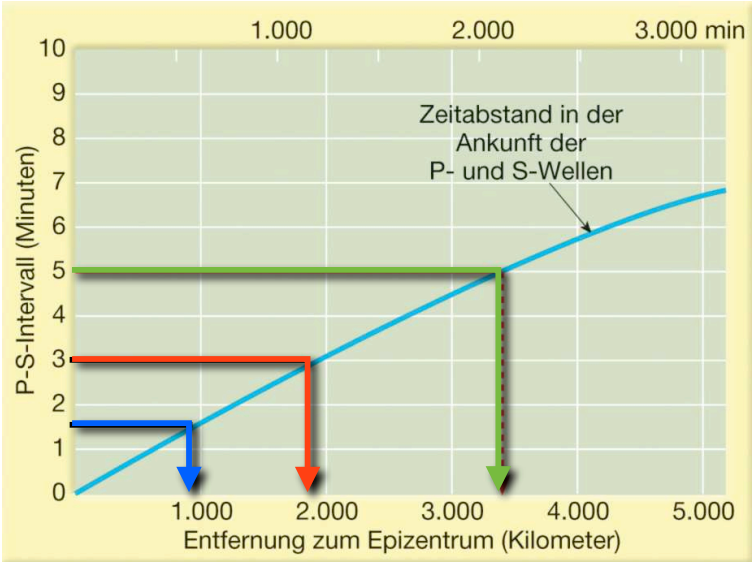


Laufzeitendiagramm

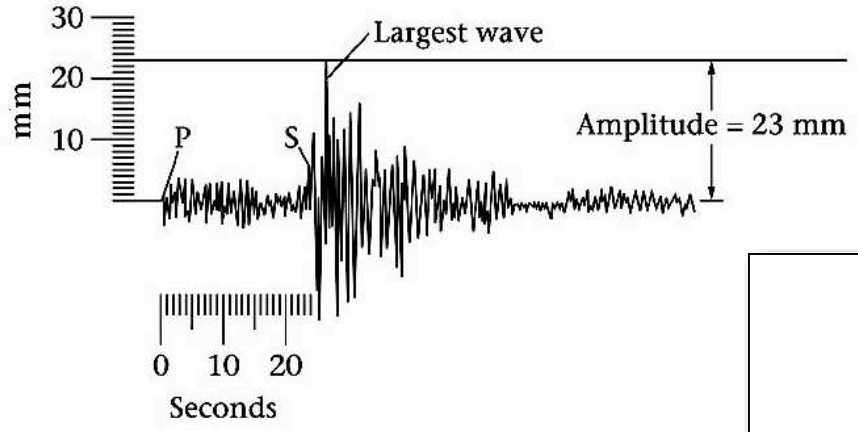


... im Schnittpunkt von 3 Kreisen





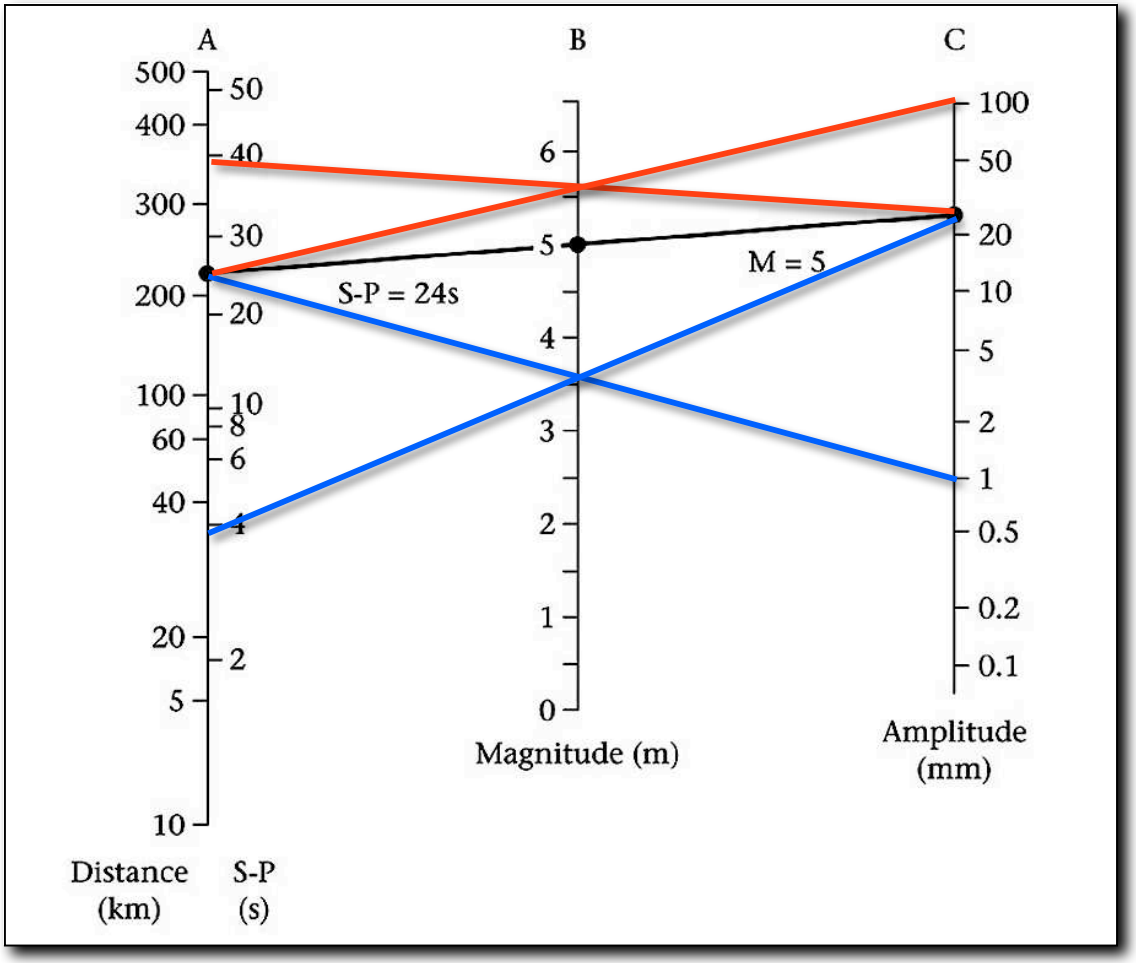
NB: von den Laufzeiten zur Magnitude



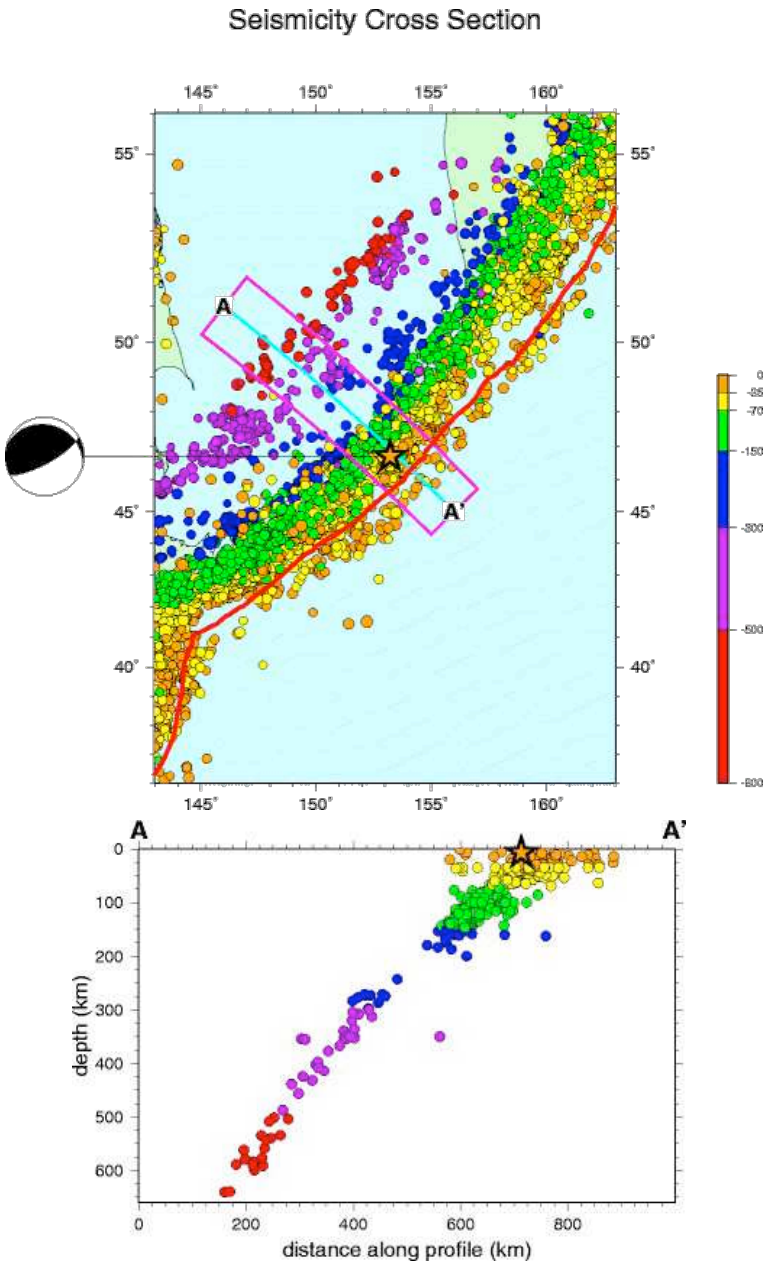
Produkt:

Amplitude x Distanz

⇒ Magnitude



Subduktion - Wadati-Benioff-Zone



Kiyoo Wadati
(1902 - 1995)

Victor Hugo Benioff
(1899 - 1968)

Wadati: deep earthquakes (>300km) are associated with <u>oceanic trenches</u>
Benioff: distribution of epicenters are evidence for <u>fault origin</u> of ocean deeps

... die 3. Plattengrenze: die Subduktionszone

Der Hawaii Hotspot

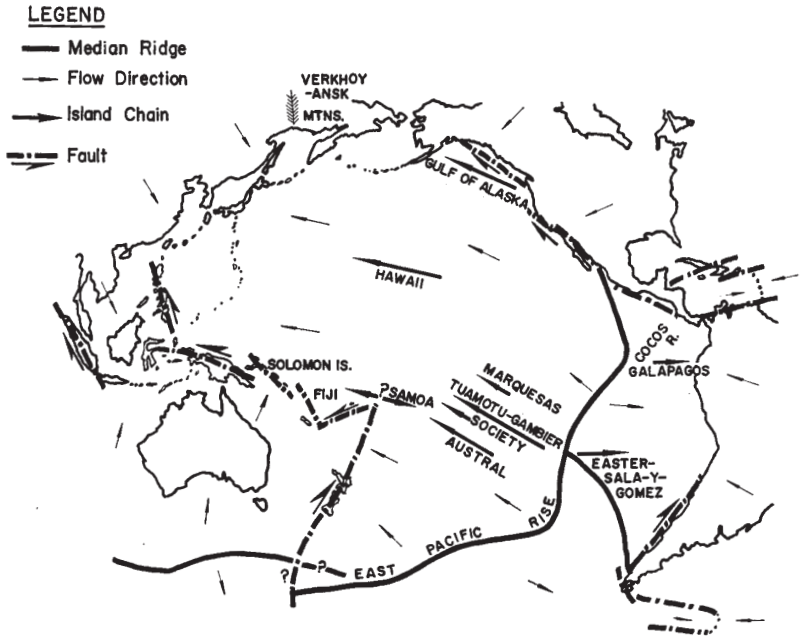


FIG. 1. Sketch of Pacific Ocean. Heavy arrows show nine linear chains of islands and seamounts which increase in age in direction of arrow. Single-headed arrows show direction of motion, where known, along large transcurrent faults. Small arrows show postulated direction of flow away from median ridges.

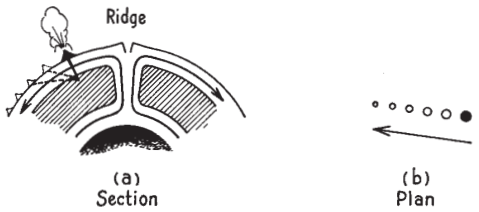
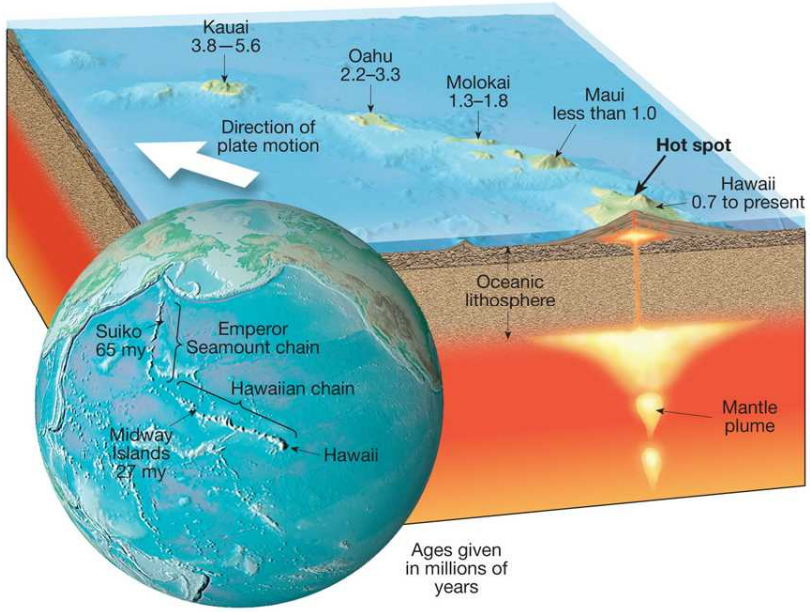
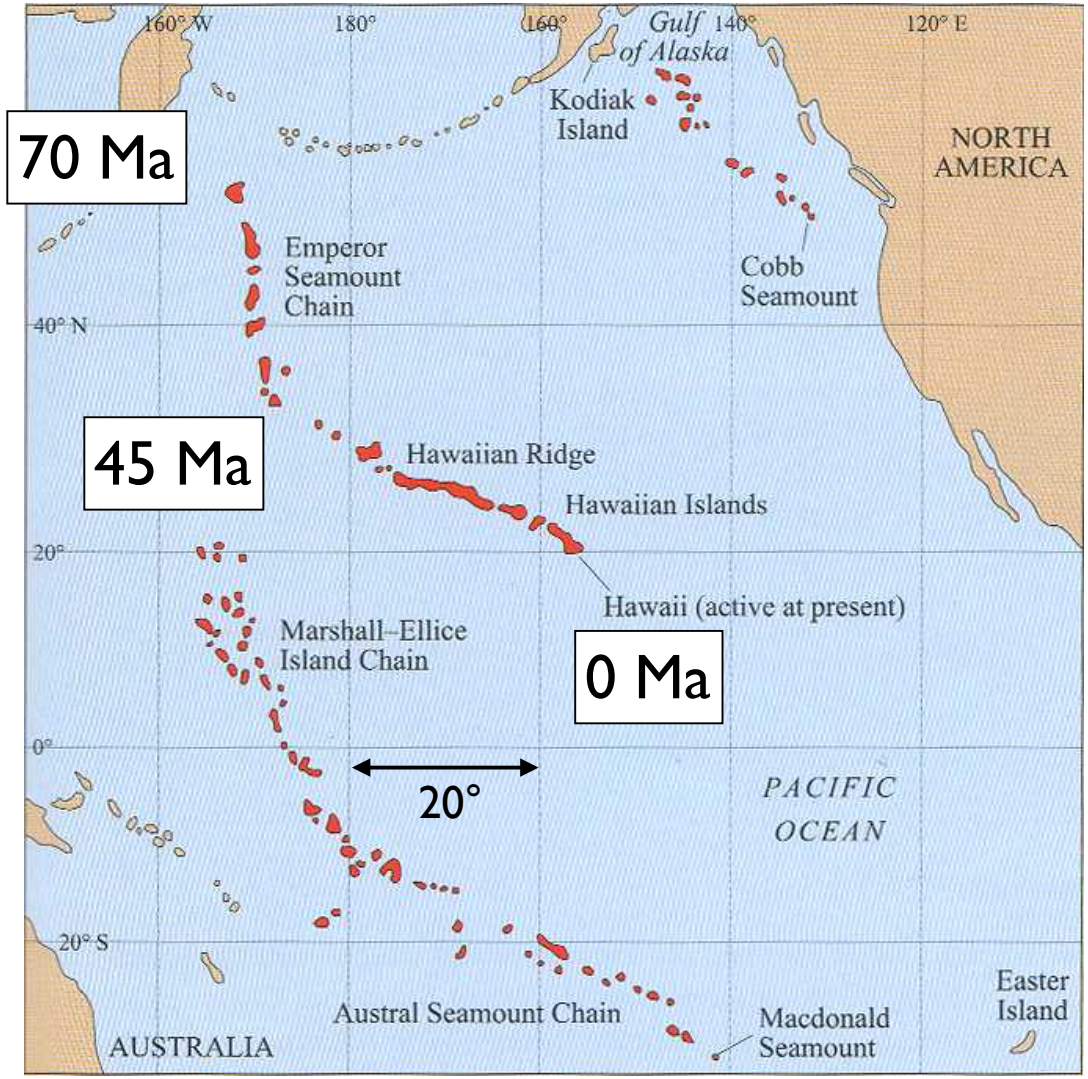


FIG. 5. Diagram to illustrate that if lava is generated in the stable core of a convection cell, and the surface is carried by the jet stream, then one source can give rise to a chain of extinct volcanoes even if the source is not over a rising current. This is proposed as a possible origin of the Hawaiian chain of islands.



Wilson, J. Tuzo (1963)
"A Possible Origin of the Hawaiian Islands"

Hotspots und Mantle Plumes



Mit welcher Geschwindigkeit bewegt sich die Pazifische Platte über den hot spot, der heute Hawaii ist ?

Zeit aus Altersdatierung:

NW: 70 Ma

SE (Hawaii): 0 Ma

$\Rightarrow t \approx 7 \cdot 10^7$ a

Weg des Hotspots:

10° am Äquator ≈ 1000 km

$\Rightarrow d \approx 6 \cdot 10^6$ m

Geschwindigkeit = Weg / Zeit:

6'000'000 m / 70'000'000 a

≈ 0.1 m/a d.h. 10 cm/a

Die Entdeckung der Transform Faults

IRIS Magnitude 7.7 PAKISTAN
Tuesday, September 24, 2013 at 11:29:48 UTC

This earthquake occurred near the plate boundaries of the Eurasian, Arabian, and Indian Plates.

flect a complex plate boundary
the Eurasian Plate in the east,
th the Eurasian Plate in the

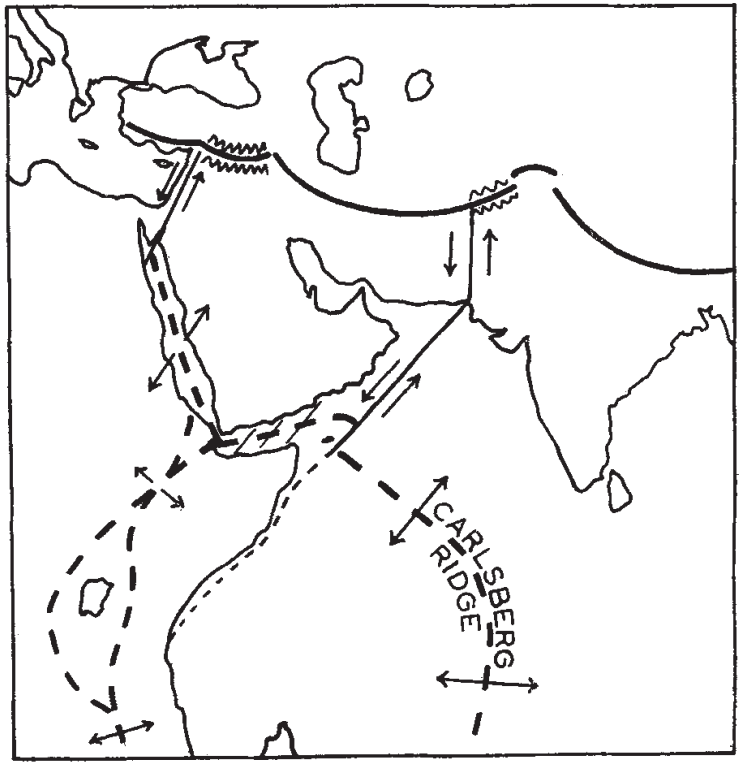
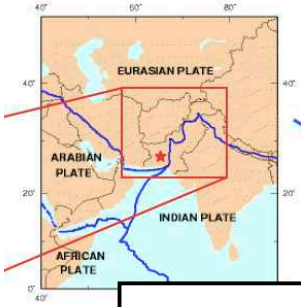


Fig. 8. Sketch illustrating the end of the Carlsberg mid-ocean ridge by a large transform fault (ridge–convex arc type) extending to the Hindu Kush, the end of the rift up the Red Sea by a similar transform fault extending into Turkey and the still younger East African rifts



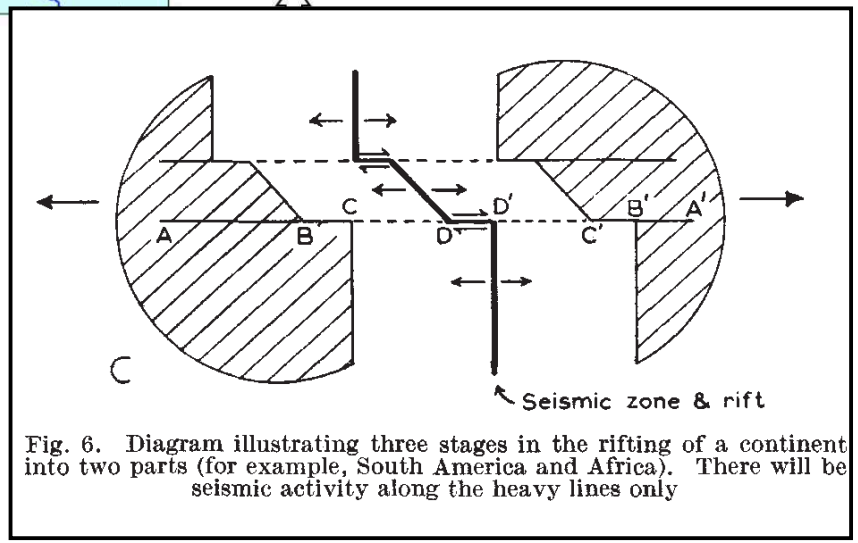


Fig. 6. Diagram illustrating three stages in the rifting of a continent into two parts (for example, South America and Africa). There will be seismic activity along the heavy lines only

Wilson, J. Tuzo (1965)
"A new Class of Faults and their Bearing on Continental Drift"

... die 4. Plattengrenze: die Transformbrüche

das letzte Puzzlestein zur Plattentektonik

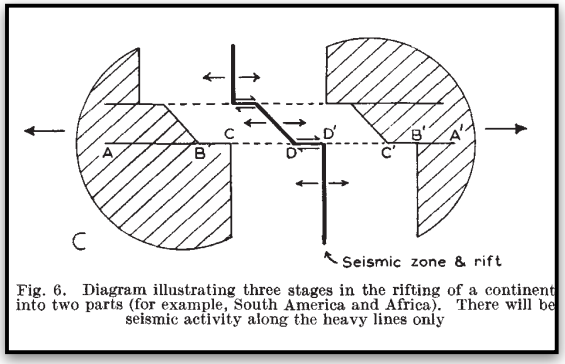
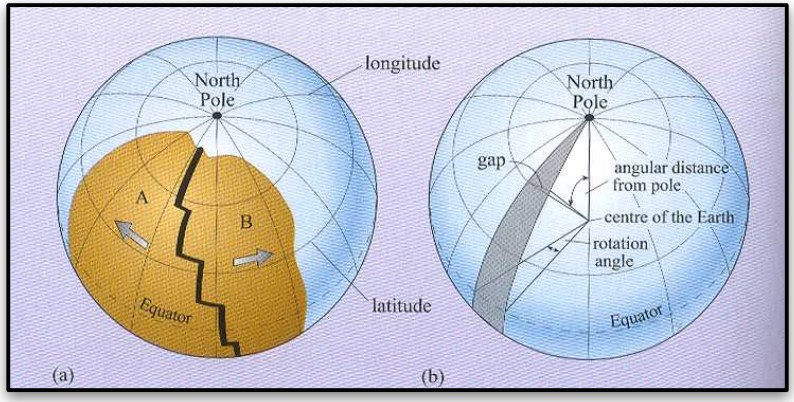
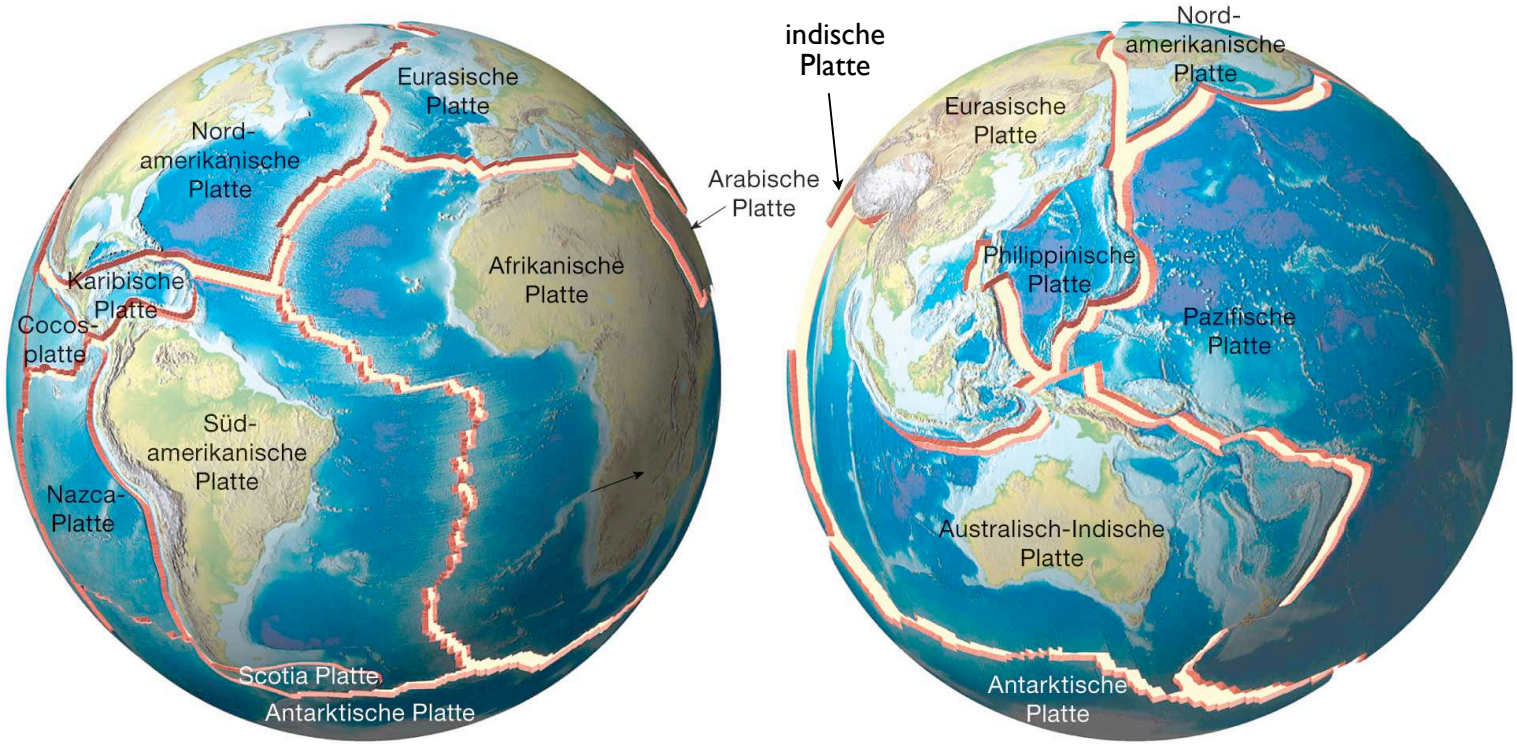


Fig. 6. Diagram illustrating three stages in the rifting of a continent into two parts (for example, South America and Africa). There will be seismic activity along the heavy lines only





nun sind die Platten definiert

Schalenbau der Erde

Lithosphäre

Asthenosphäre

Unterer Mantel (Mesosphäre)

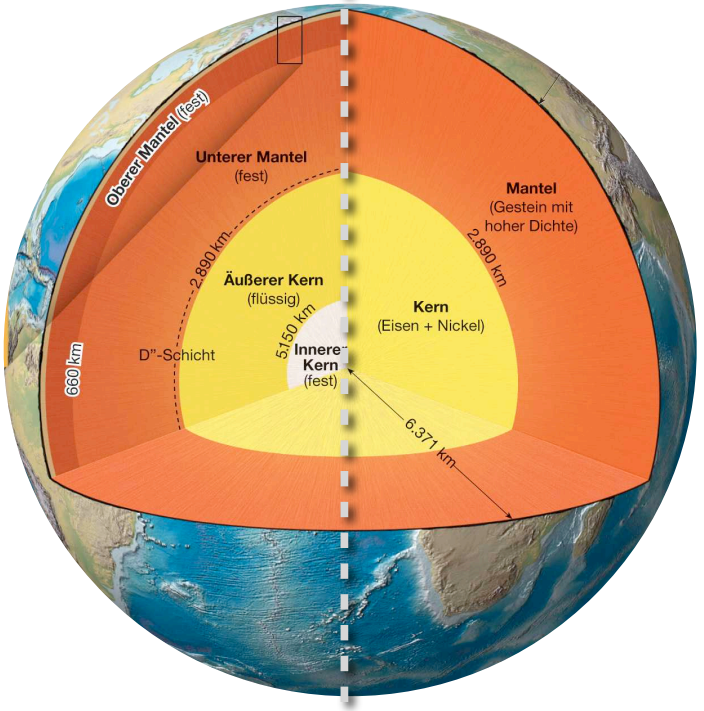
fest

Äusserer Kern

flüssig

Innerer Kern

fest



Kruste

Granodiorit, Basalt

Mantel

Peridotit

Kern

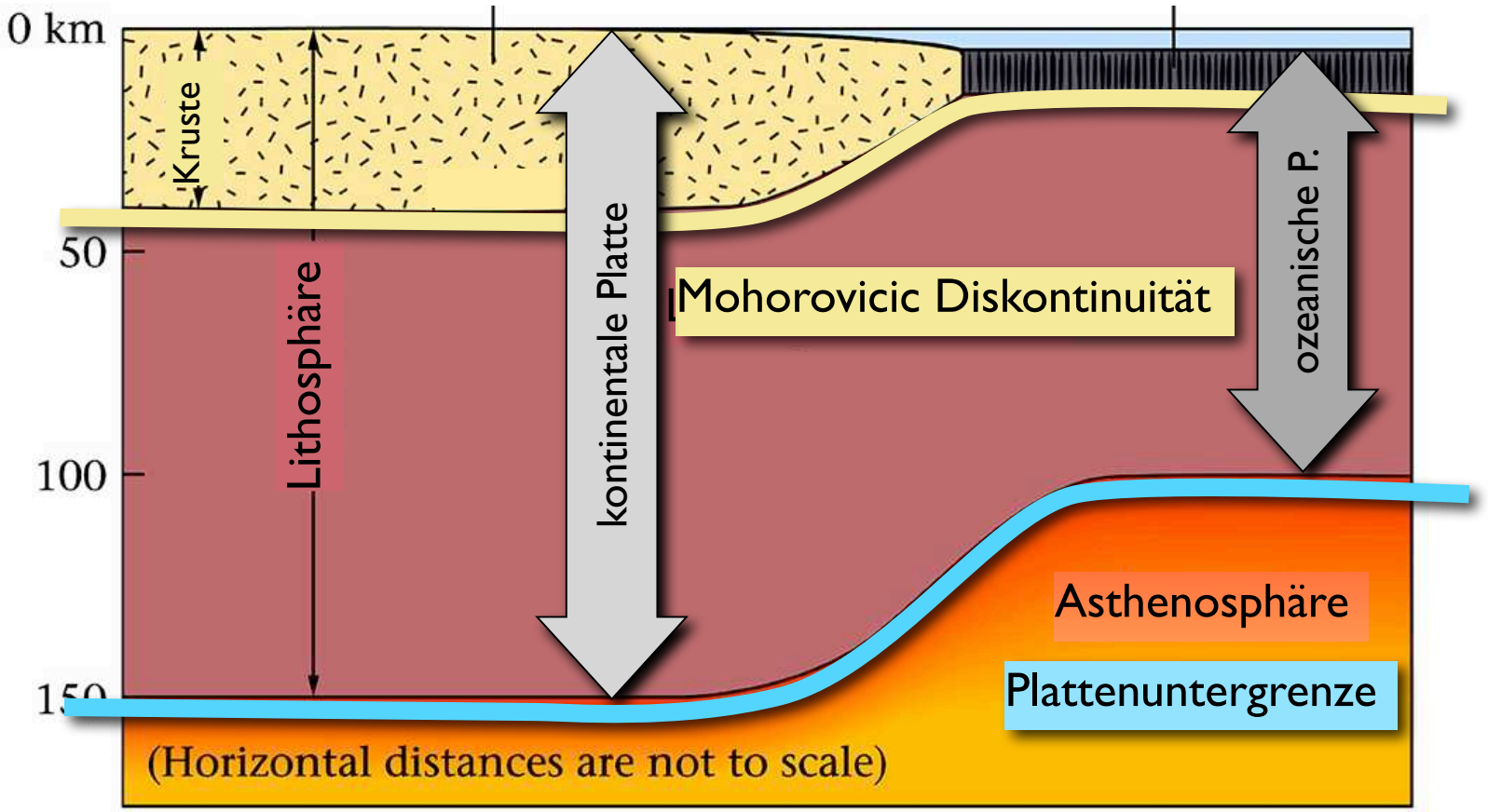
Fe-Ni-Legierung

Physikalische / rheologische Eigenschaften

Chemische / mineralogische Zusammensetzung

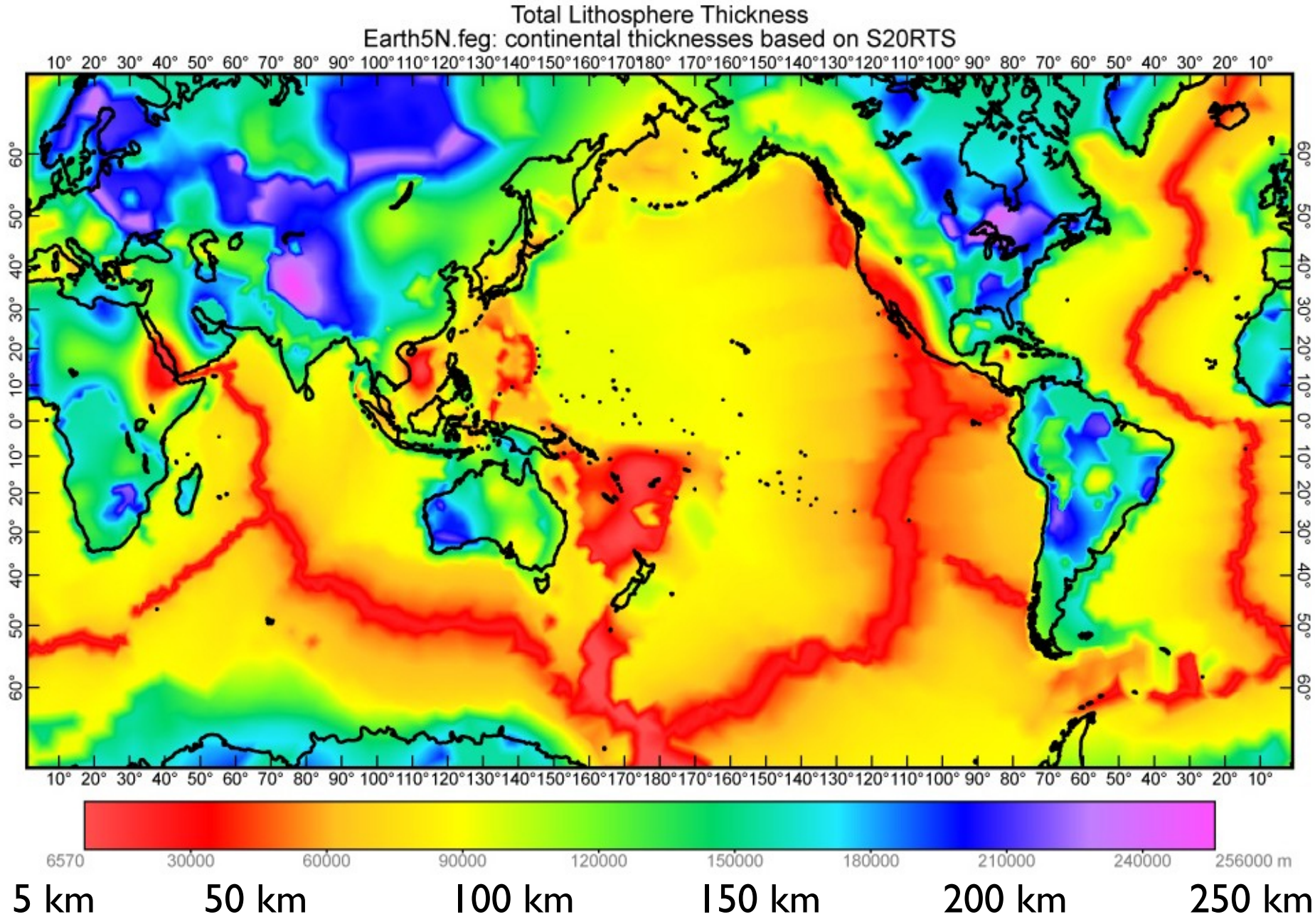
Platten sind Lithosphärenplatten

Kruste ≠ Tektonische Platte



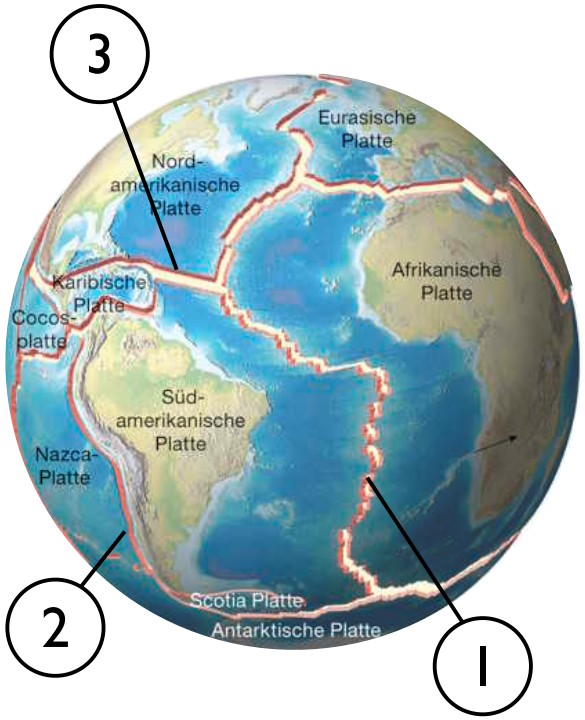
Platten sind Lithosphärenplatten:
bestehen aus Kruste und Mantel - haben Festigkeit

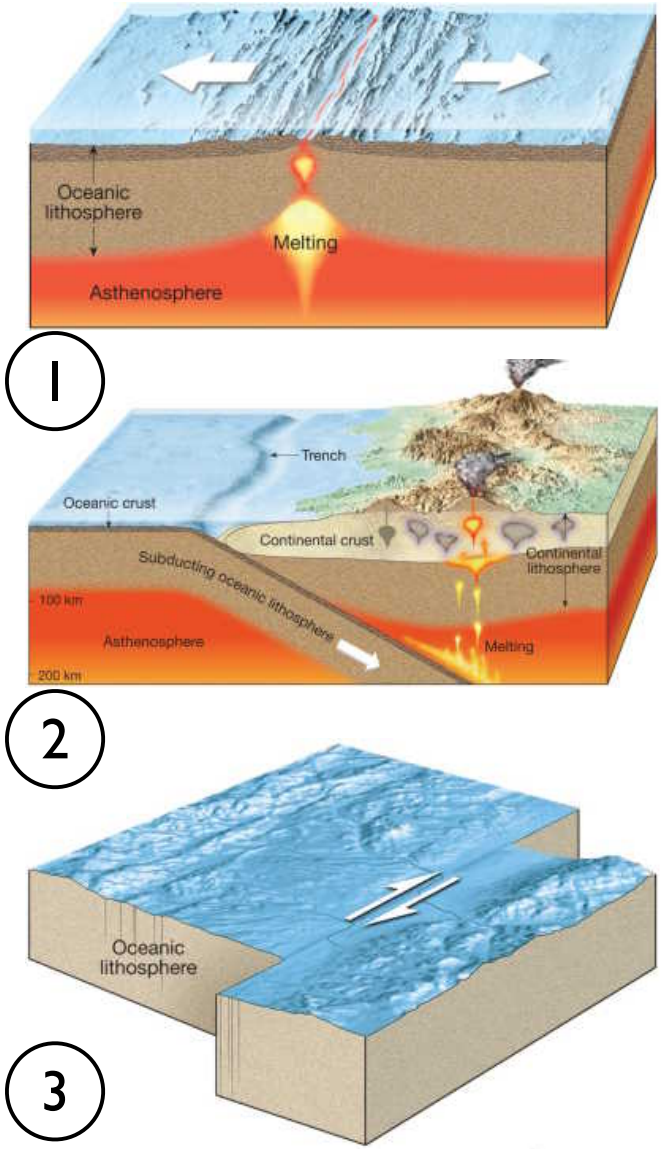
Dicke der Lithosphäre



Plattengrenzen: 3 Typen

bezüglich Erdoberfläche	bezüglich Bewegungssinn
konstruktiv	= distensiv
destruktiv	= kompressiv
konservativ	= Transform

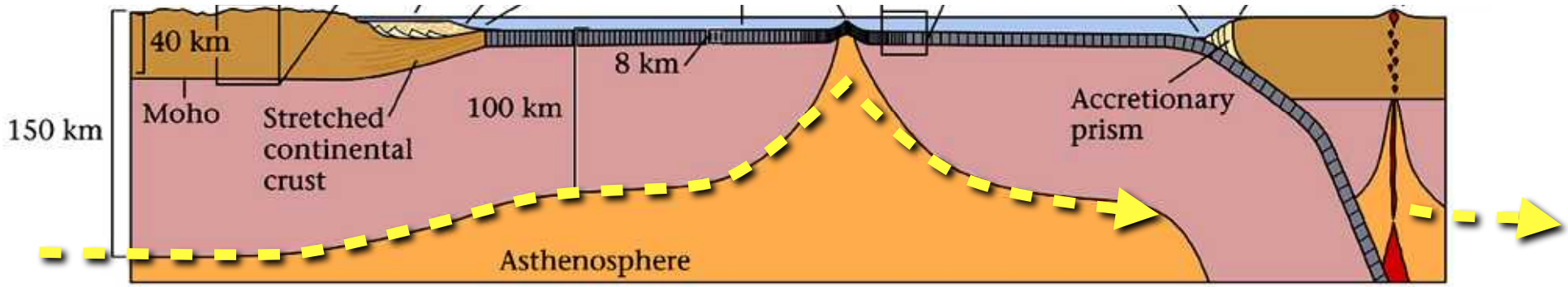




... und der 4. Typ

konstruktive Plattengrenze

destruktive Plattengrenze



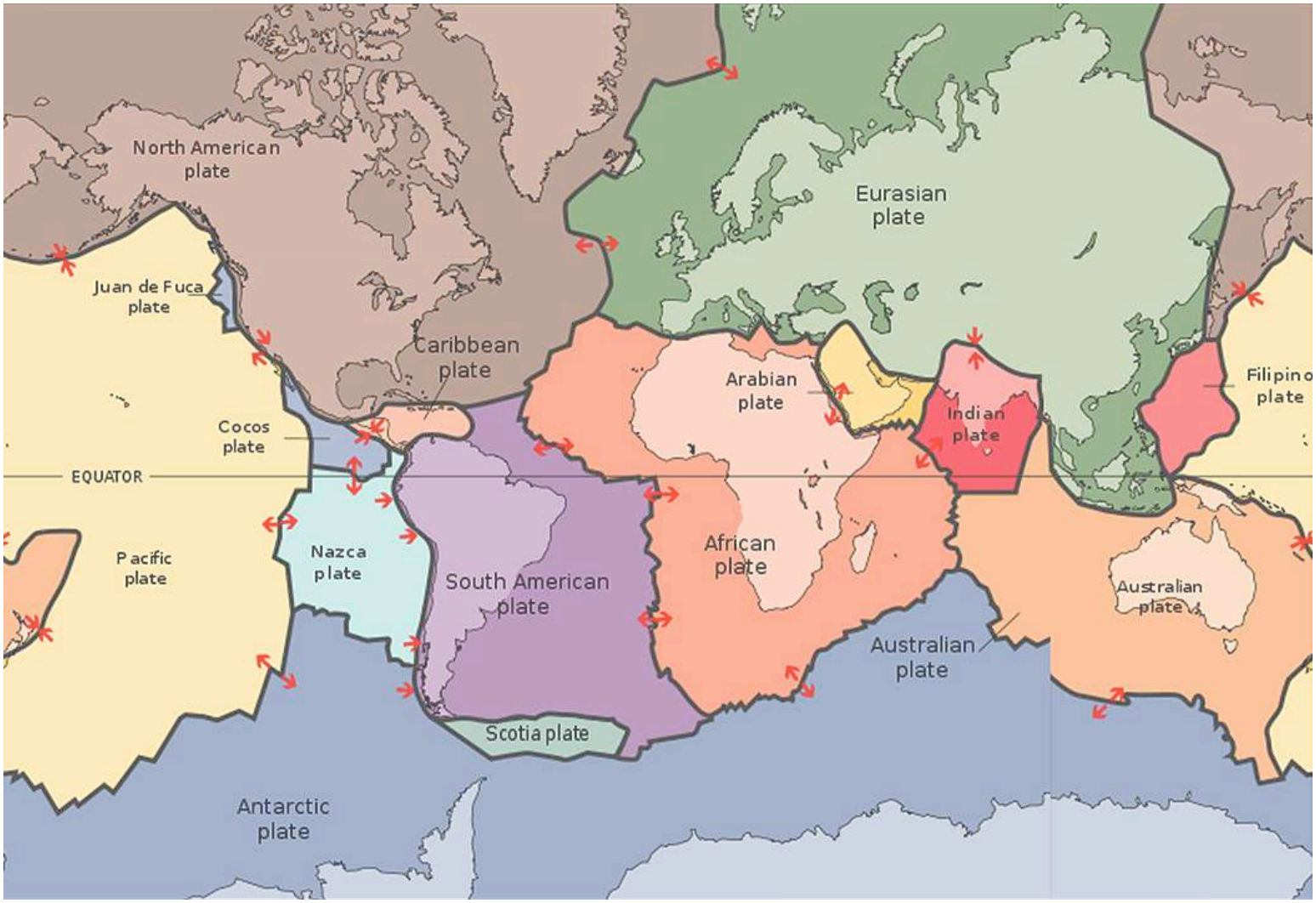
mittelozean. Rücken

Tiefseegraben

Untergrenze = Grenze Lithosphäre / Asthenosphäre

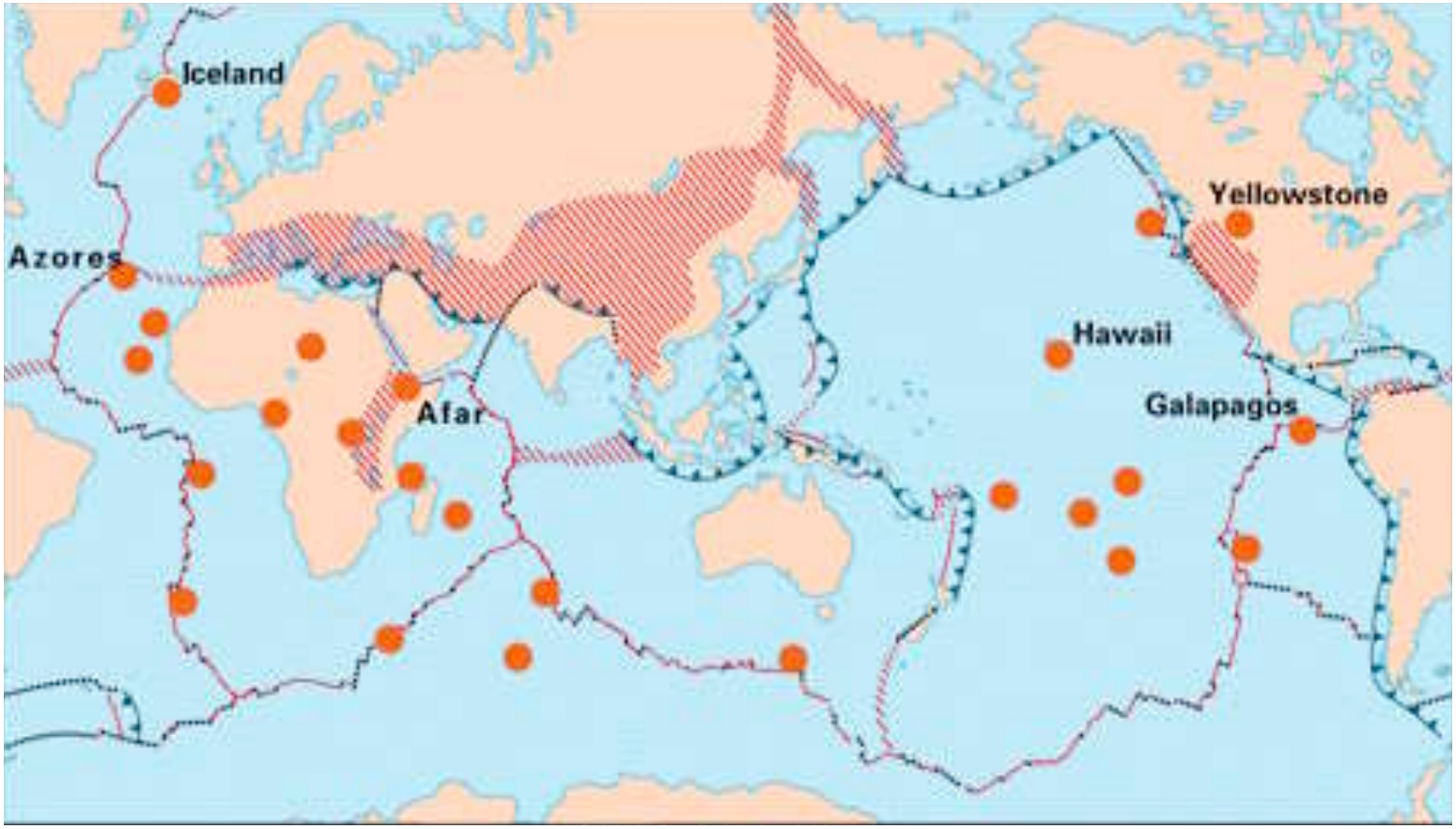
Woran man Plattengrenzen erkennen kann

7 grosse und 6 kleine Platten



dunkel: ozeanische Anteile
hell: kontinentale Anteile

Plattengrenzen und -grenzzonen



konstruktive / divergente Plattengrenze

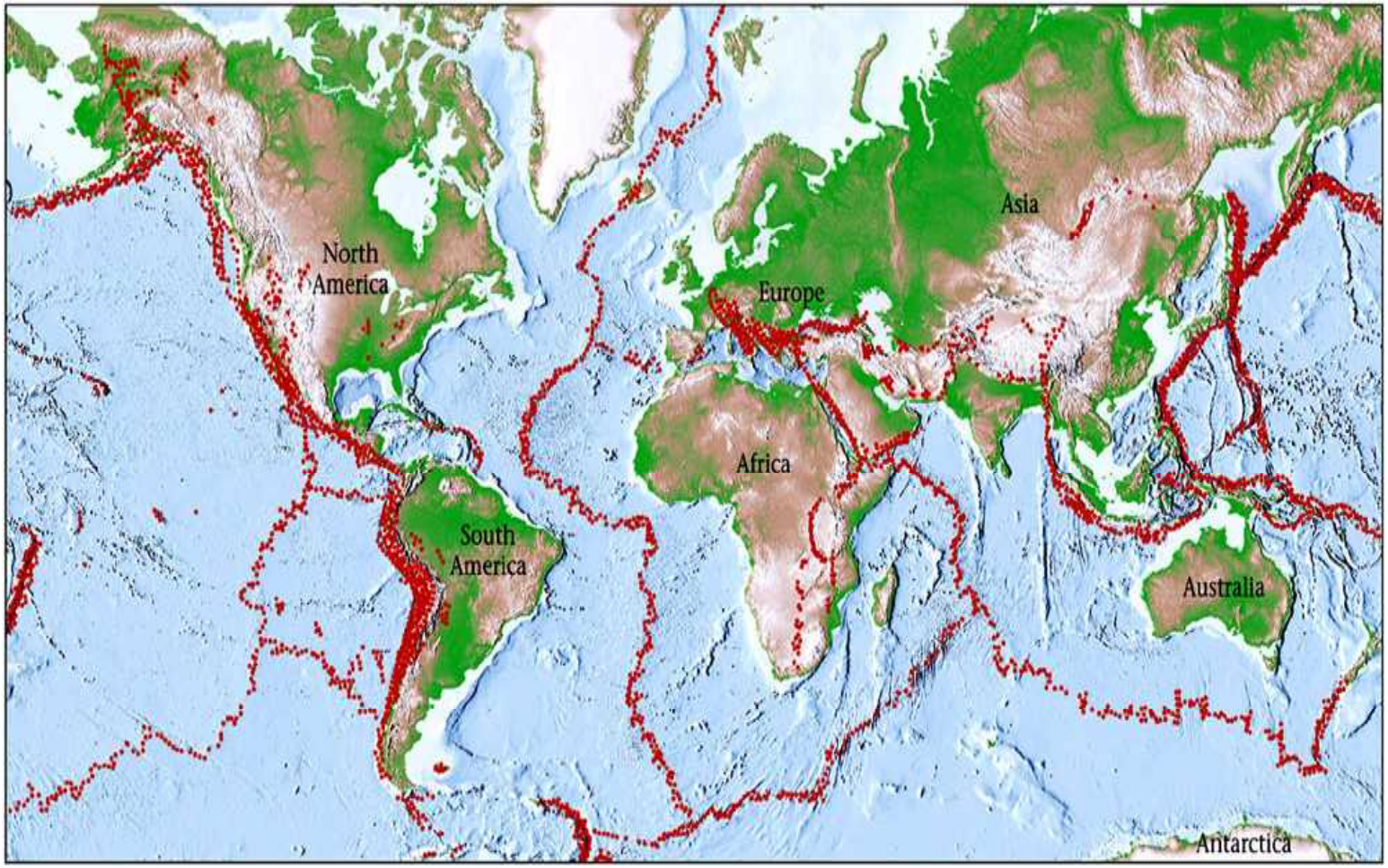
destruktive / konvergente Plattengrenze

konservative /Transform-Plattengrenze

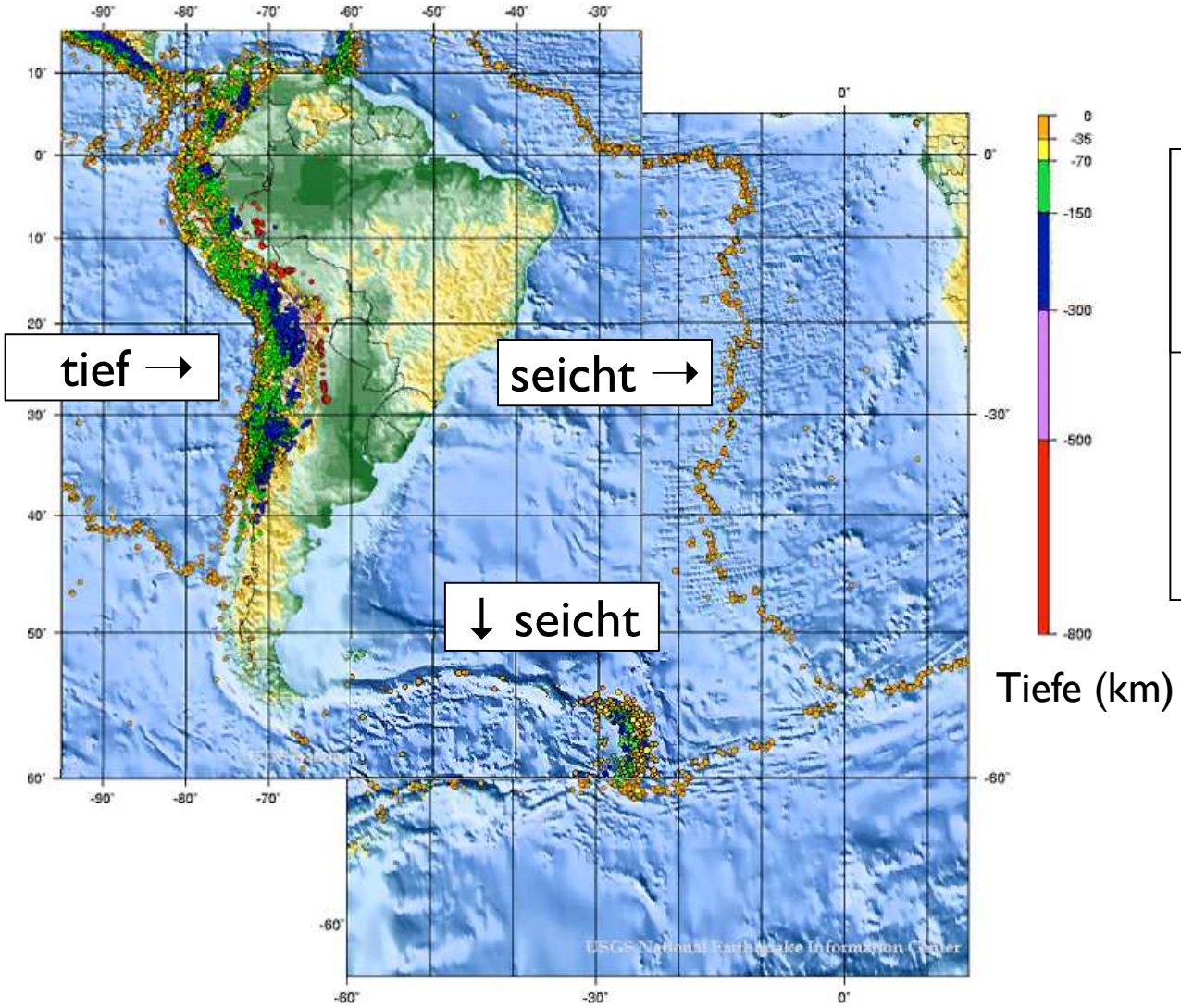
Platten - Grenzzonen

Hotspots

Erdbeben an Plattengrenzen



Chrakteristische Tiefe der Erdbeben

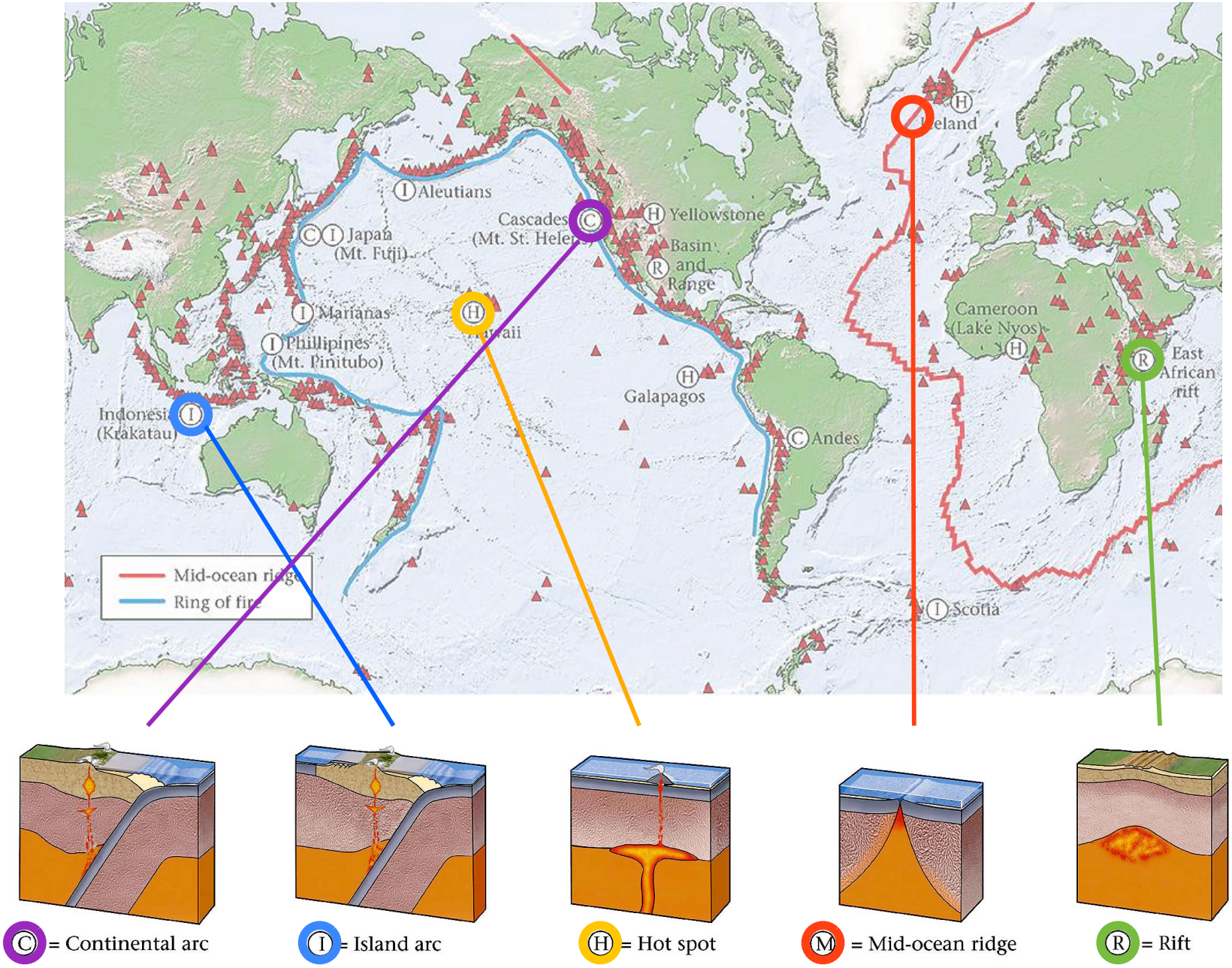


Typ Plattengrenze	Tiefe der Erdbeben
konstruktiv	seicht
destruktiv	tief
Transform	seicht

seicht: bis 50 km
tief: bis 700 km

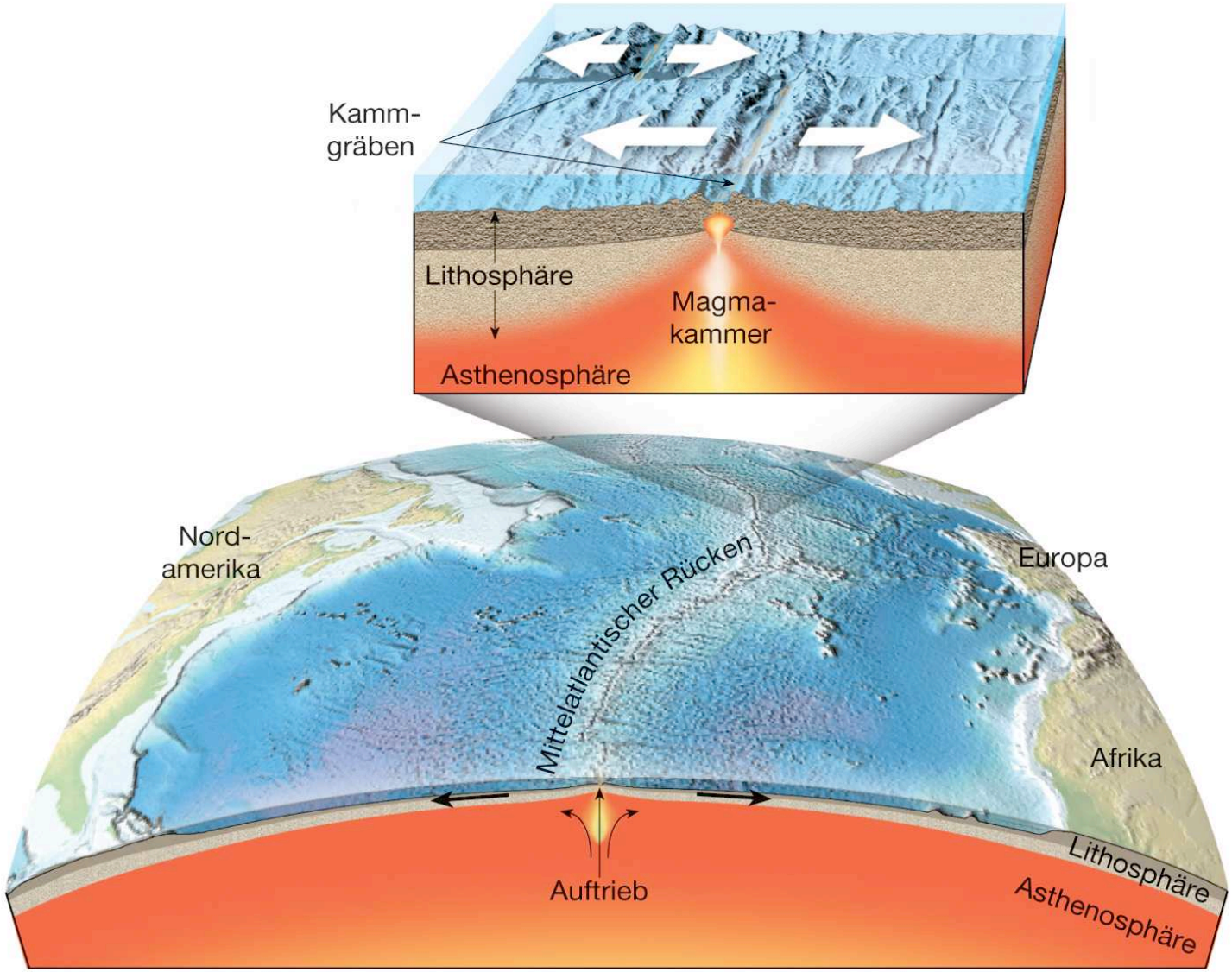
http://earthquake.usgs.gov/regional/world/seismicity/

Vulkanismus an Plattengrenzen



konstruktive Plattengrenzen

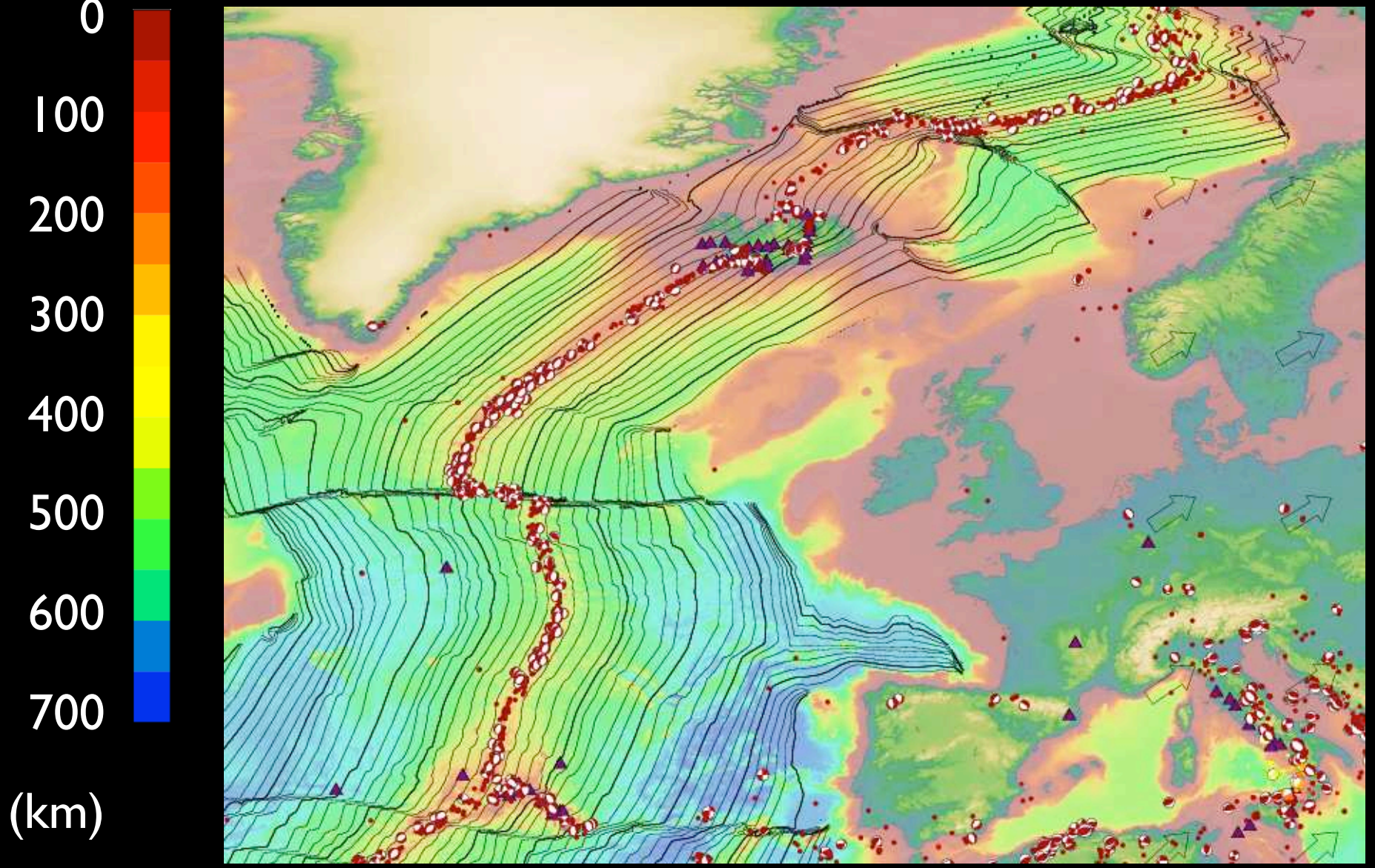
Konstruktive Plattengrenzen



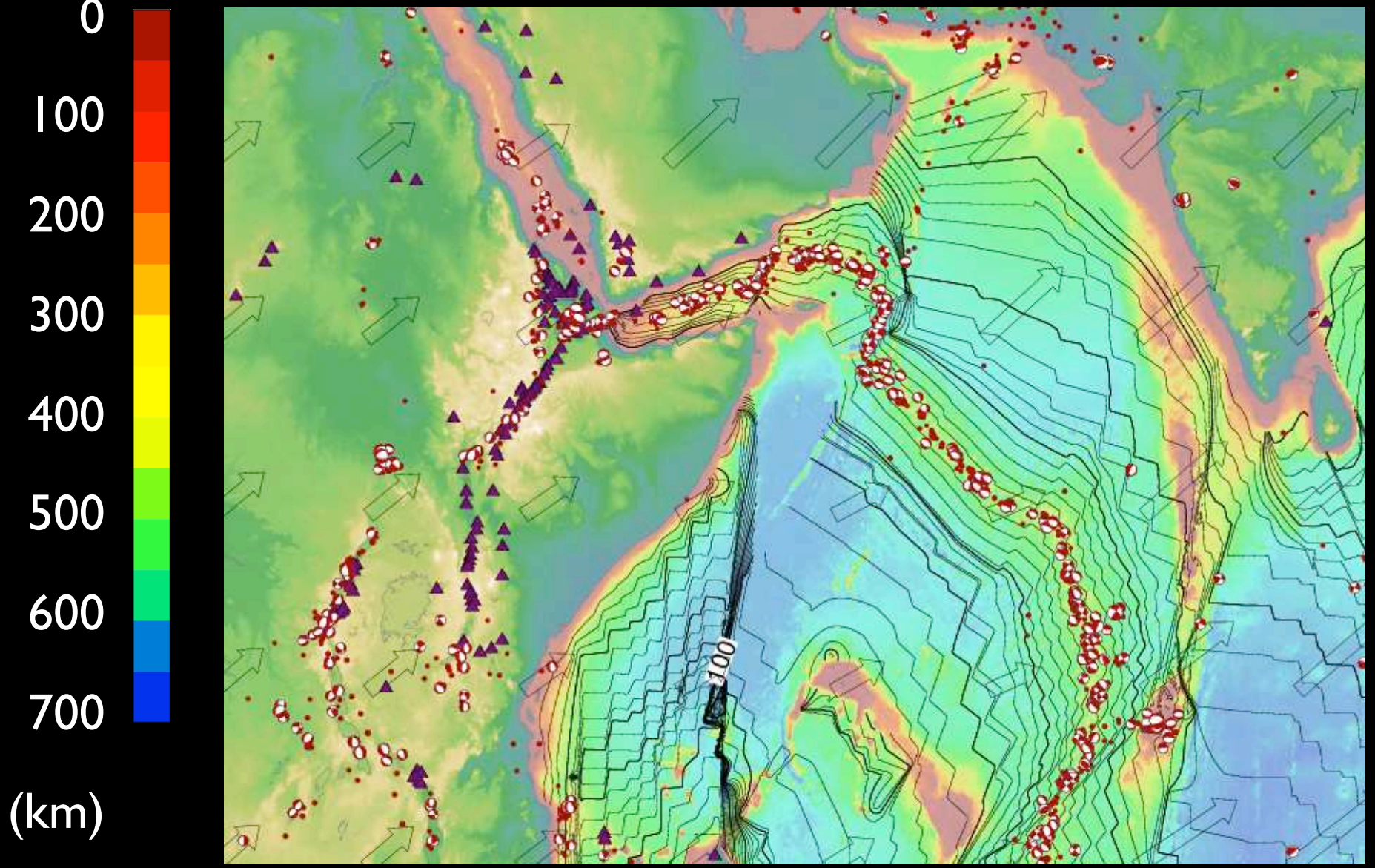
(physikalisch)
konstruktiv
=
(kinematisch)
divergent
=
(geometrisch)
distensiv

Abbildung 2.21: Die meisten divergenten Plattengrenzen befinden sich an den Kämmen der Ozeanischen Rücken.

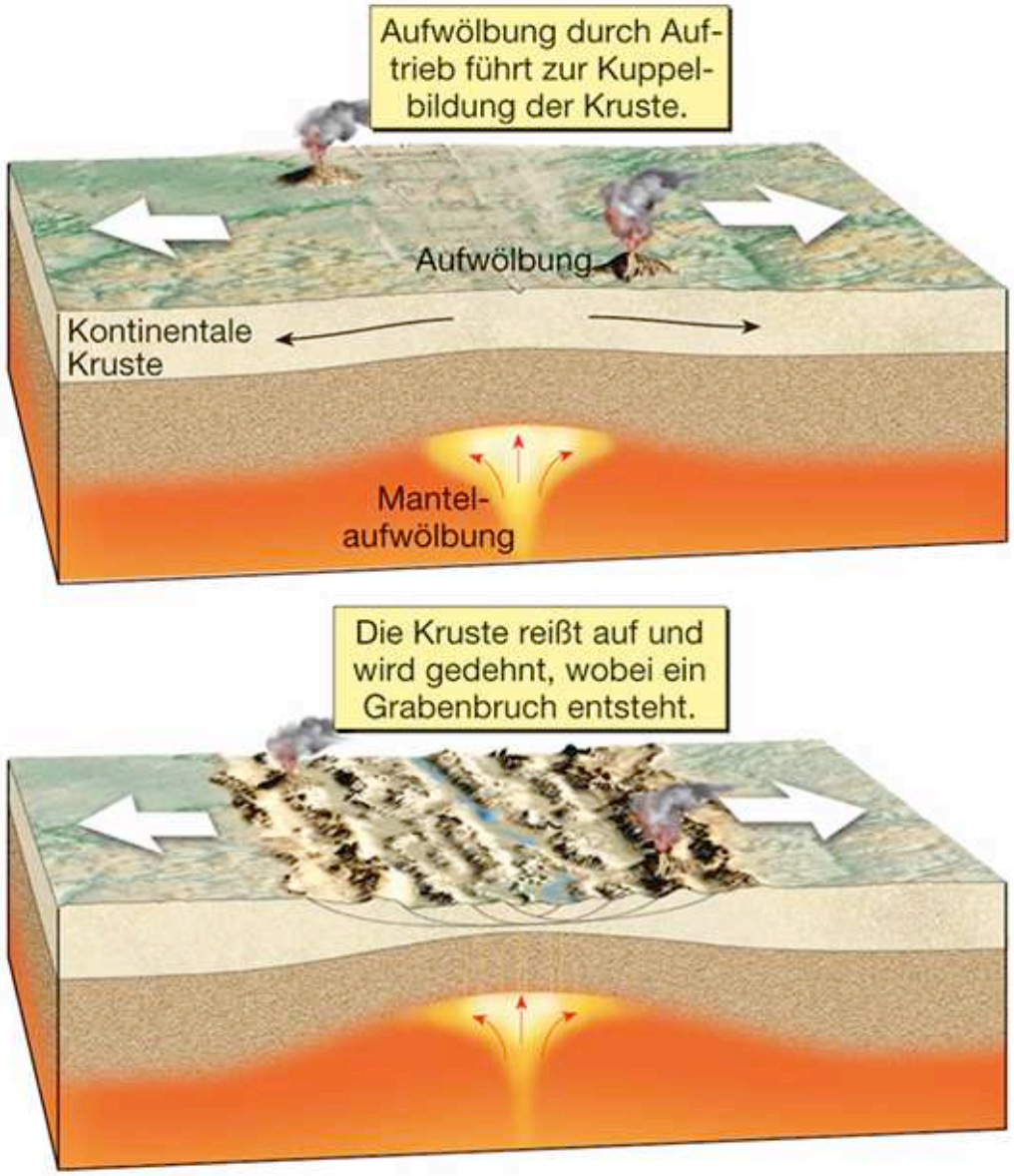
Konstruktive Plattengrenzen



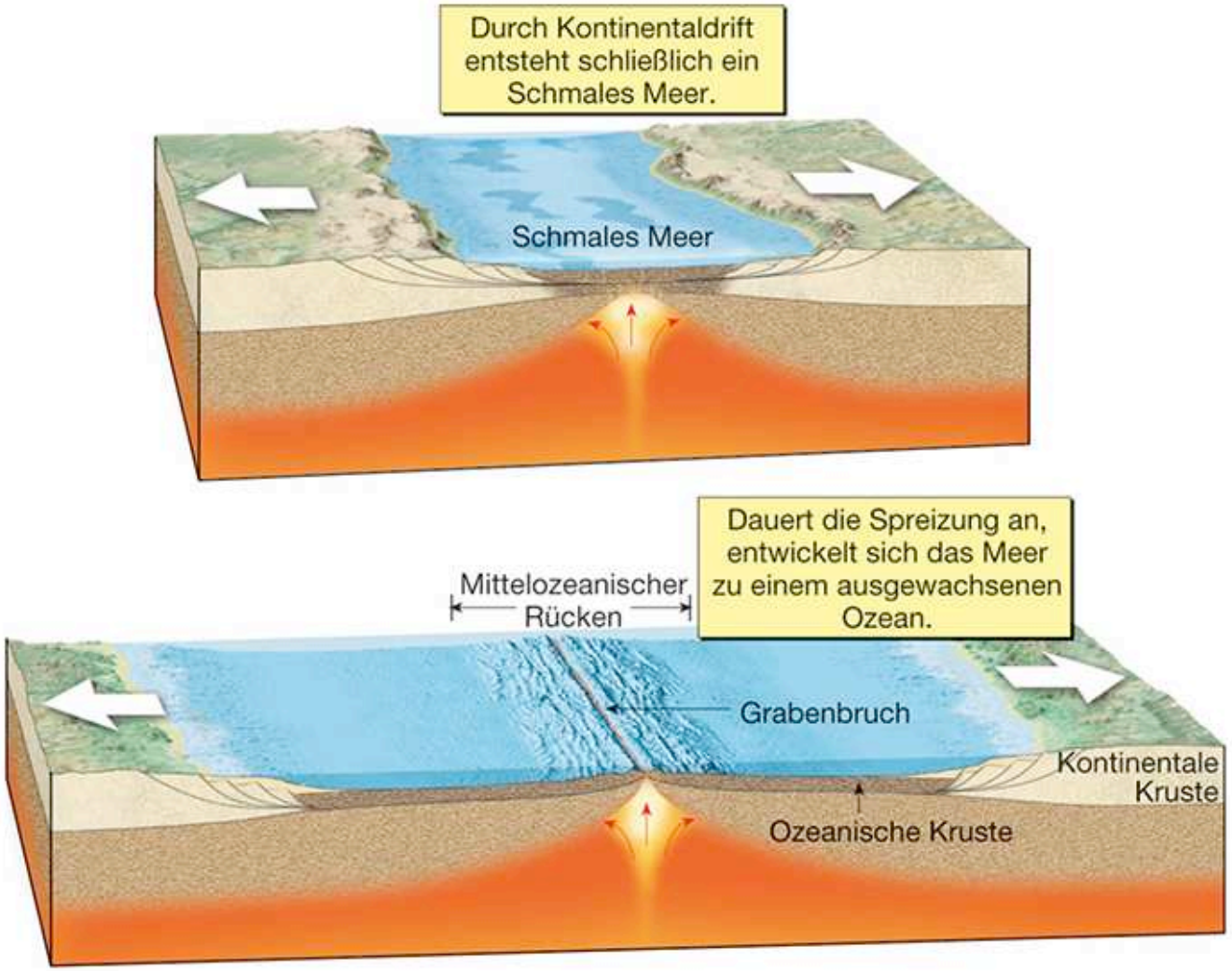
Konstruktive Plattengrenzen

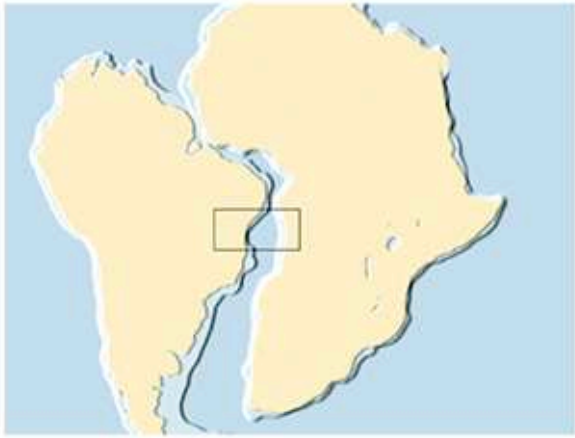


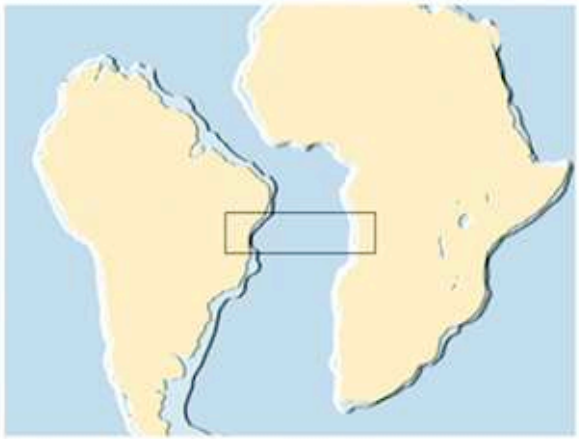
vom kontinentalen Grabenbruch ...



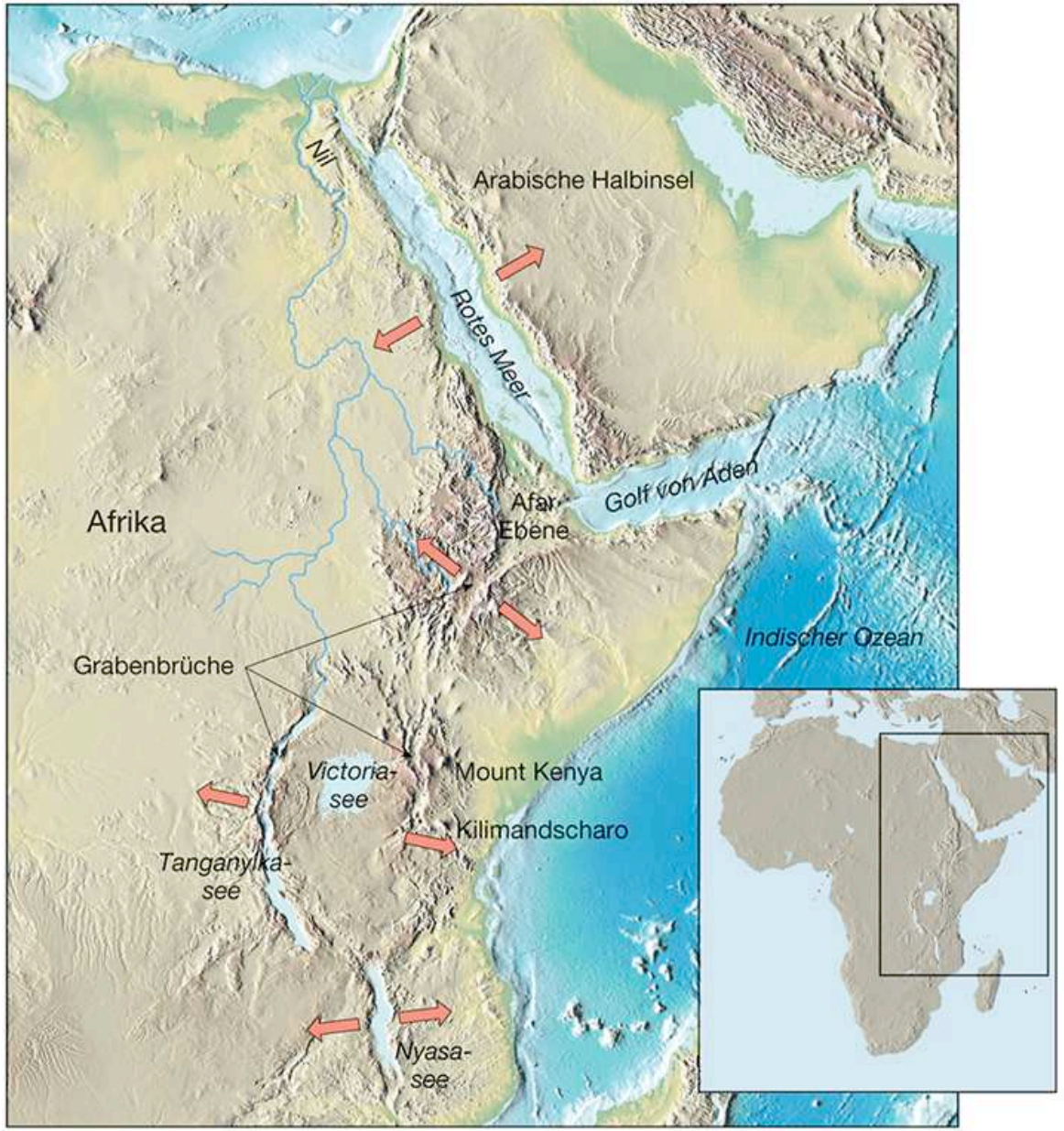
... zum Ozean


Durch Kontinentaldrift entsteht schließlich ein Schmales Meer.
Schmales Meer
Dauert die Spreizung an, entwickelt sich das Meer zu einem ausgewachsenen Ozean.
Mittelozeanischer Rücken
Grabenbruch
Kontinentale Kruste
Ozeanische Kruste





Beispiel: Ostafrikanischer Grabenbruch

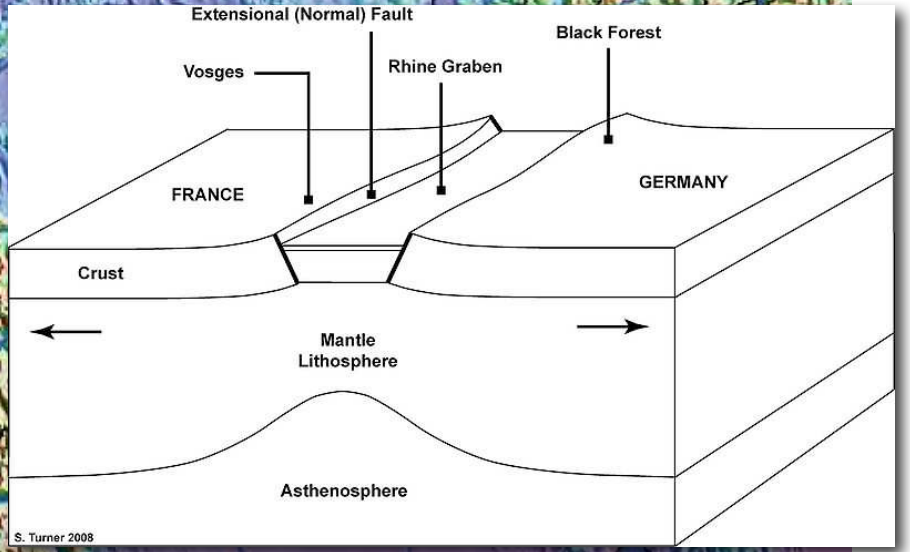


aktuell
aktiv

Beispiel: Rhein - Bresse Graben

Eozän - Miozän

Ära-them	System	Serie	≈ Alter (mya)
Käno-zoikum	Quartär	Holozän	0,0117–0
		Pleistozän	2,588–0,0117
	Neogen	Pliozän	5,332–2,588
		Miozän	23,03–5,332
	Paläogen	Oligozän	33,9–23,03
		Eozän	55,8–33,9
		Paläozän	65,5–55,8
tiefer	tiefer	tiefer	älter



http://en.wikipedia.org/wiki/File:Rhinegrabencross.jpg

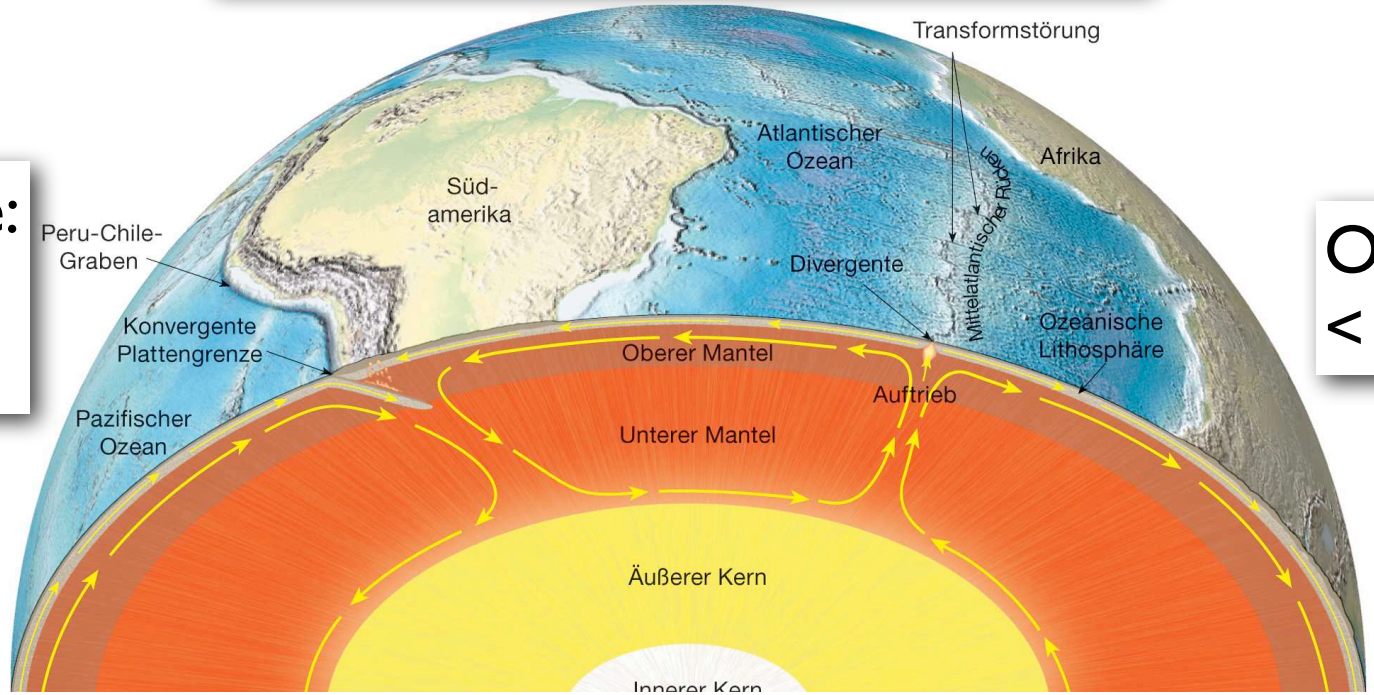
destruktive Plattengrenzen

wohin mit der Lithosphäre ?

Produzierte Fläche pro Jahr:
70 000 km ozeanische Rücken, 7cm / a spreading
$70 \cdot 10^6 \cdot 0.07 \approx 5 \cdot 10^6$ m^2 (≈ 5 km^2)
$= 10^{-8}$ Erdoberfläche

Verdoppelung in 100 Ma !!

Kontinente:
4.5 Ga
konstant



Ozeane :
< 180 Ma

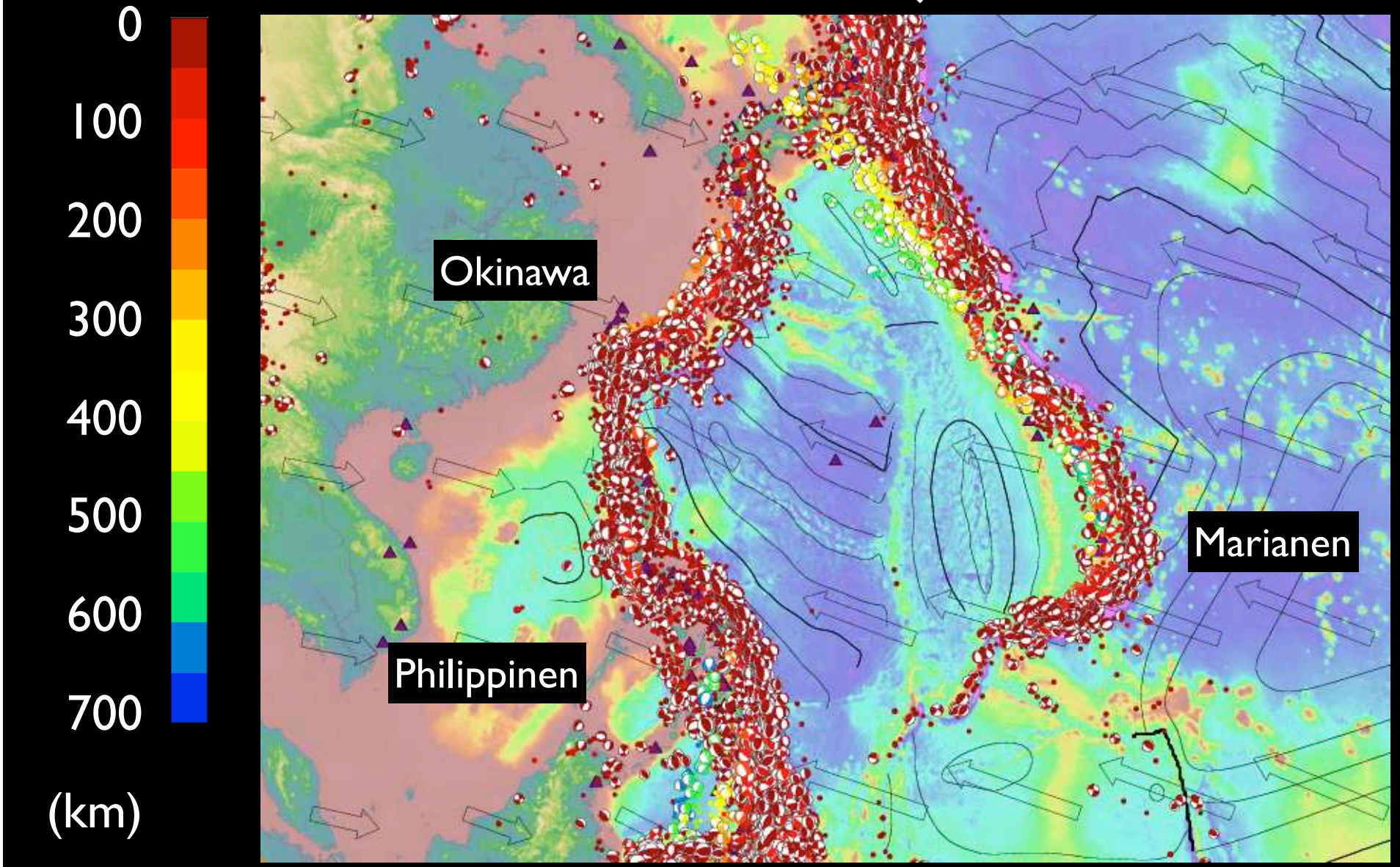
Plattengrenzen: 3 Typen

konstruktive	distensive
destruktive	kompressive
konservative	Transform-

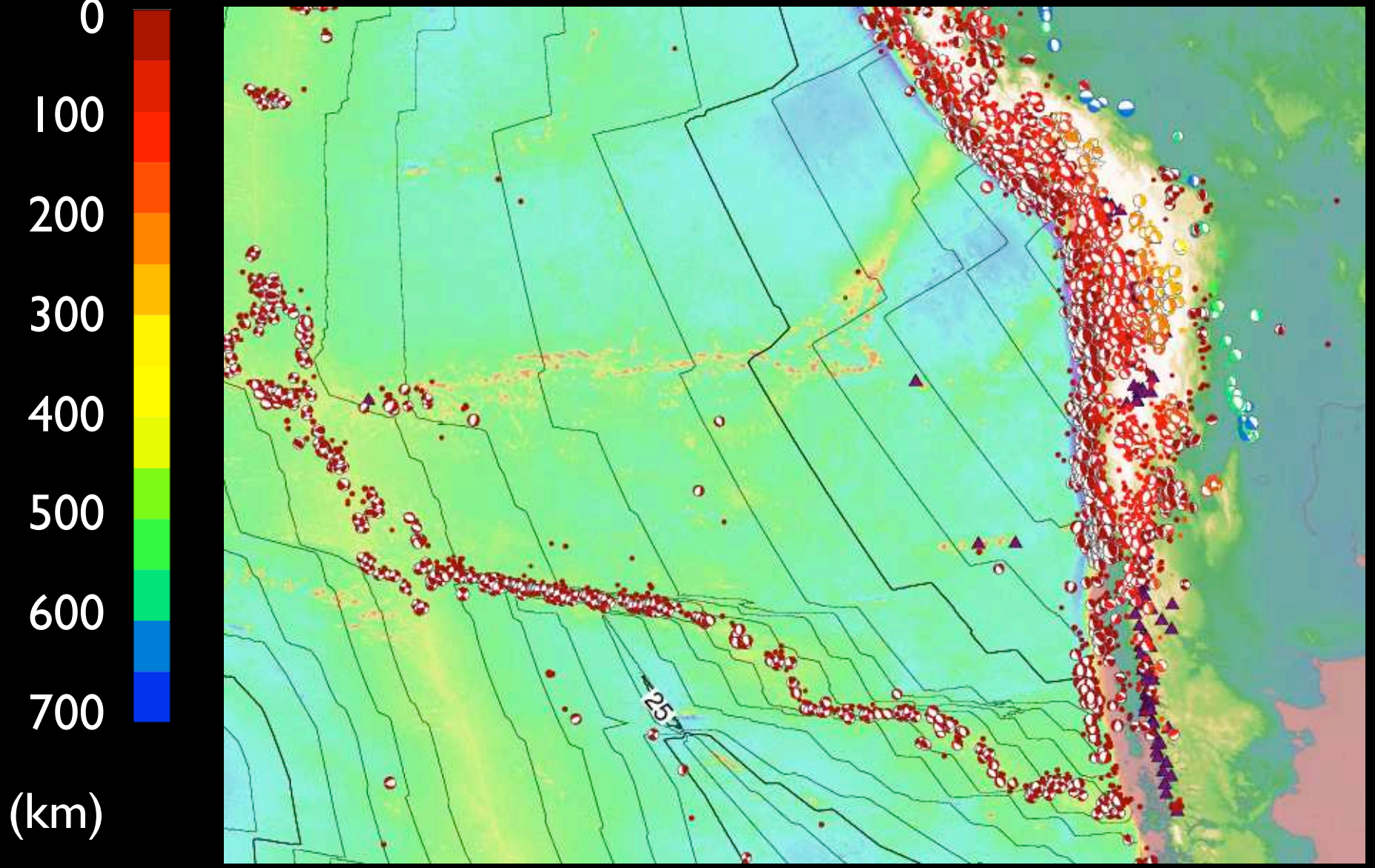
destruktive Plattengrenzen: 3 Typen

Ozean	Ozean
Ozean	Kontinent
Kontinent	Kontinent

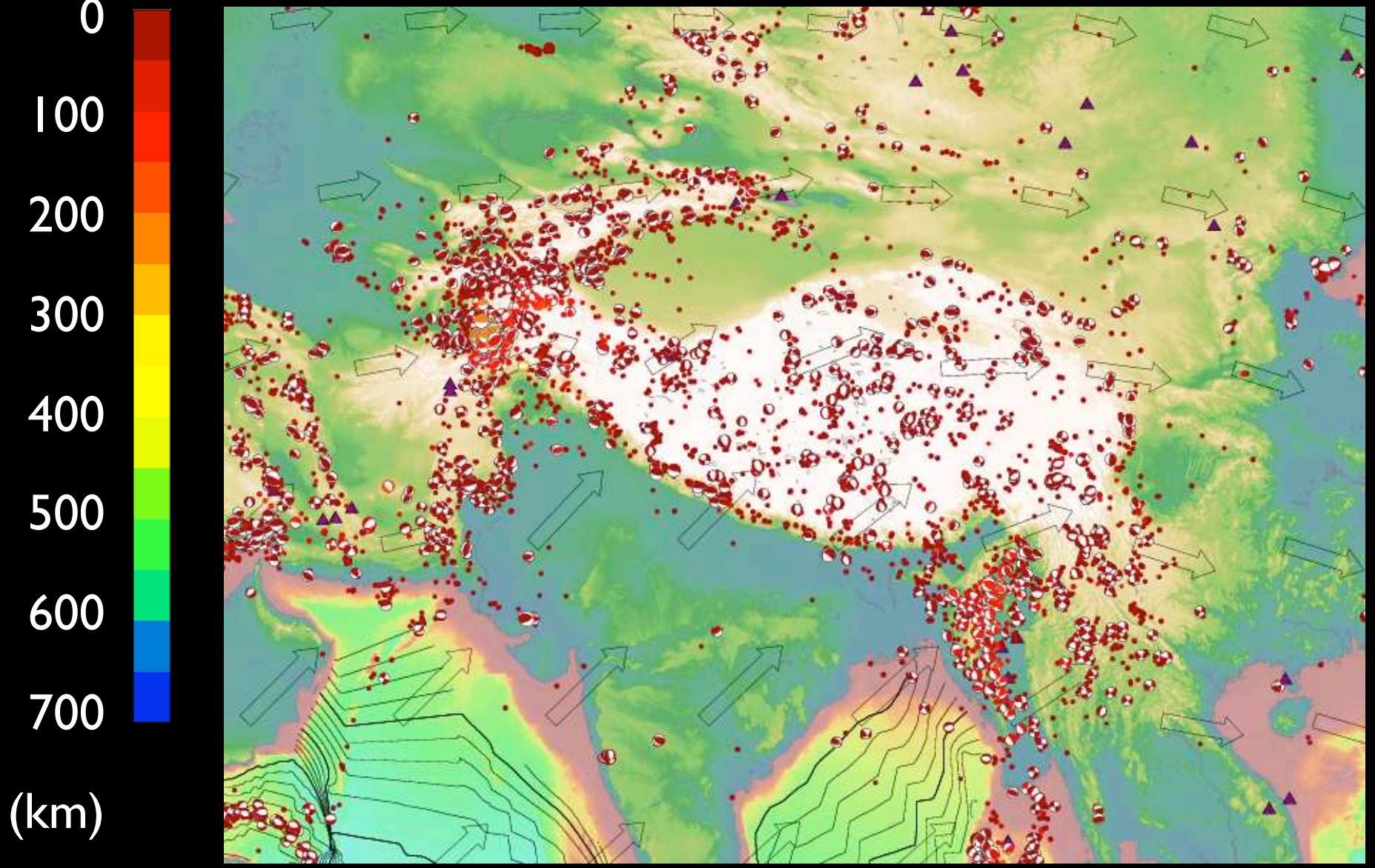
Ozean - Ozean


Mt Fuji
0
100
200
300
400
500
600
700
(km)
Okinawa
Philippinen
Marianen

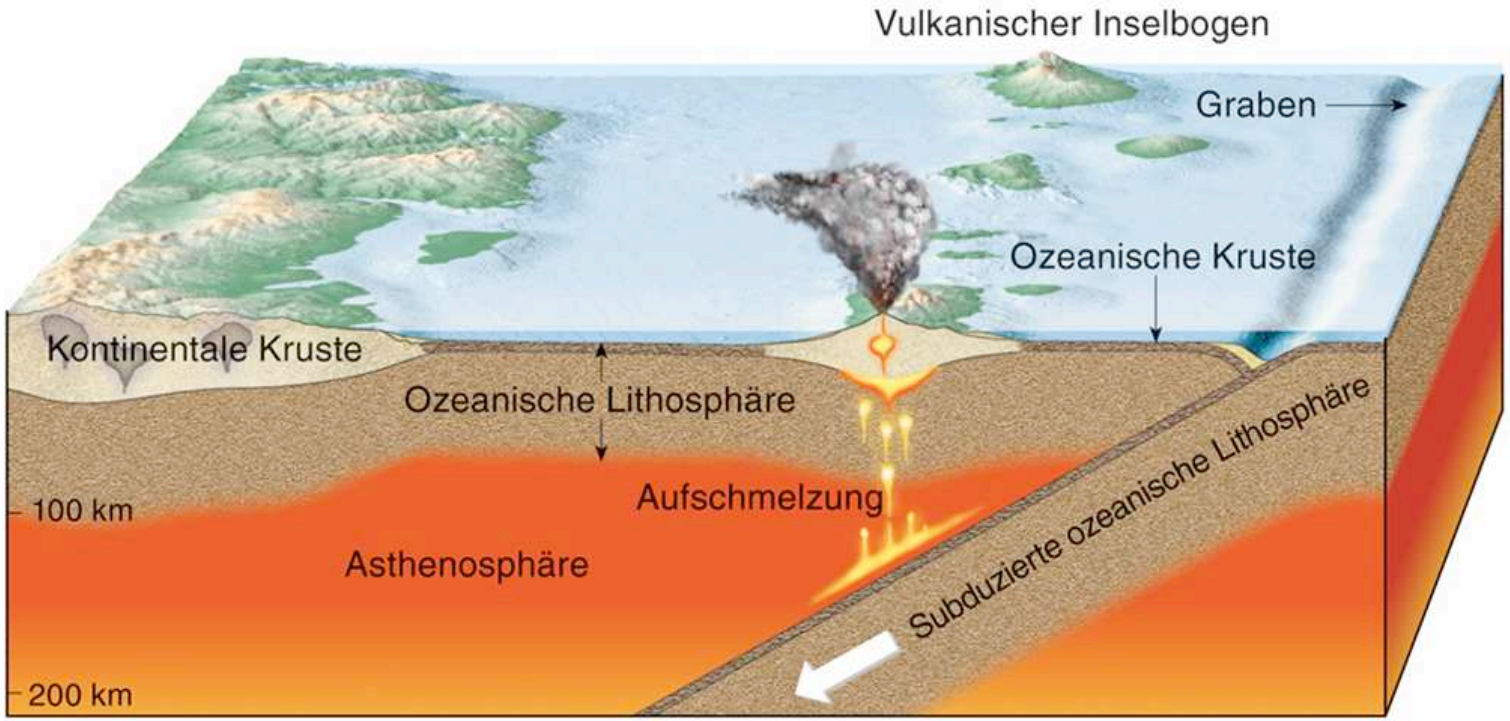
Ozean - Kontinent



Kontinent - Kontinent

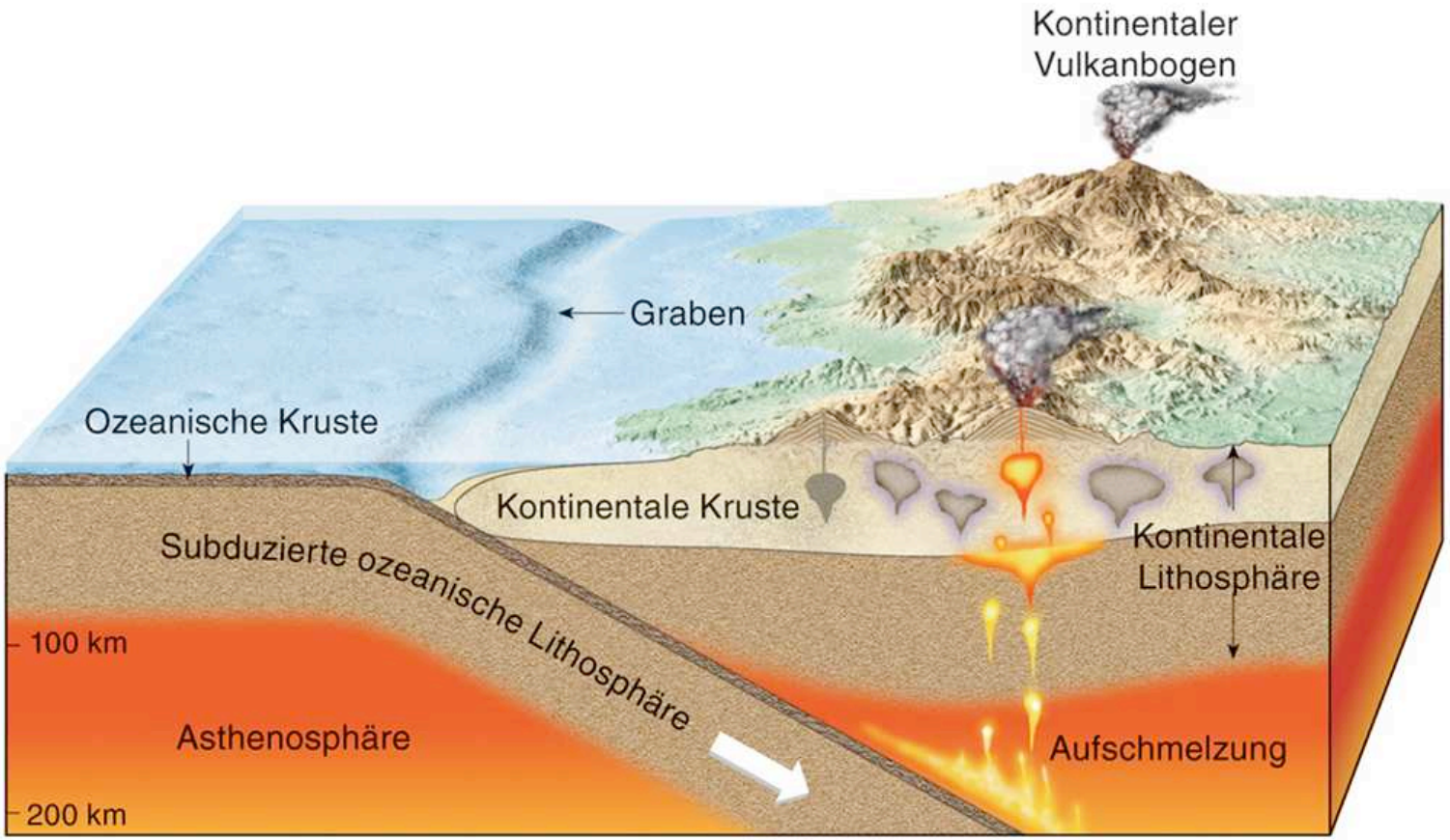


Ozean - Ozean



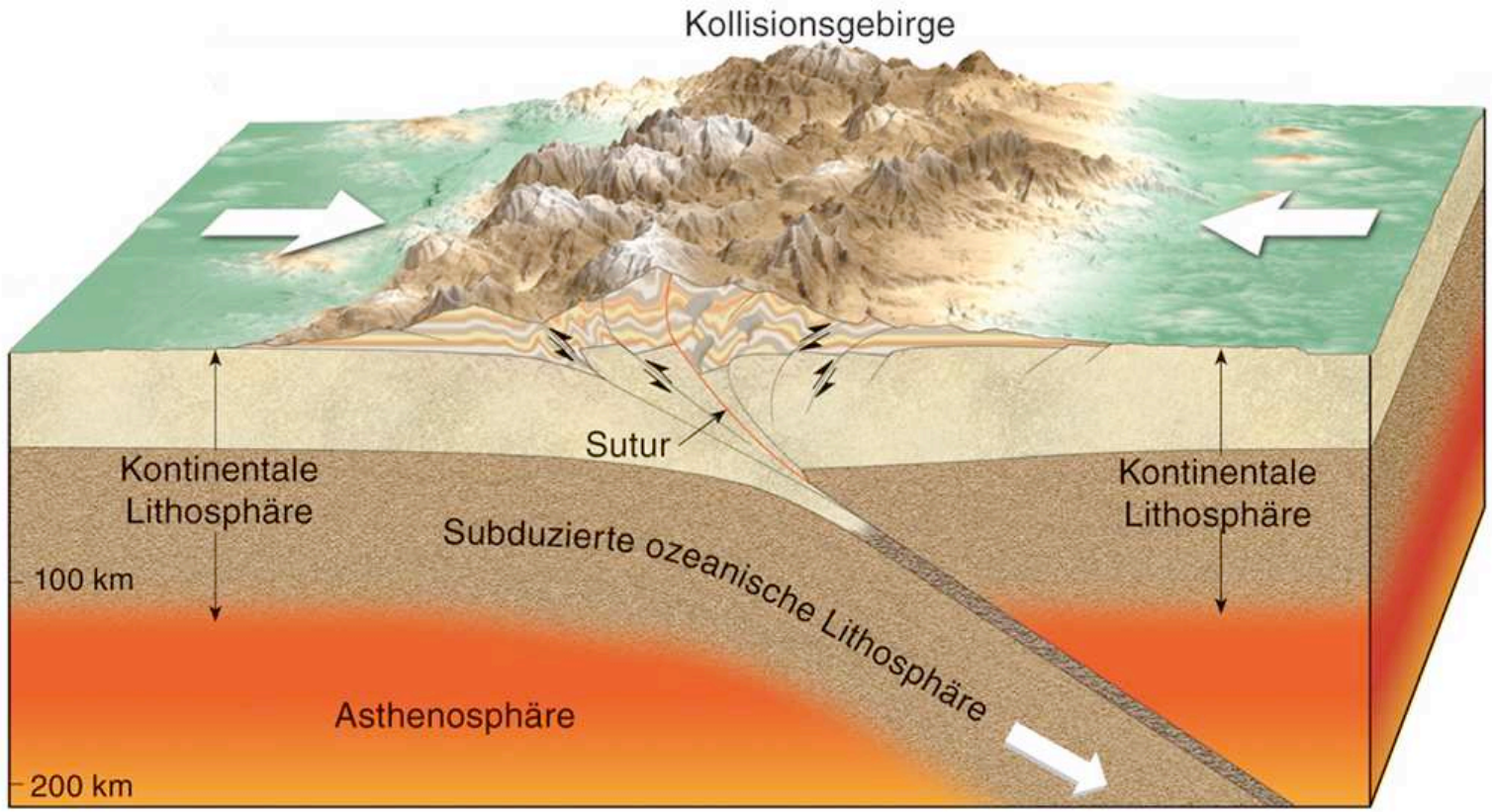
dichtere Platte sinkt hinunter
Vulkanismus am Ozenanboden
Vulkanische Inselbögen: Japan, Aleuten, Tonga

Ozean - Kontinent



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

Kontinent - Kontinent

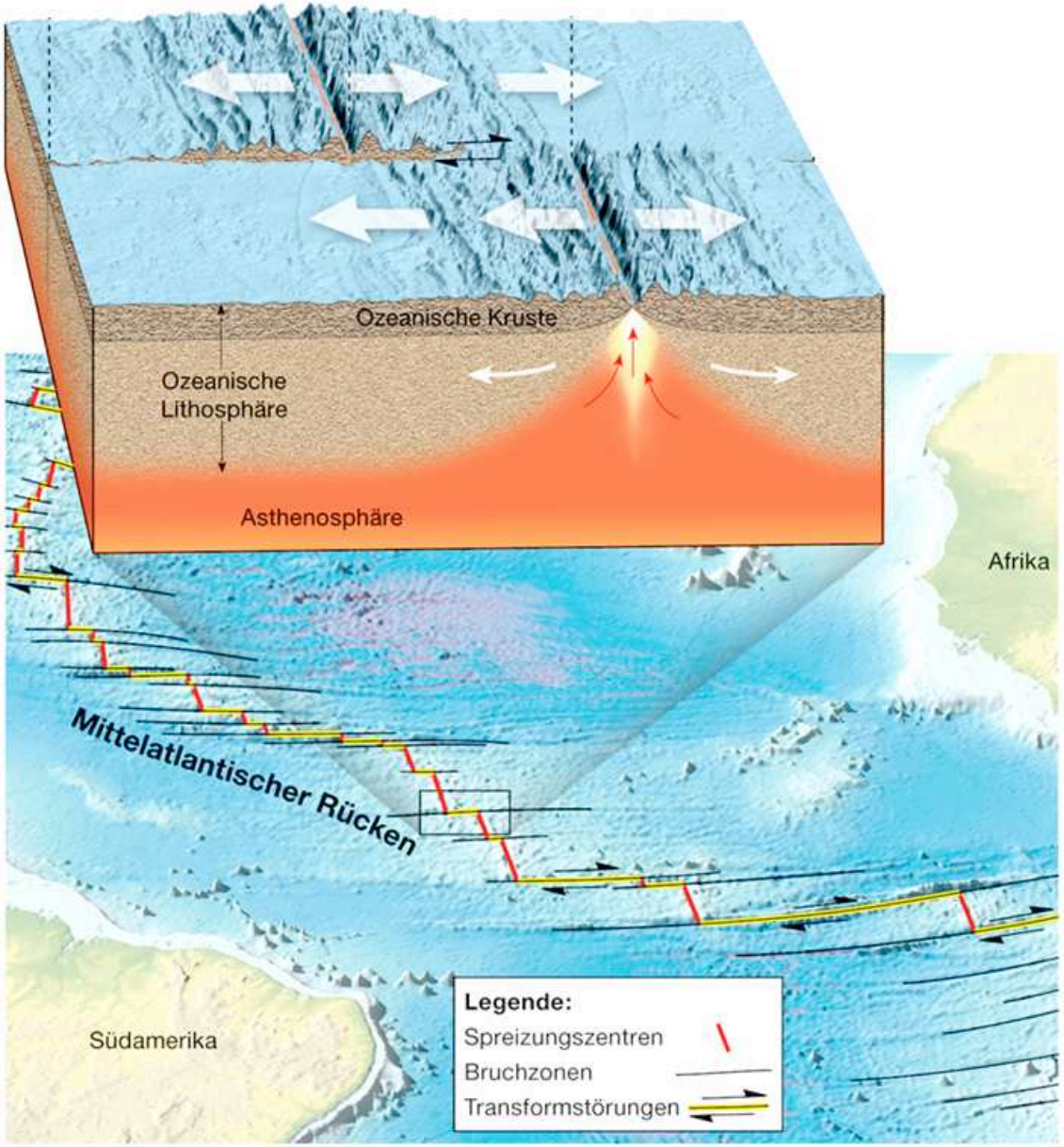


Fortgesetzte Subduktion → kontinentale Kollision
dichtere Platte wird subduziert
Kollisionsgebirge: Himalaya, Alpen, Appalachen

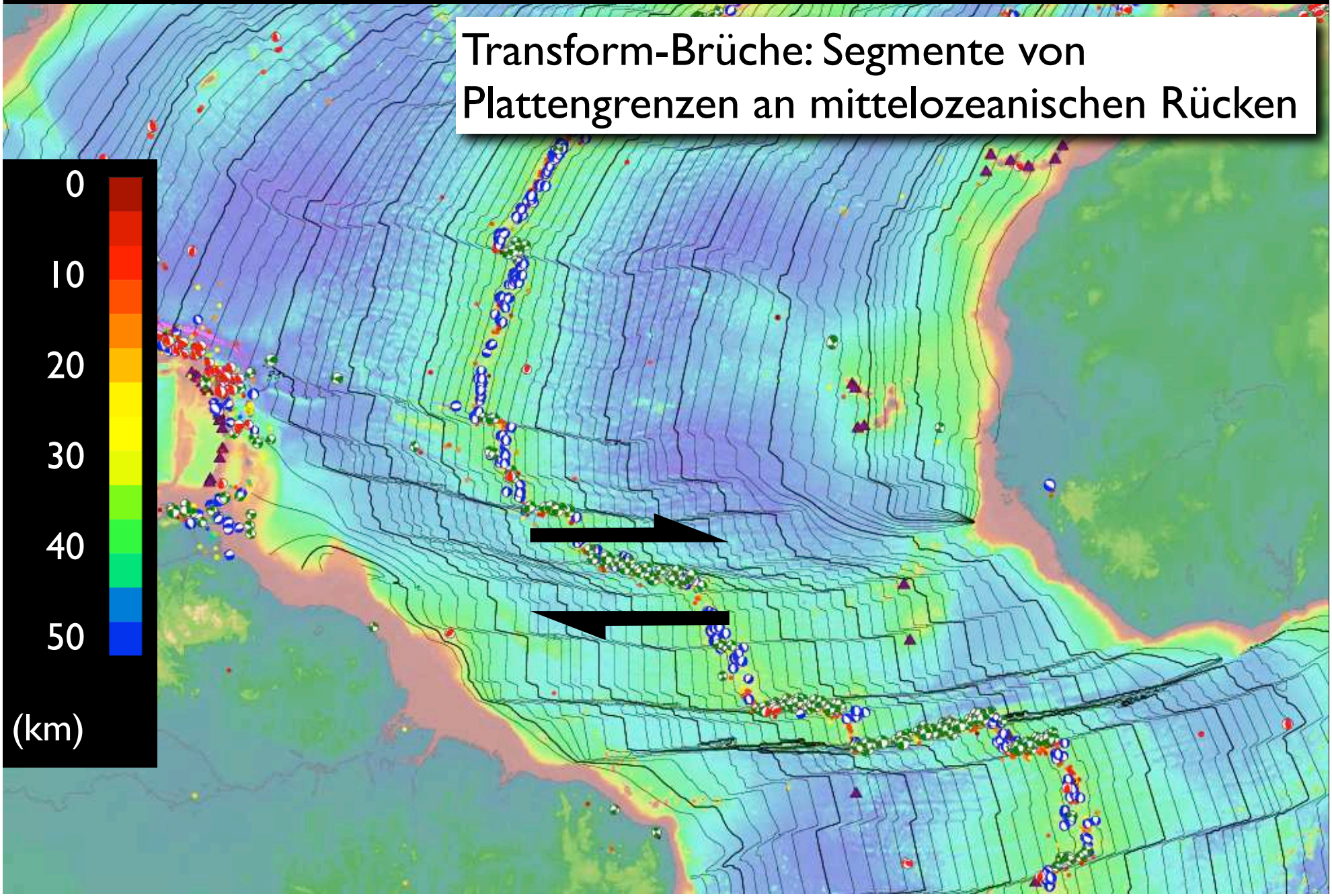
konservative (Transform-) Plattengrenzen

Konservative Plattengrenzen

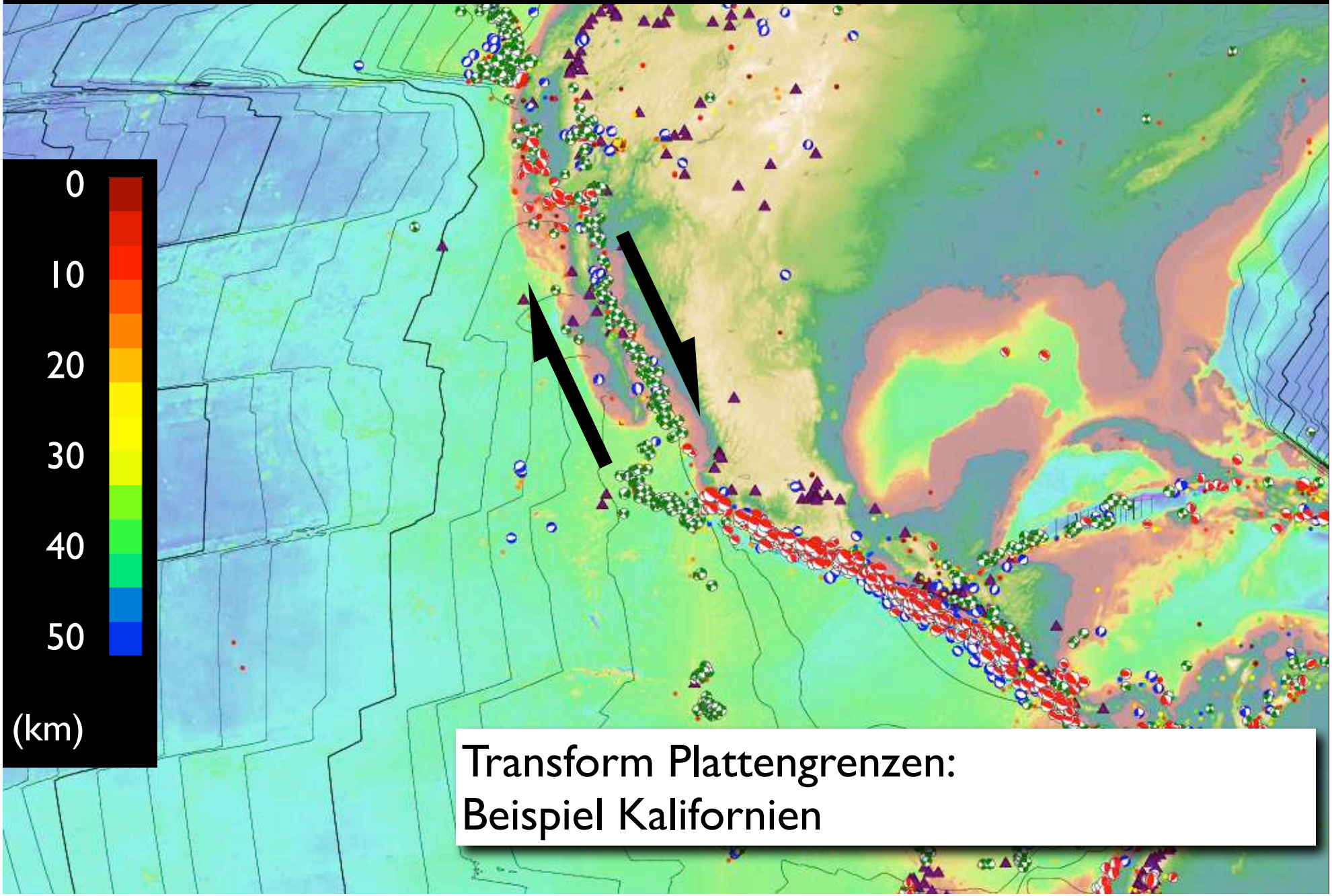
Transformbrüche
Transformstörungen



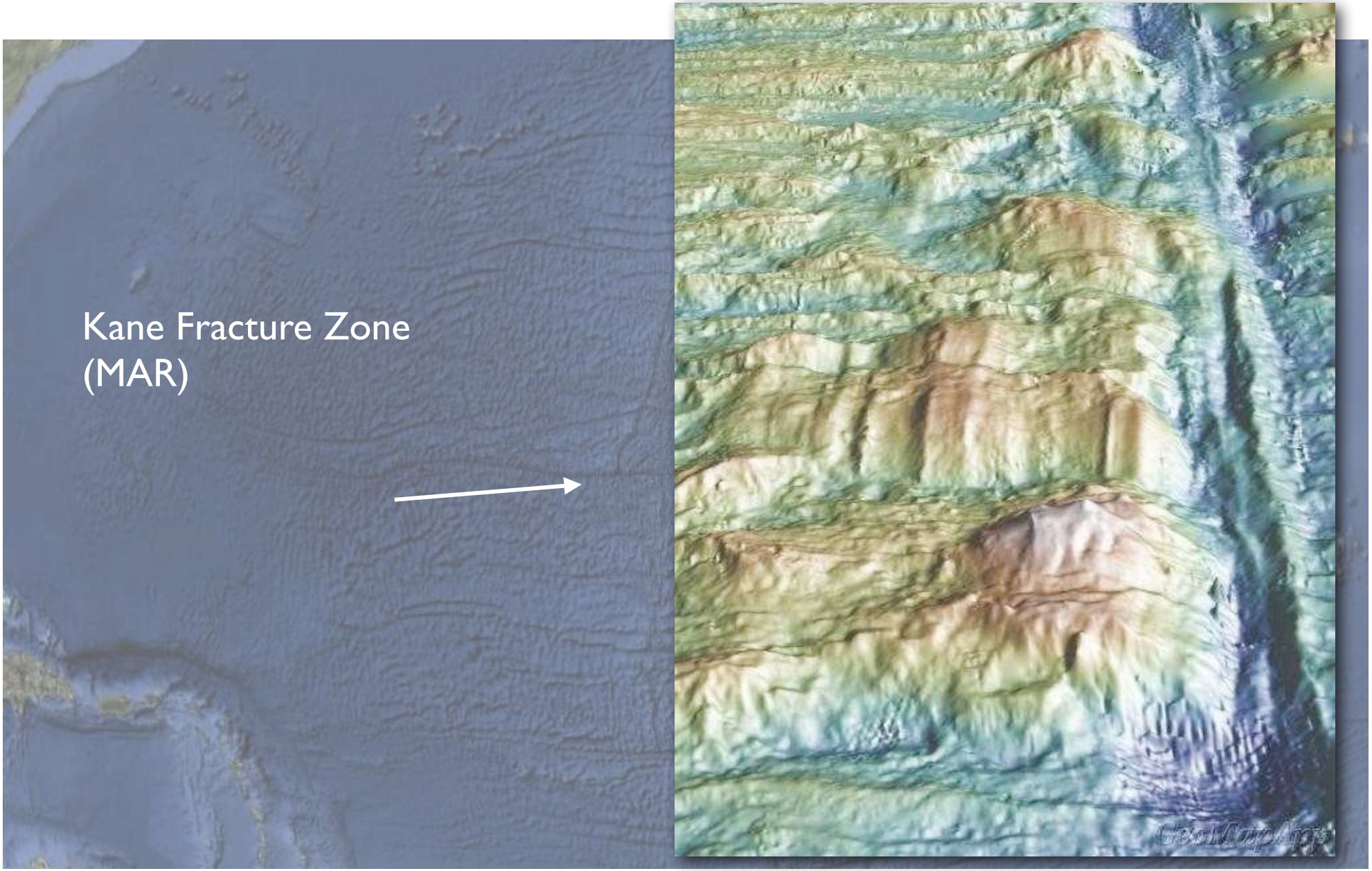
Konservative Plattengrenze



Konservative Plattengrenze

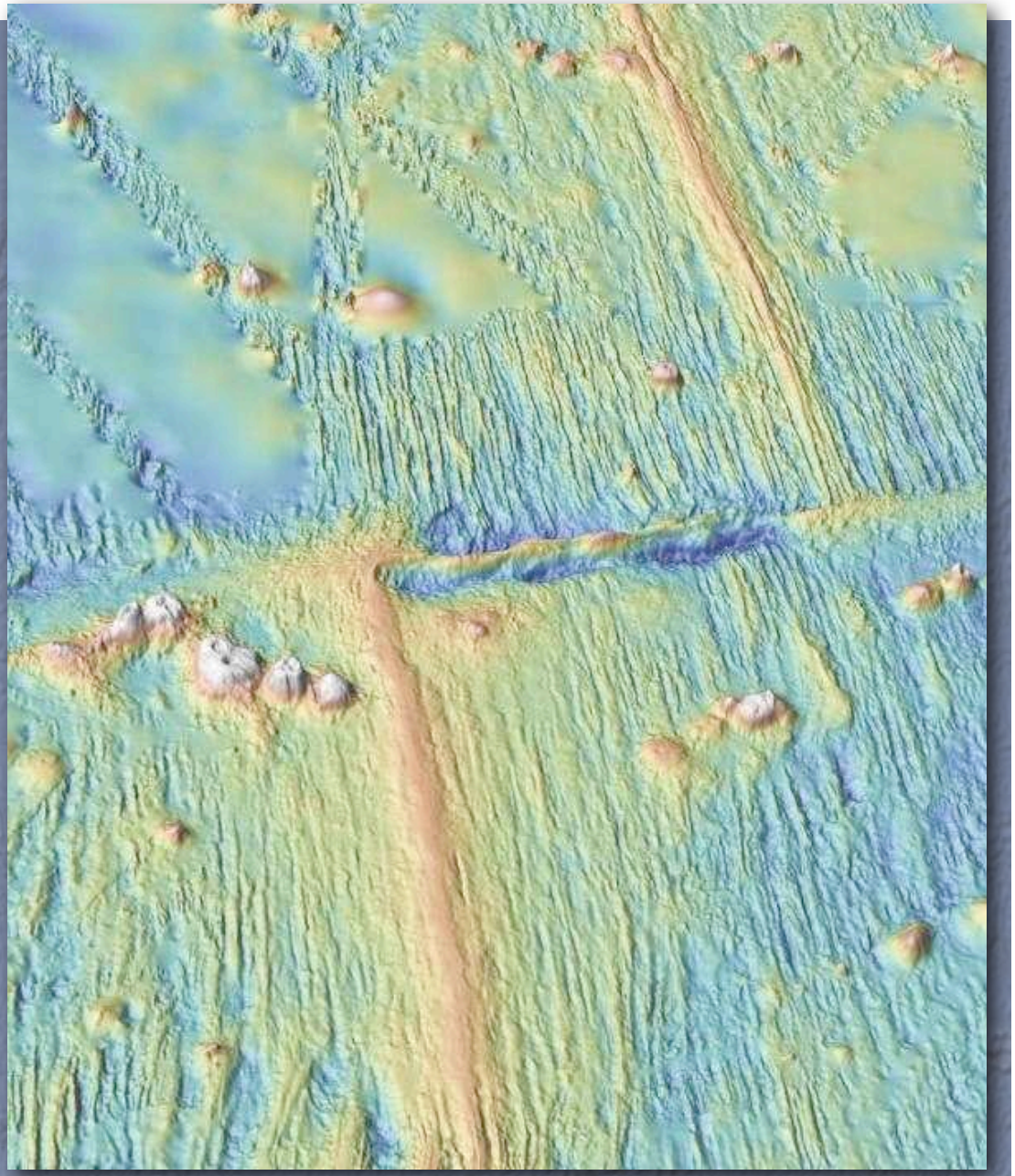


Transformbruch



Transformbruch

East Pacific Rise



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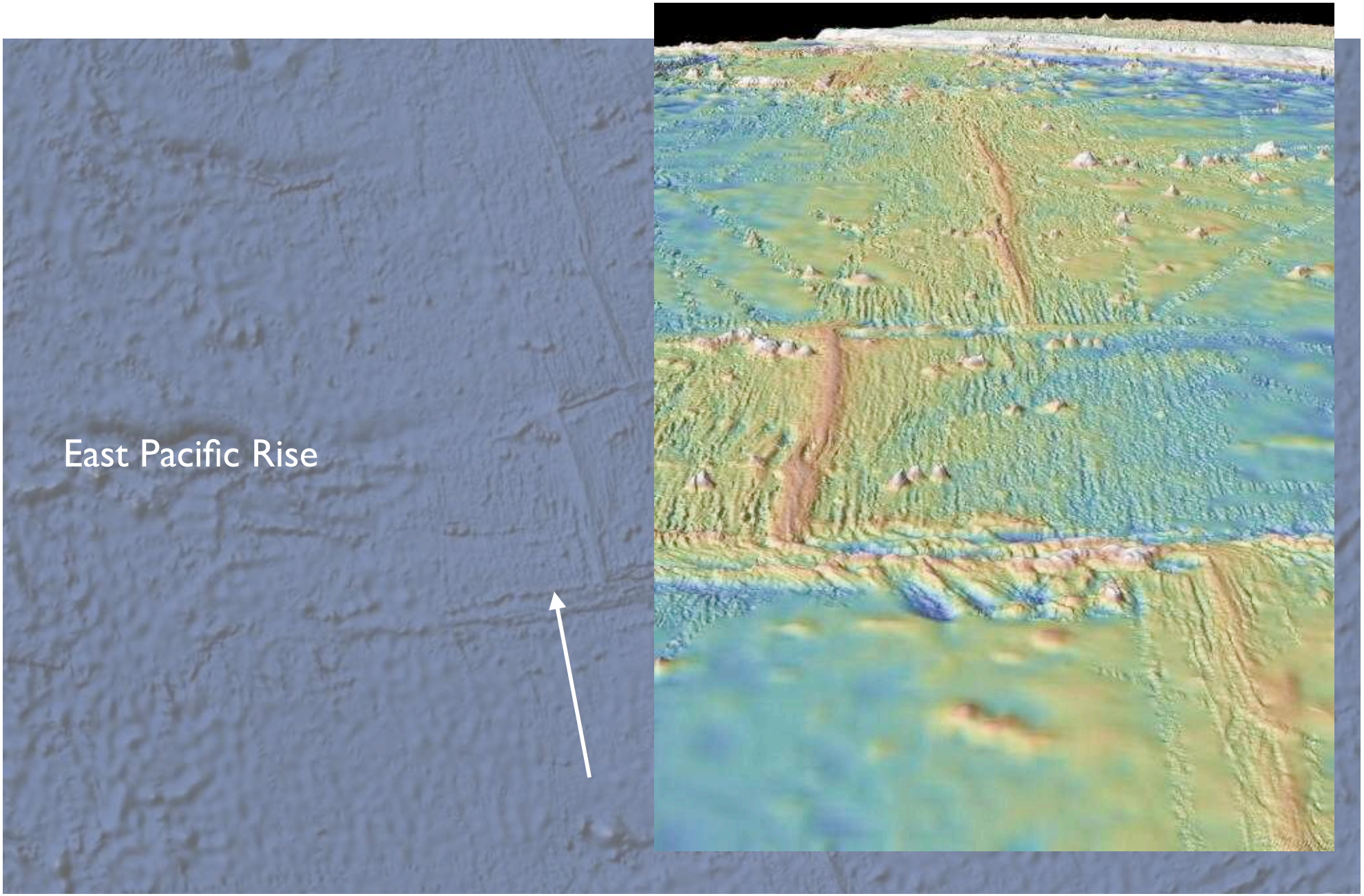
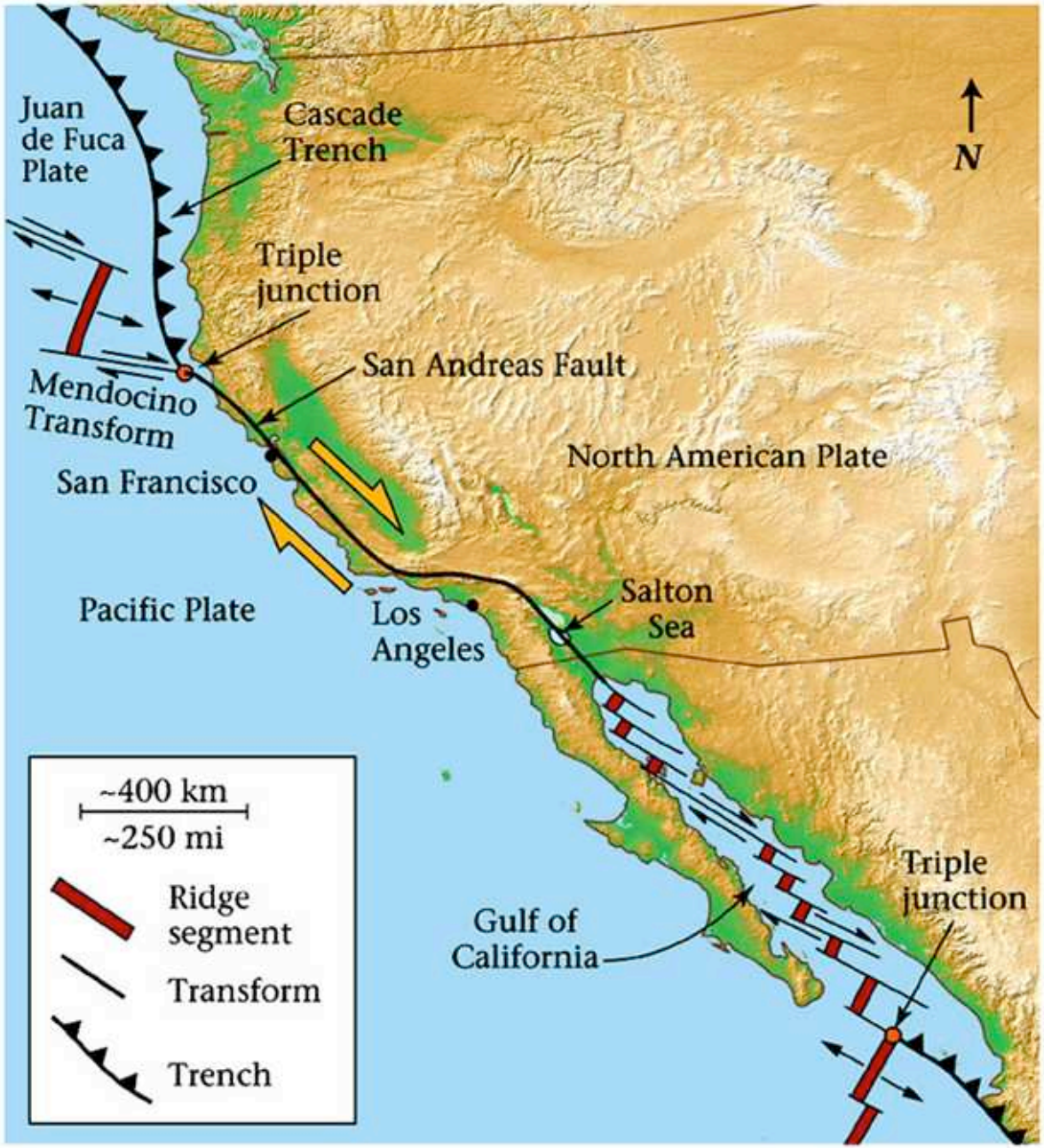
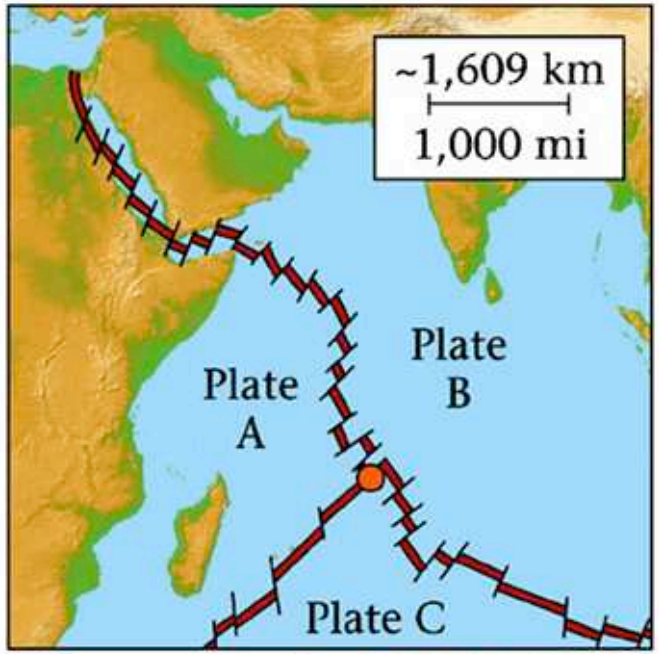
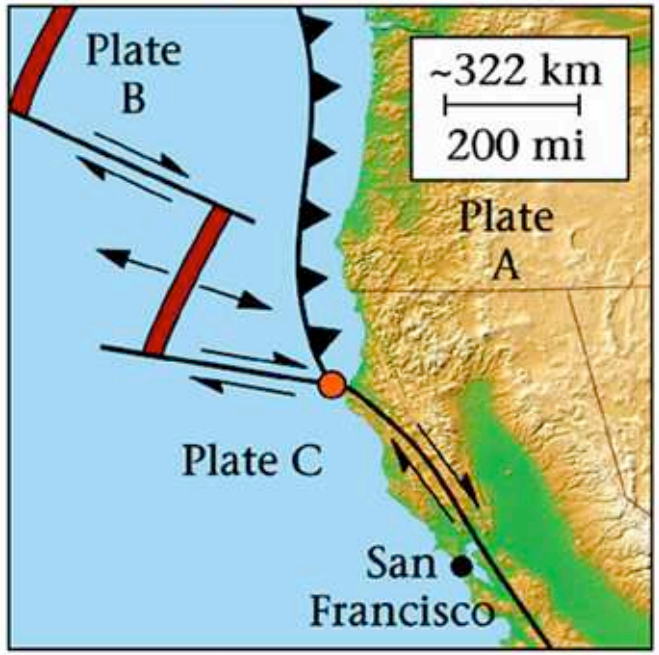


Transform - Plattengrenzen

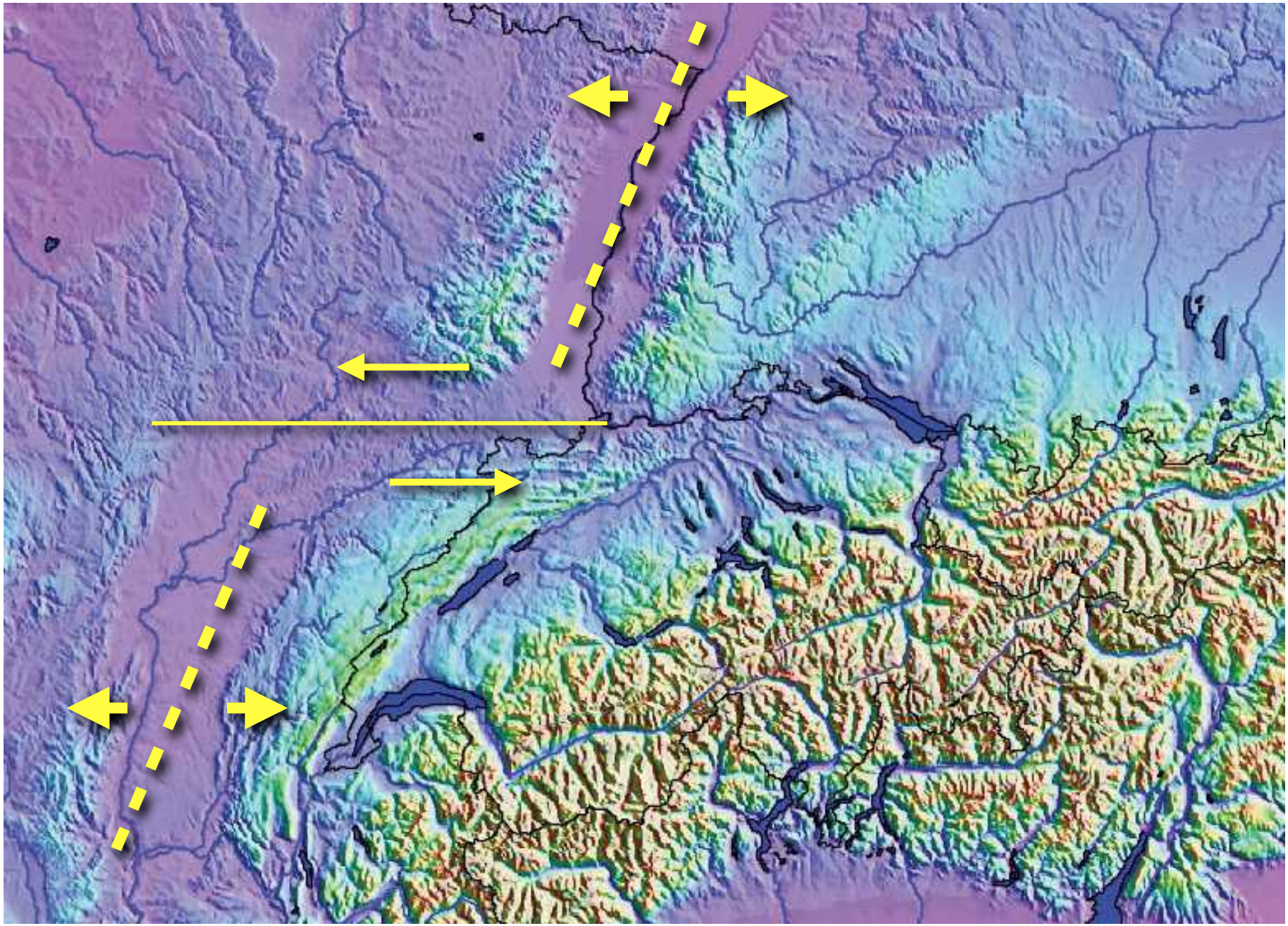






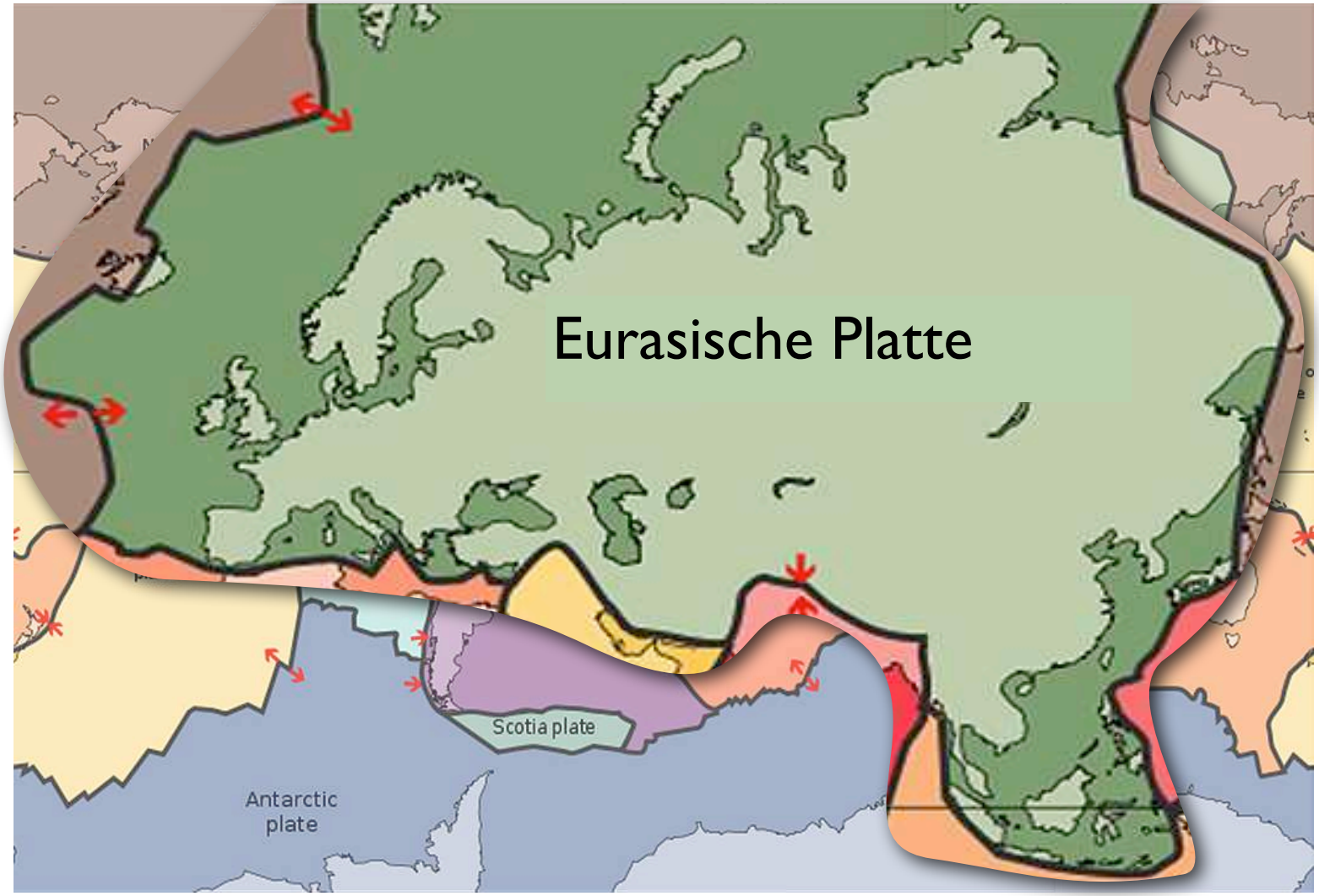
San Andreas Fault, California

Transform Rhein- Bresse- Graben



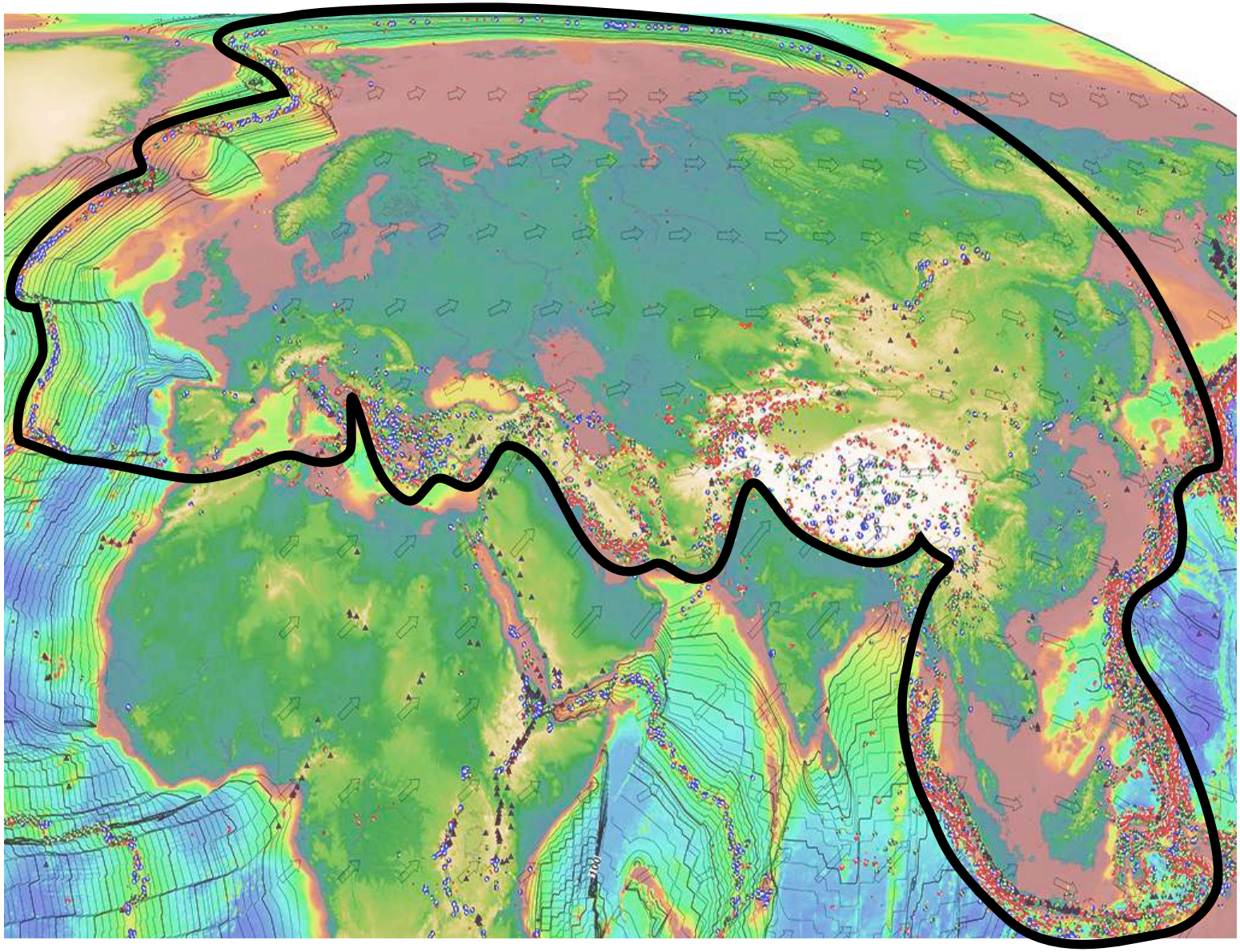
Eurasia - "unsere Platte"

Eurasische Platte

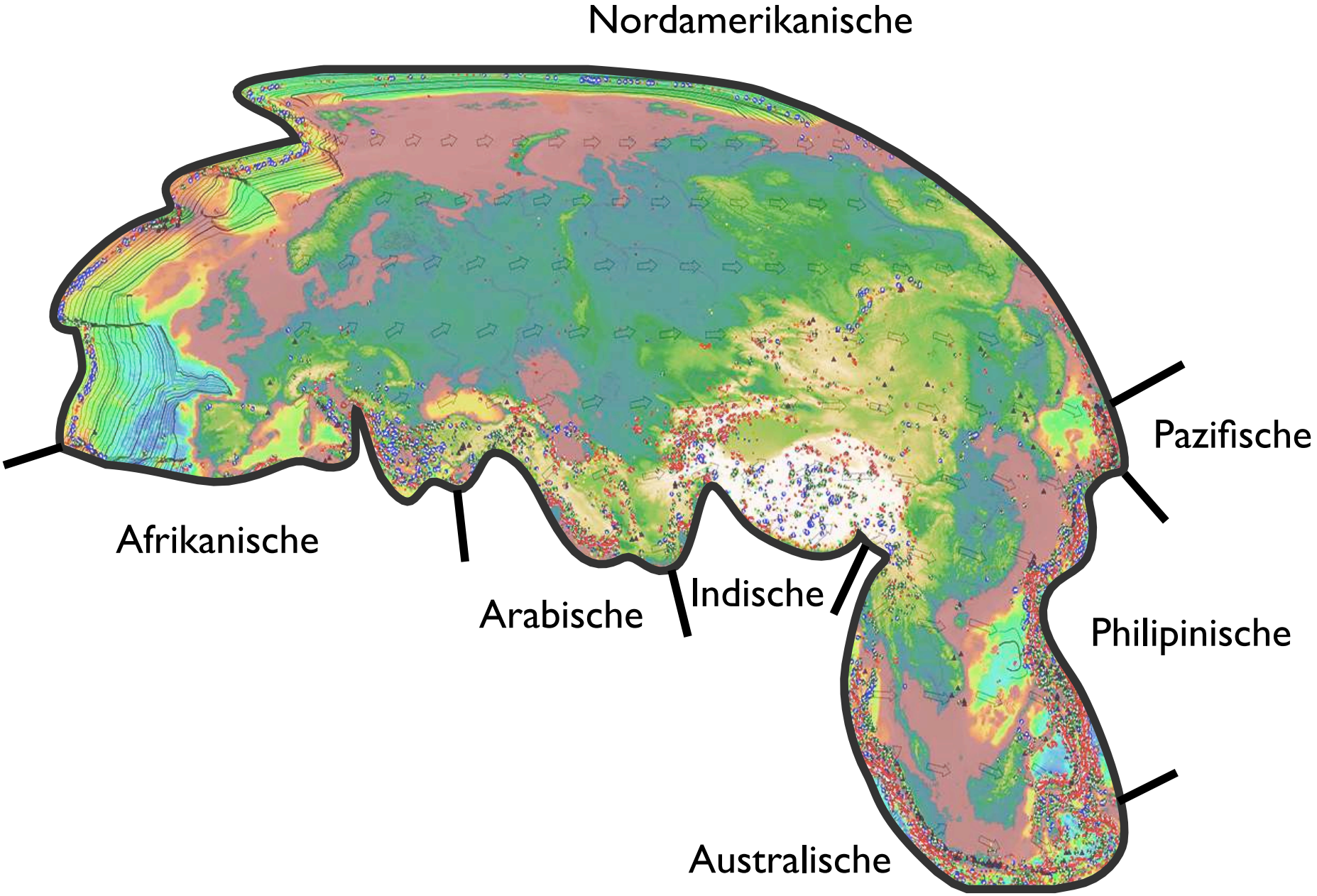


Erdbebenkarte

Seichte Beben: 0 km Tiefe 50 km Tiefe

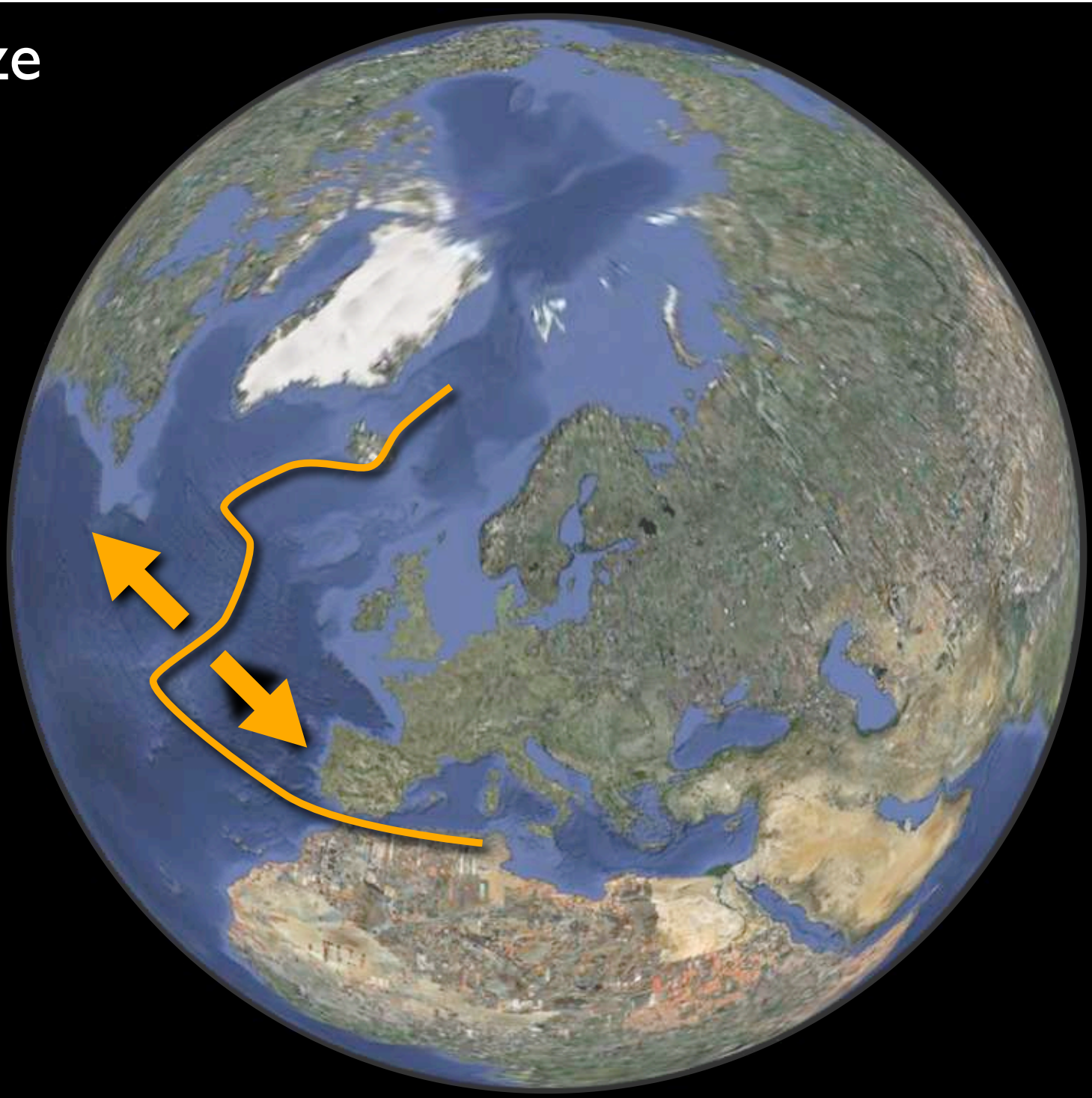


Nachbarplatten

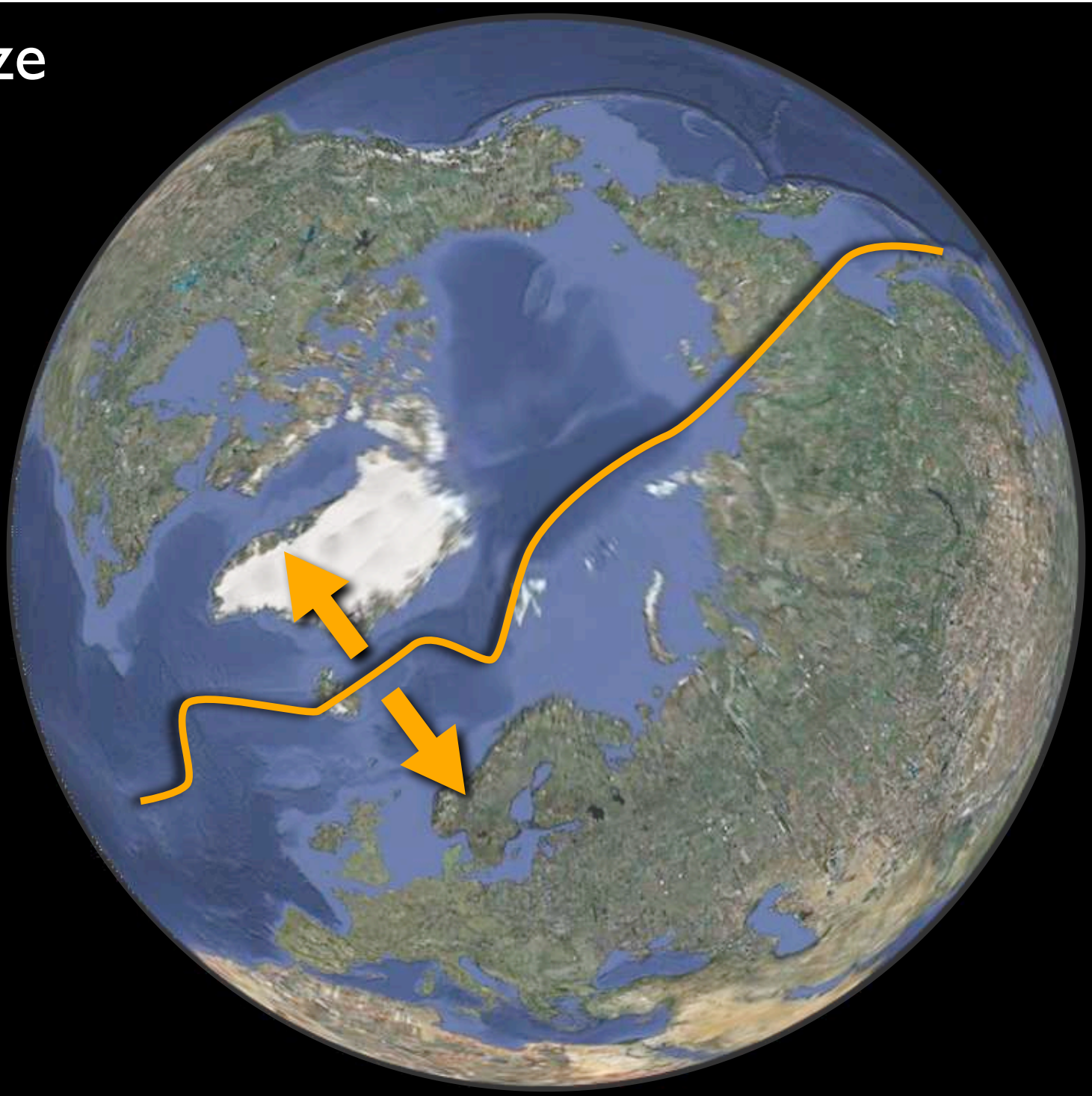


google Earth

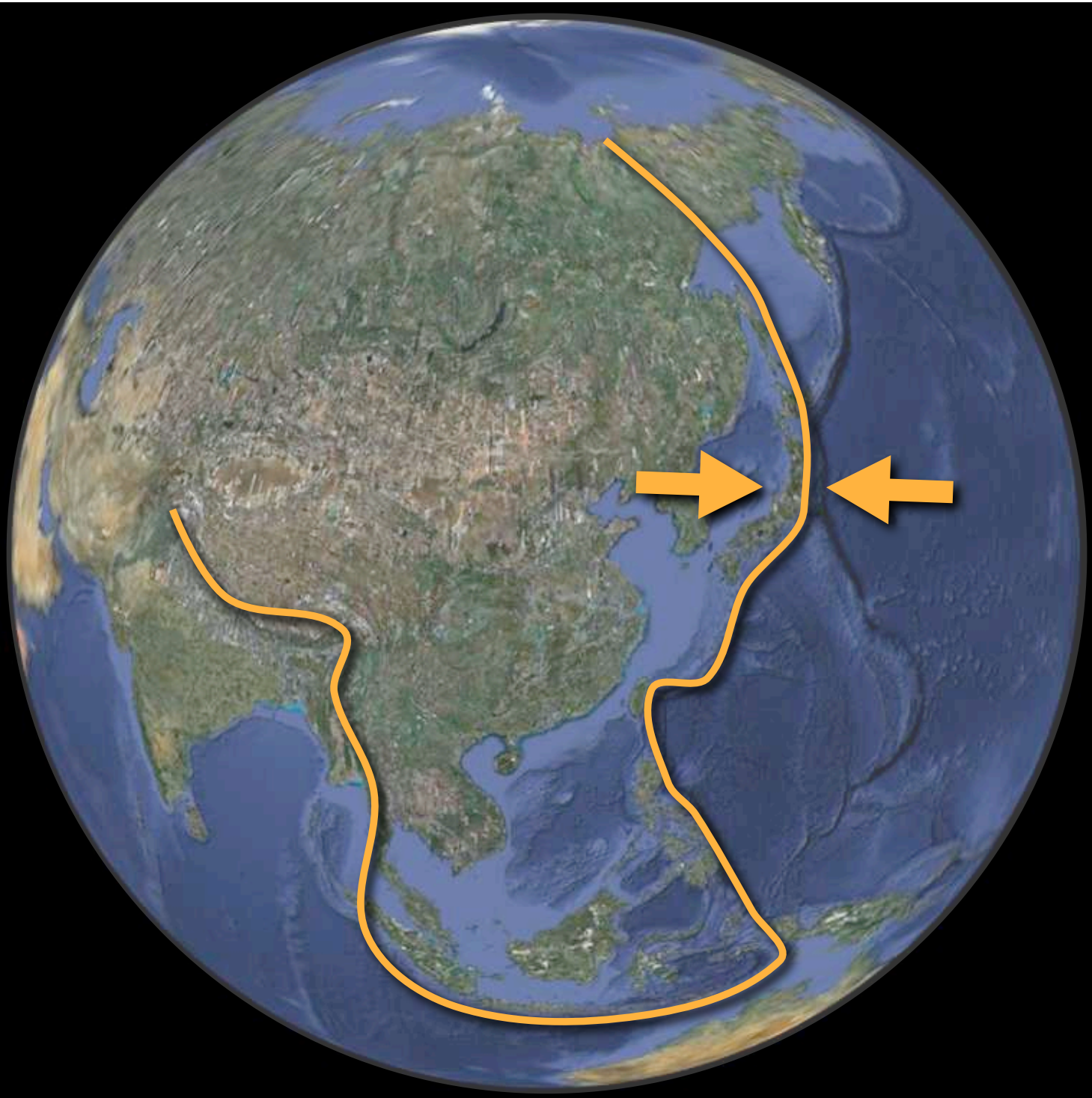
Westgrenze



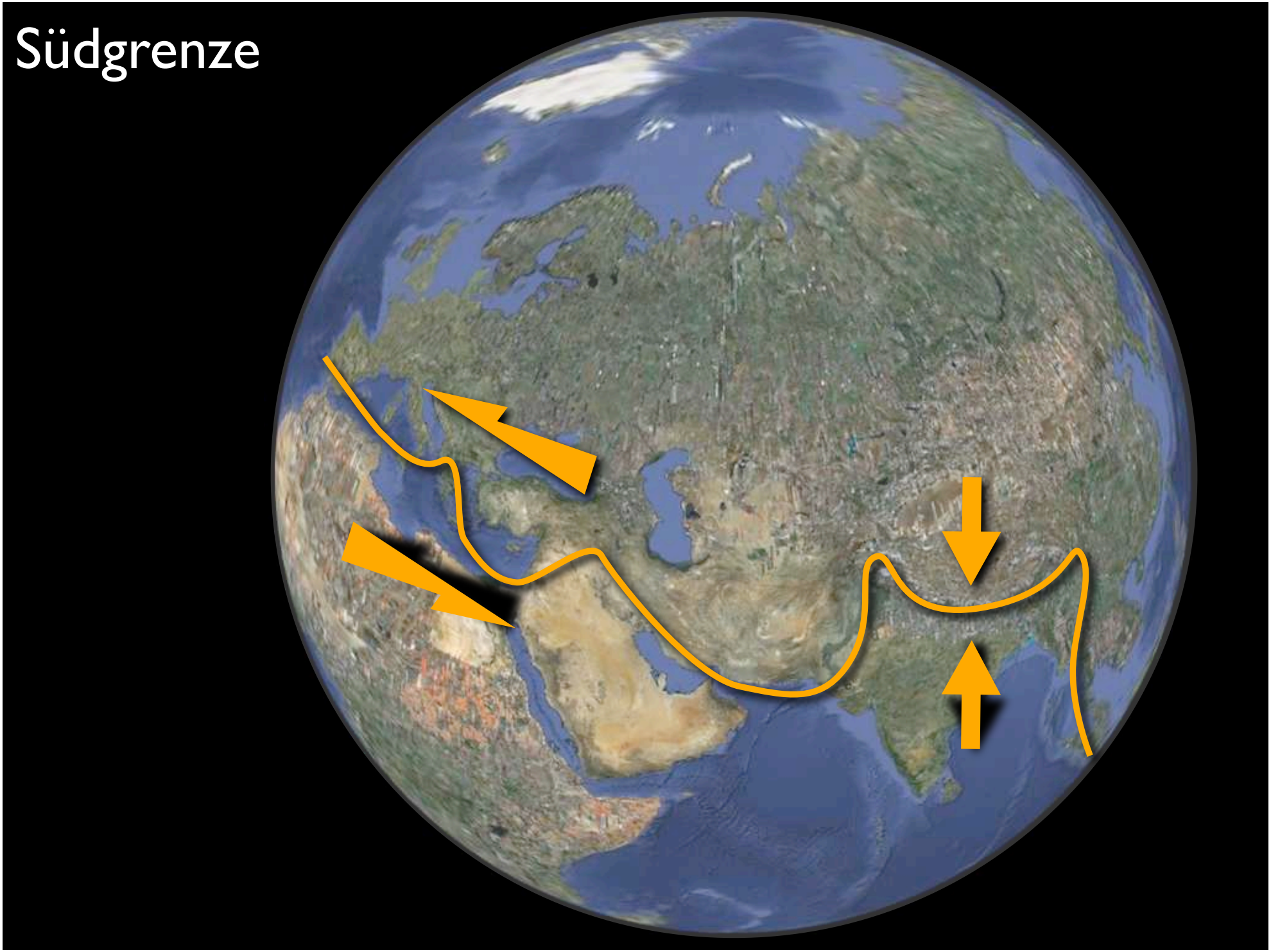
Nordgrenze



Ostgrenze



Südgrenze



Gerollter Granat in Bündnerschiefer