

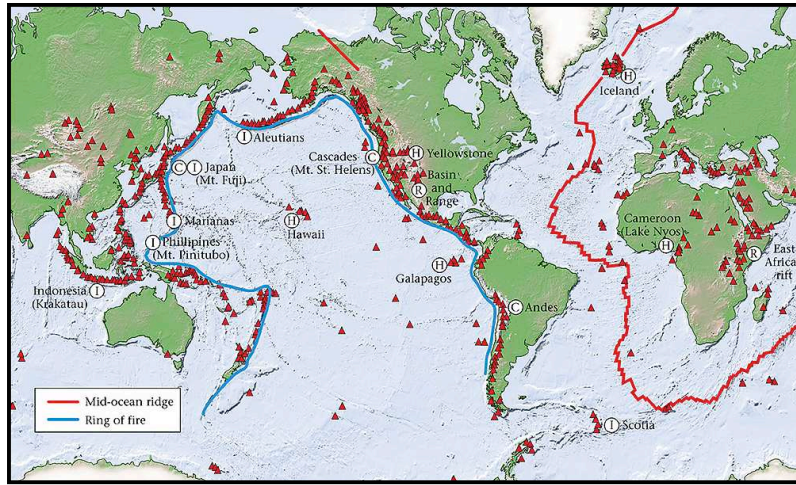
Tatort Plattengrenze

4

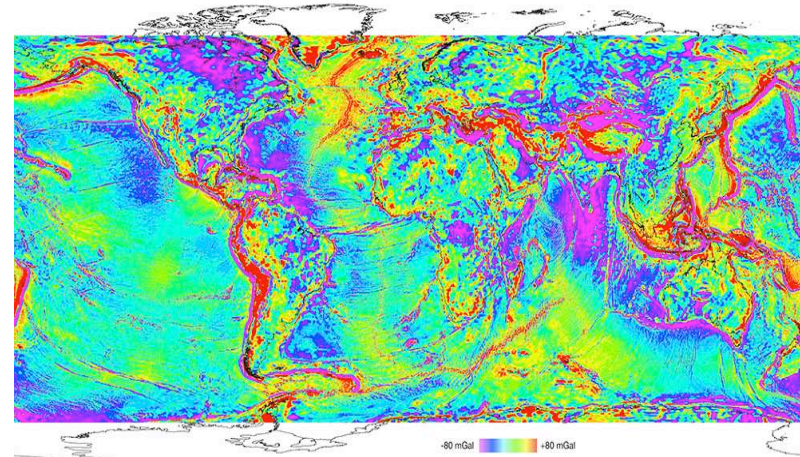
Im forensischen Labor

Profiling

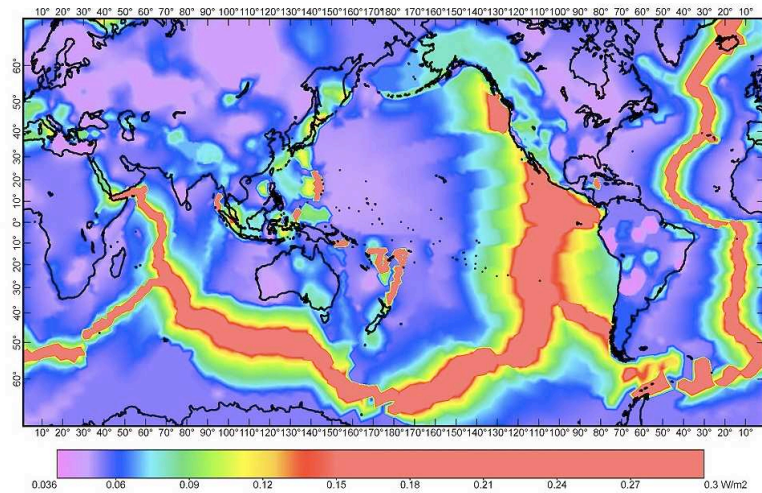
Vulkanismus



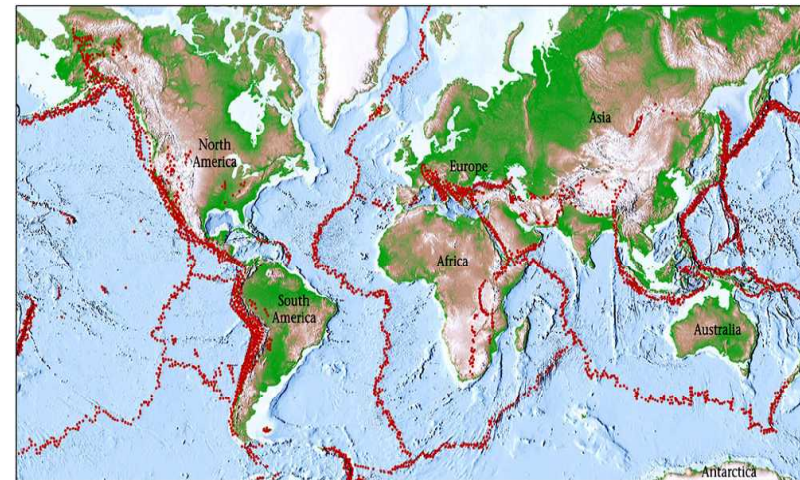
Gravimetrie



Wärmefluss

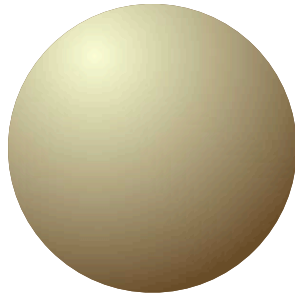


Erdbeben

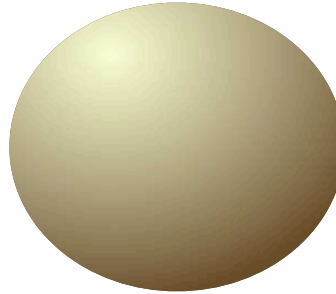


Das Geoid - die Gestalt der Erde

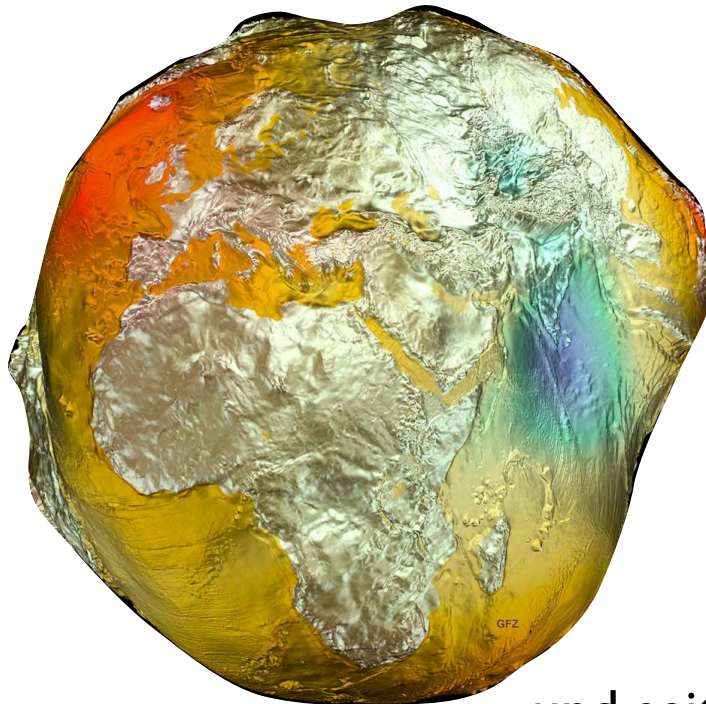
Ist die Erde ...



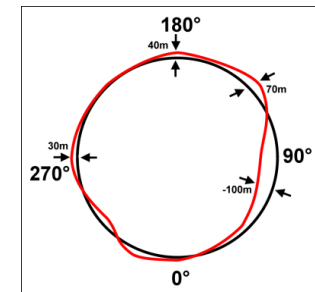
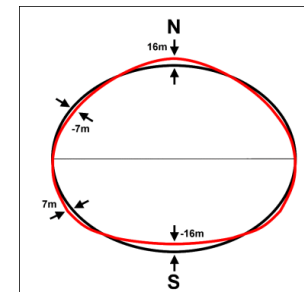
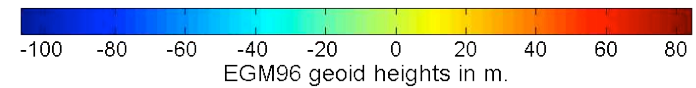
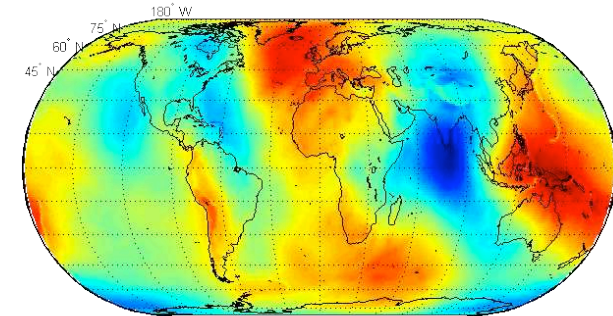
... eine Kugel ?



... ein Rotationsellipsoid ?



Seit 1828 (Carl Friedrich Gauss) ist die physikalische Form der Erde das sogenannte Geoid ...



... seit 1996 ist es ein Birne...

... und seit 2011 eine Kartoffel !

wie kommt man denn darauf ?

Die Normalschwere ist die Vektorsumme aus der Massenanziehung der Erde und der Fliehkraft, welche durch die Erdrotation entsteht.

Die **Erdanziehung** nimmt mit dem Quadrat des Abstands vom Massenzentrum der Erde - d.h. vom Pol zum Äquator - ab.

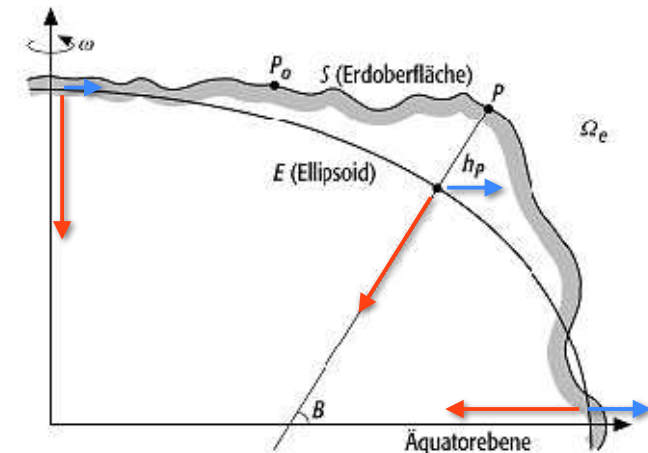
Die Wirksamkeit der **Fliehkraft** nimmt mit dem Abstand von der Drehachse - d.h. vom Pol zum Äquator - zu.

In einer Formel ausgedrückt: die Normalschwere hängt von der geographischen Breite ab:

$$g_{\text{normal}} = g_E \cdot (1 + \alpha \cdot \sin^2 \lambda + \beta \cdot \sin^2 \lambda)$$

wo λ geographische Breite
 α, β durch Messung gefundene Parameter

1 g	= 9,81 ms ⁻²	= 981 Gal	= 981'000 mGal
1 Gal	= 1 cms ⁻²	= 10 ⁻² ms ⁻²	
1 mGal		= 10 ⁻⁵ ms ⁻²	



Freiluft - Anomalie

Die Schwereanomalie ist nun die lokale Abweichung der gemessenen Schwerebeschleunigung vom theoretischen und korrigierten Normalwert

Freiluft-Anomalie $\Delta g_F = g_{\text{obs}} - (g_{\text{normal}} + C g_F)$

$\Delta g = 0$ beobachteter Wert = korrigierte Normalschwere

Im Kontinentalbereich erklärt man:

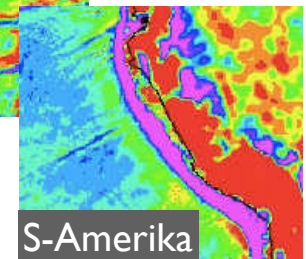
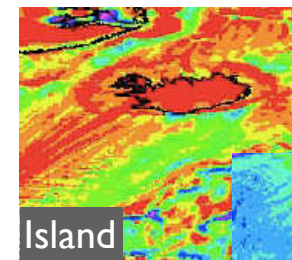
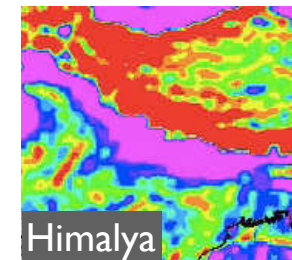
$\Delta g_F > 0$ (= typisch) durch die zusätzliche (und noch nicht berücksichtigte) Anziehung durch Gesteinsmasse unter dem Messpunkt

$\Delta g_F < 0$ durch eine sehr geringe Dichte der Gesteinsmasse unter dem Messpunkt

Im Ozeanbereich erklärt man:

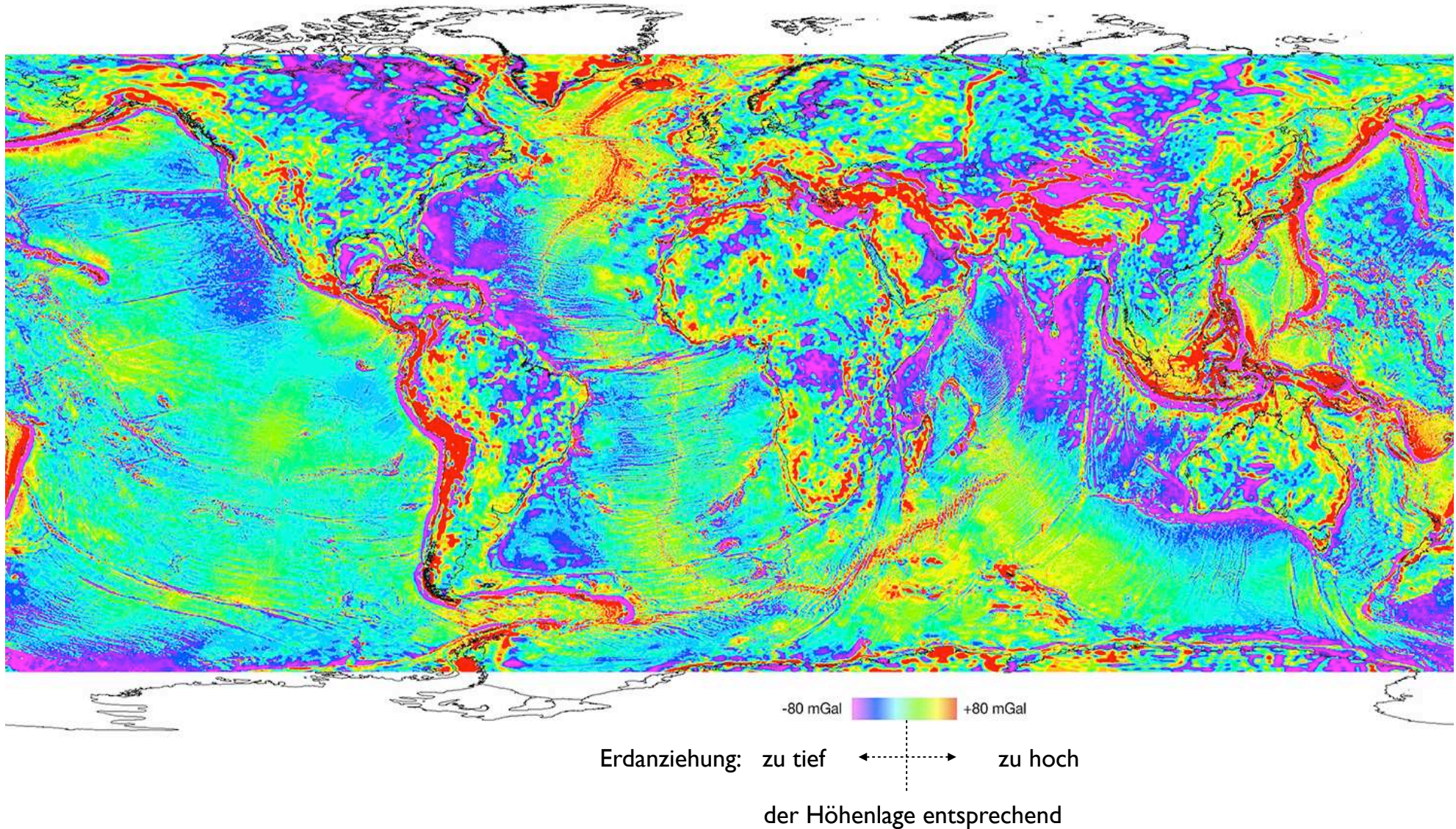
$\Delta g_F > 0$ durch oberflächennahes dichtes (Mantel-) material

$\Delta g_F < 0$ (= typisch) durch die fehlende Anziehung durch das Wasser, vor allem bei grosser Wassertiefe

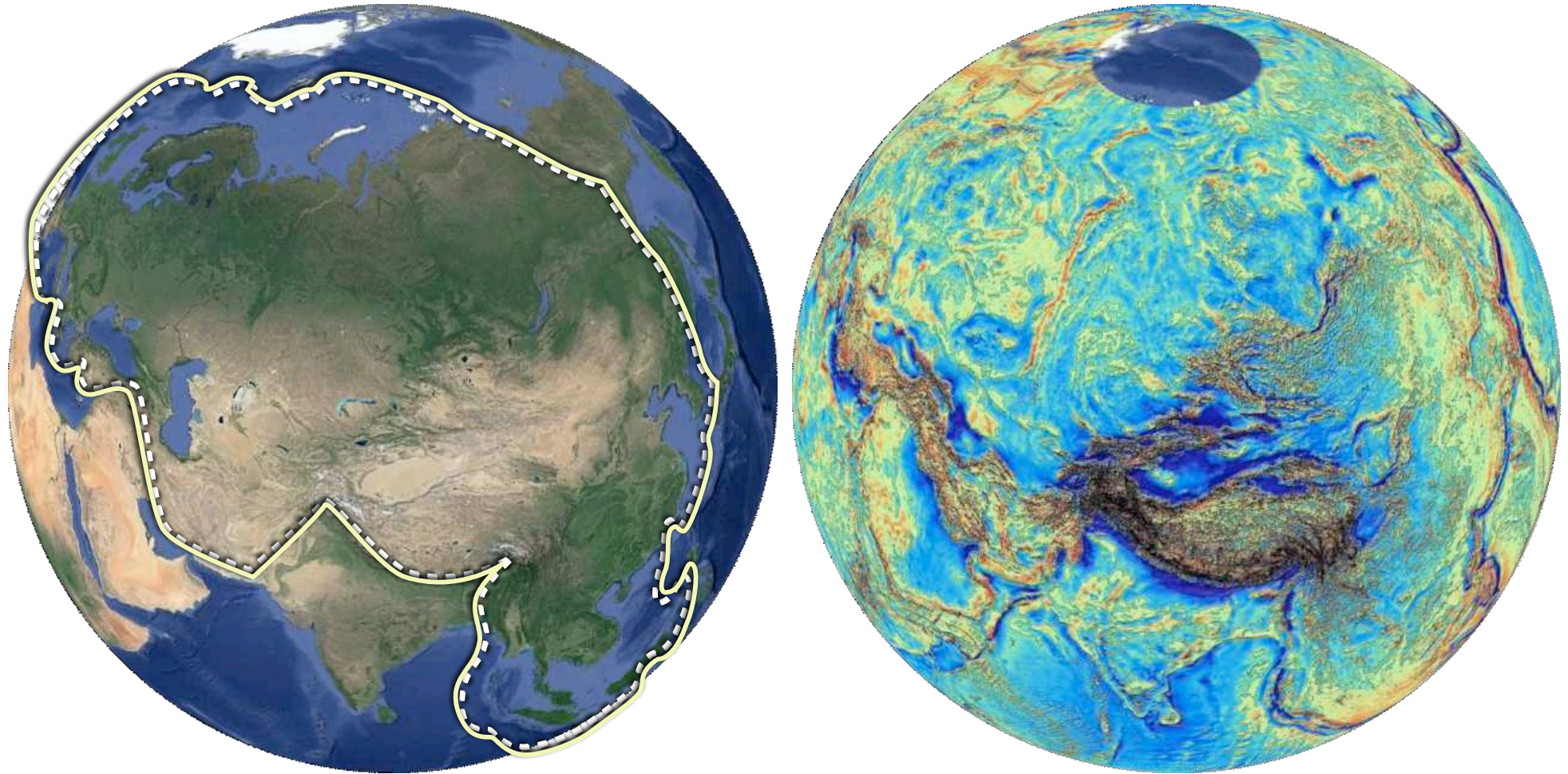


Welt - Schwerekarte

<http://www.ngu.no/geodynamics/gplates/> --- Free Air Gravity Anomaly Map



Freiluft - Anomalie der Eurasischen Platte



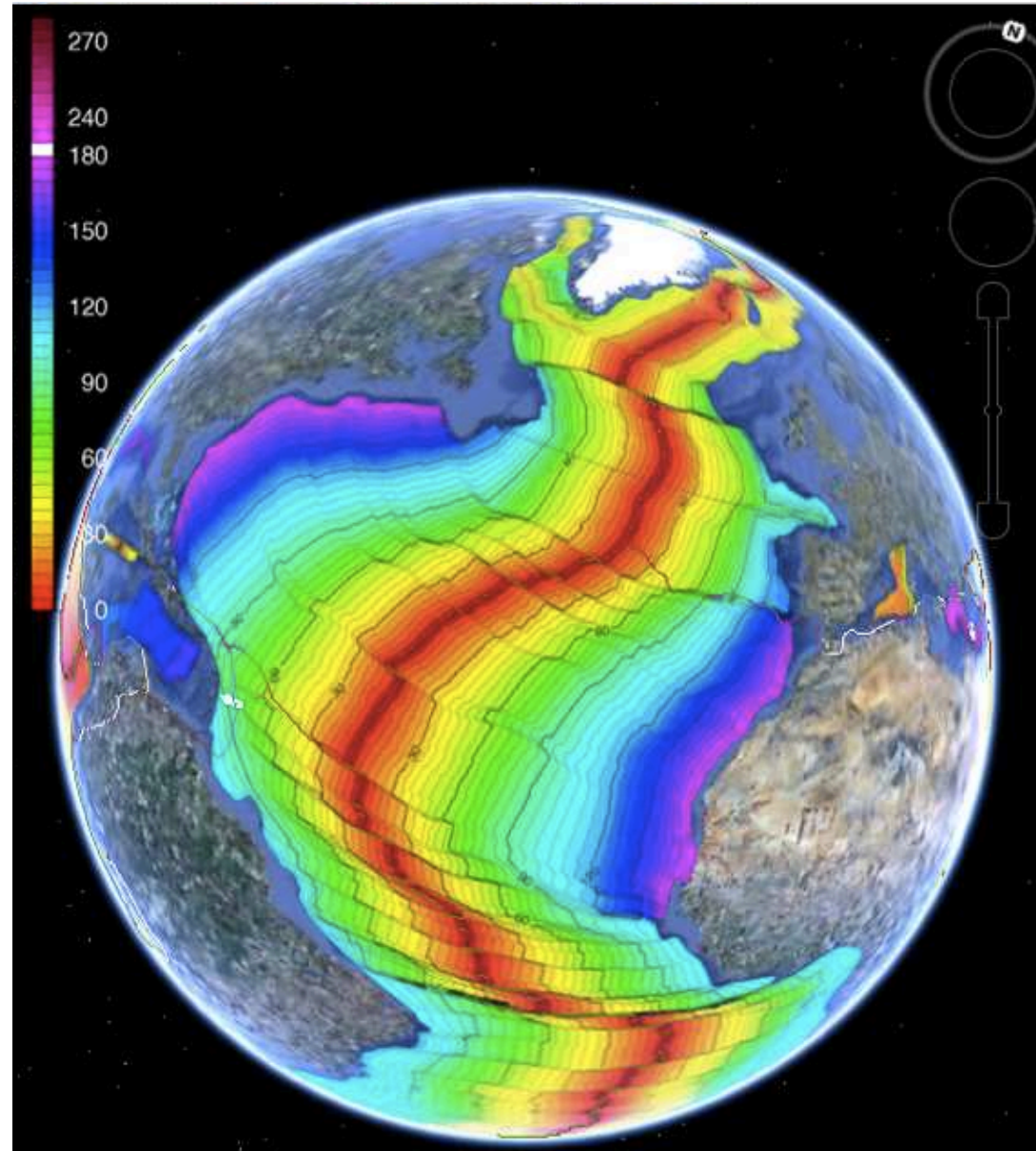
Der Mittelatlantische Rücken

Alter des Ozeanbodens

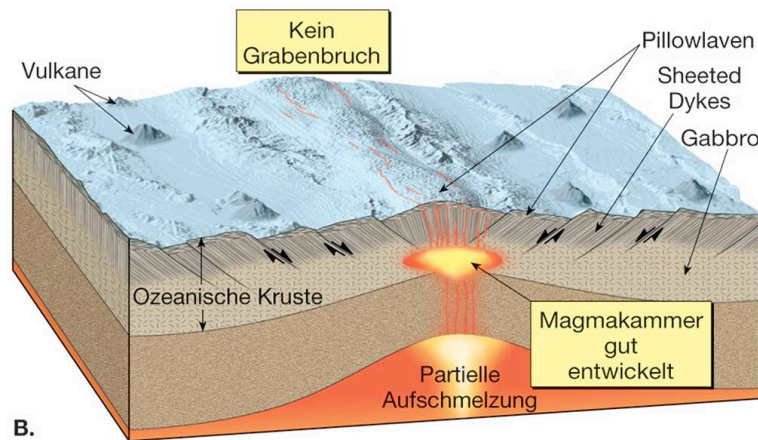
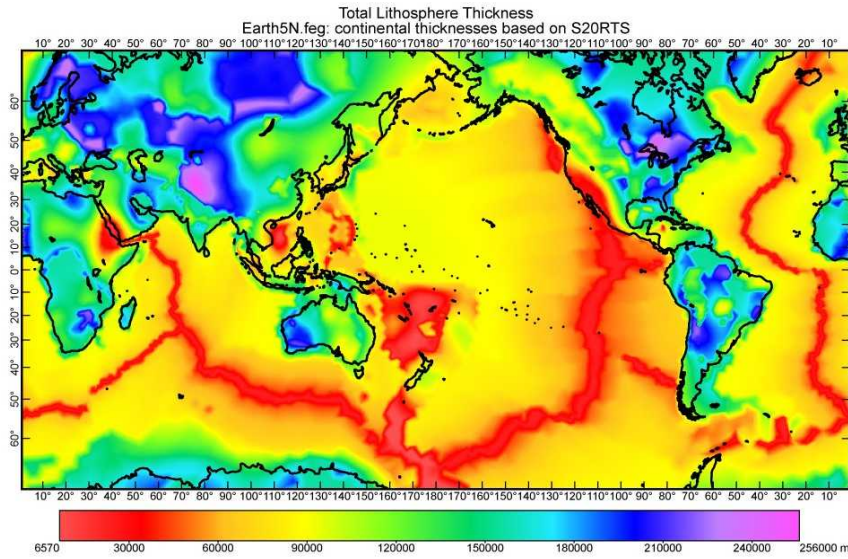
180 Ma

90 Ma

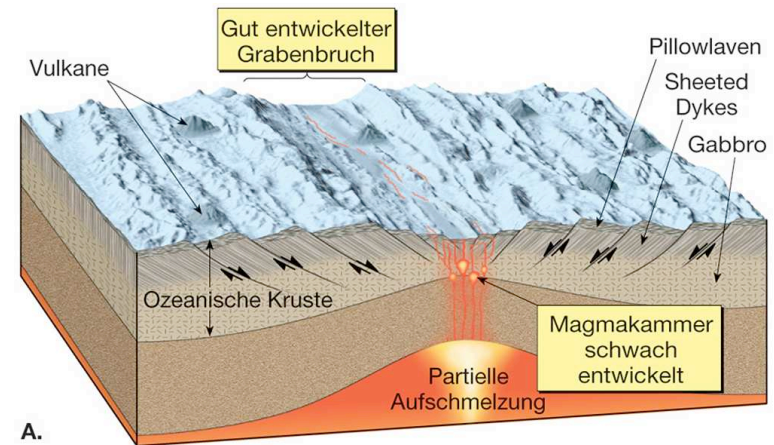
0 Ma



Seafloor Spreading

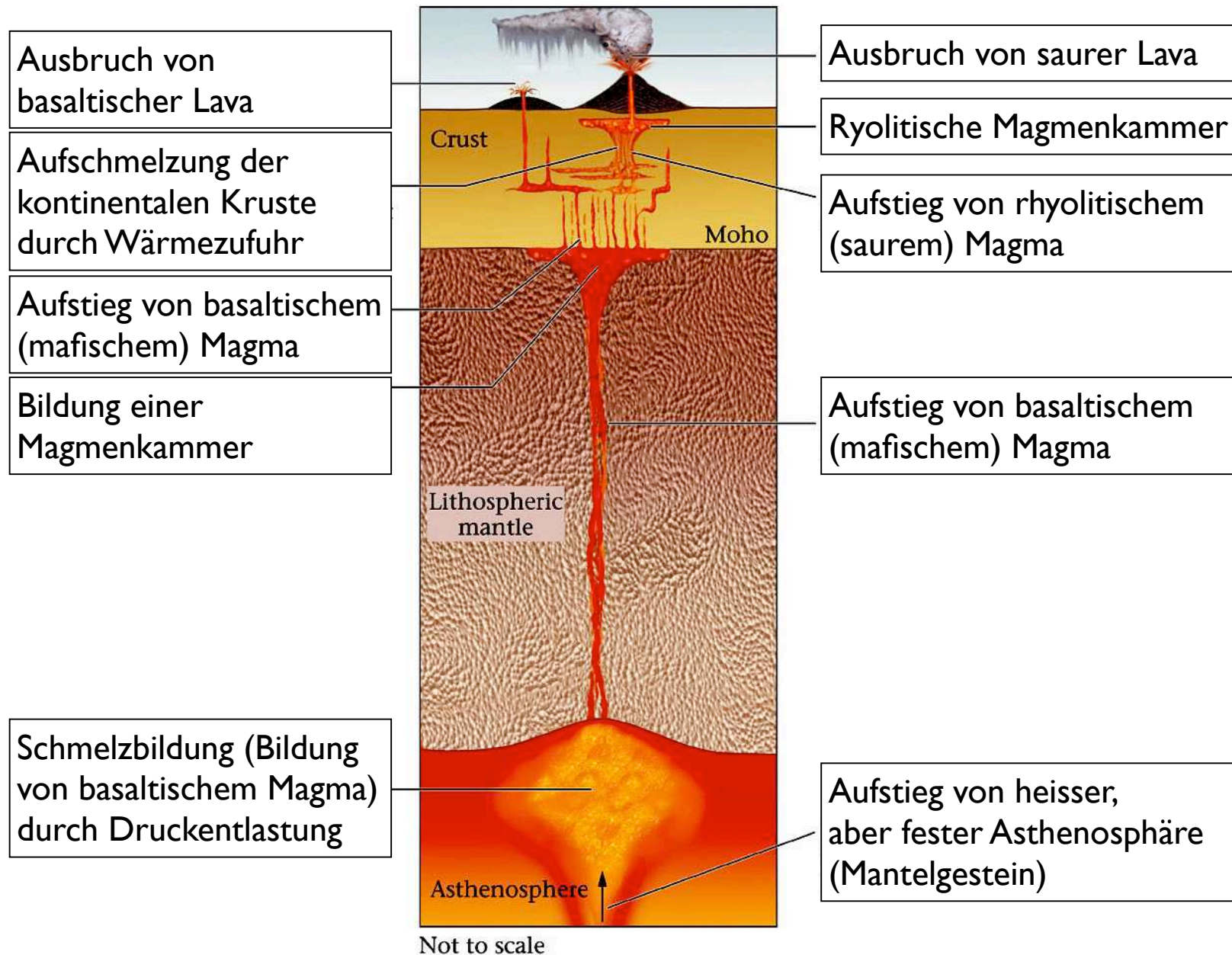


schnelle Öffnung
(Ostpazifischer Rücken)



langsame Öffnung
(Mittelatlantischer Rücken)

Magma aus dem Mantel



Plutone und Vulkane

Erstarrungsgeschwindigkeit

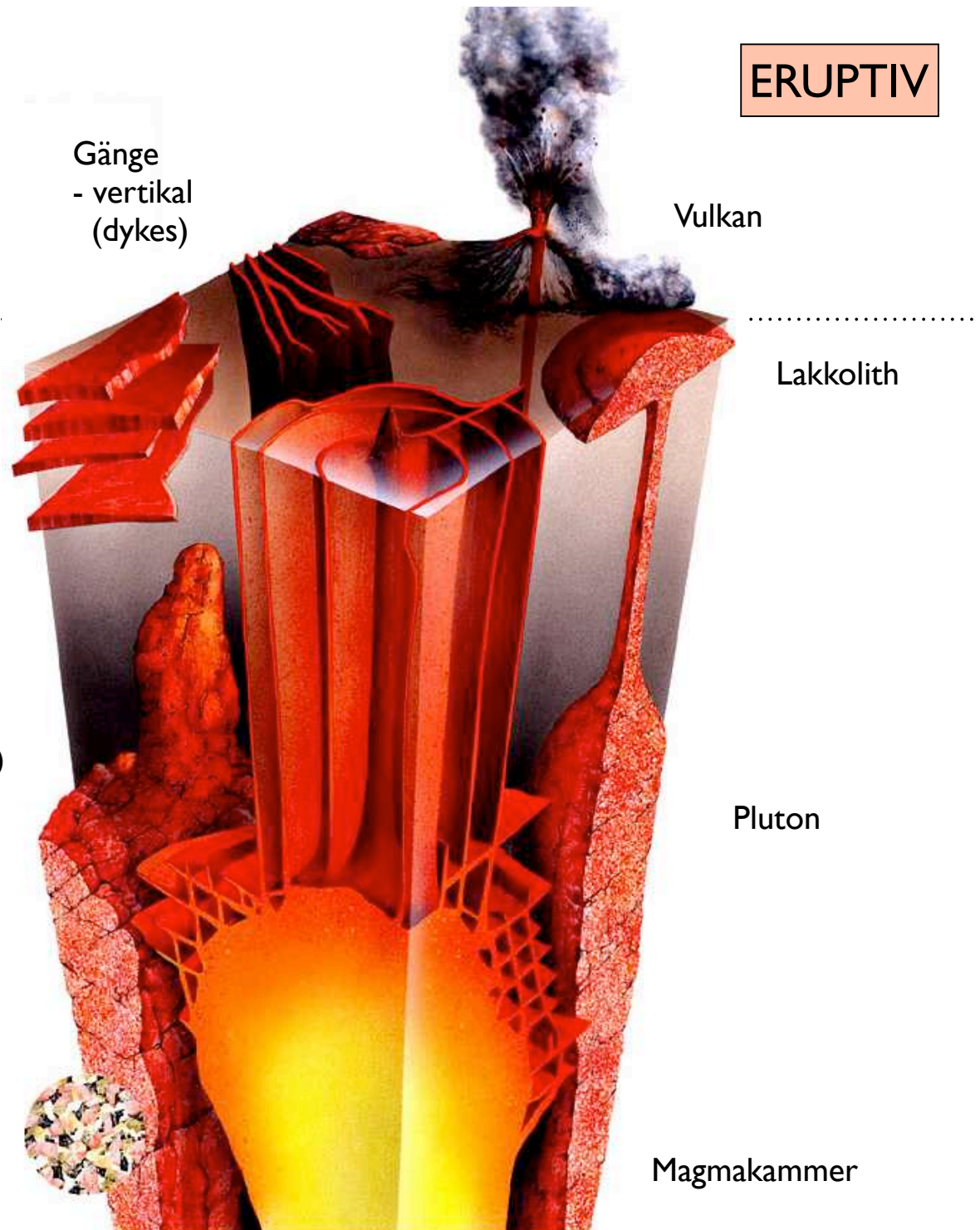


INTRUSIV

Gänge
- horizontal
(sills)

Gänge
- vertikal
- radial
(ring dykes)

Gänge
- vertikal
(dykes)



ERUPTIV

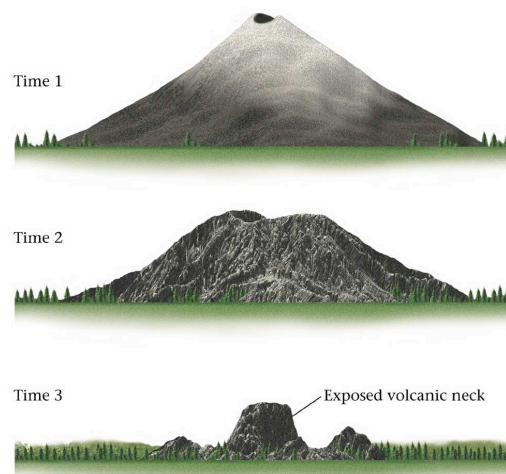
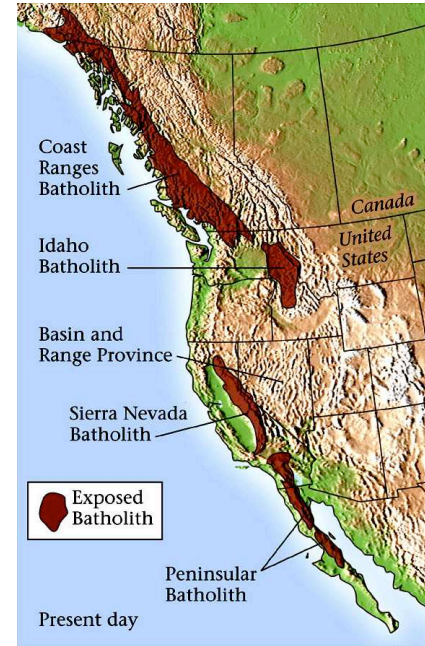
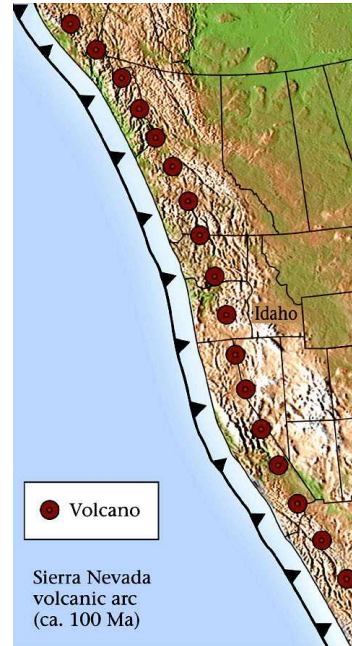
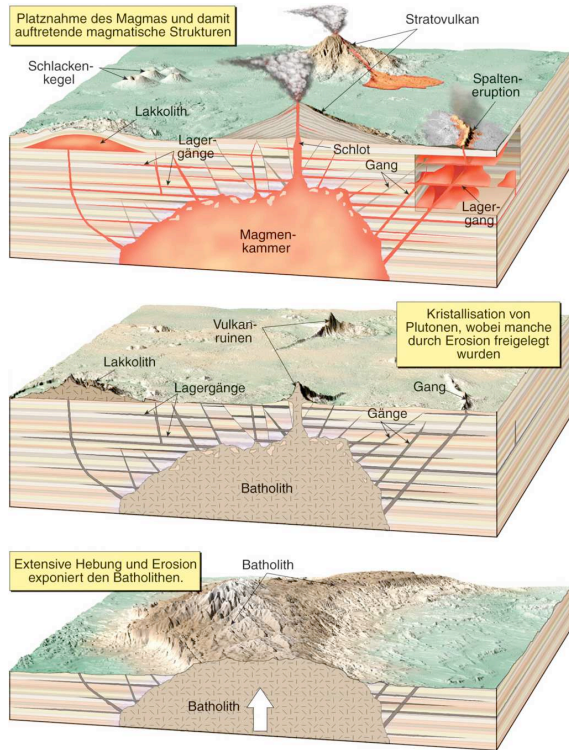
Vulkan

Lakkolith

Pluton

Magmakammer

Wirkung von Hebung und Erosion

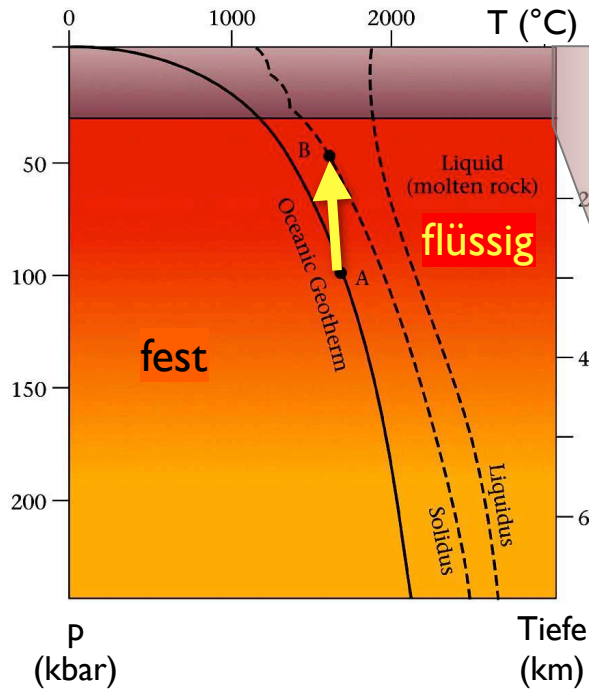


Devil's Tower, Wyoming, U.S.A.

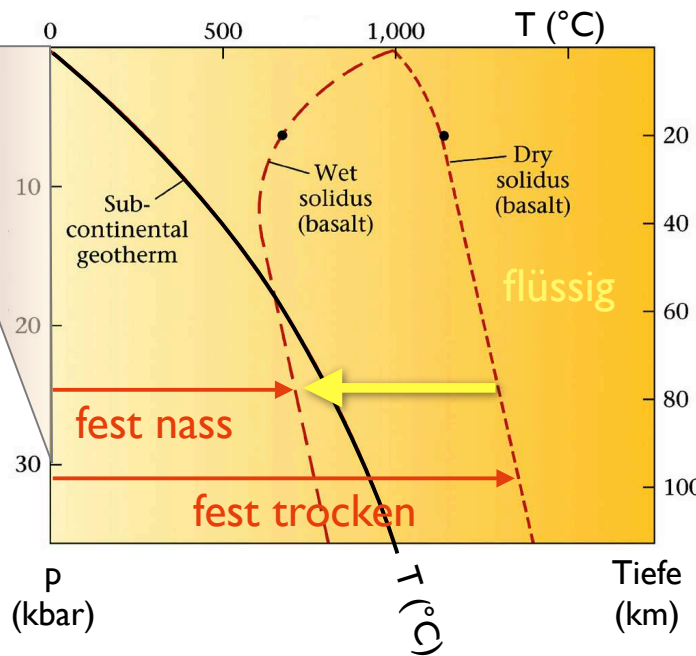
in der Hitze der Nacht

Wie gewinnt man Magma aus festem Gestein ?

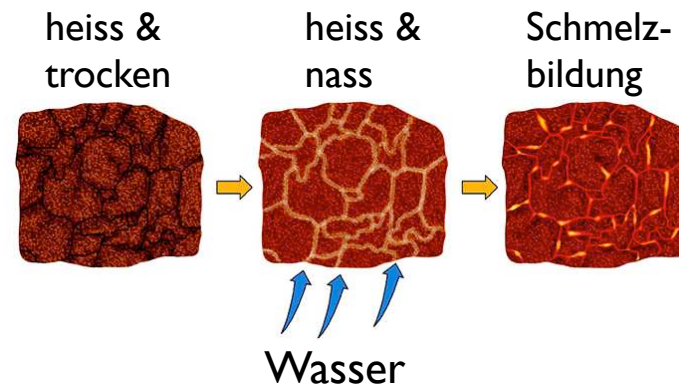
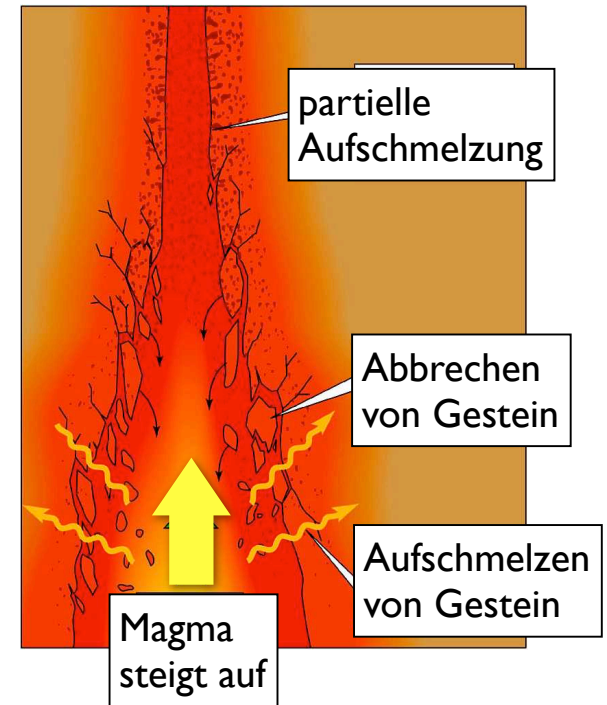
Druckentlastung



Wasserzufuhr



Wärmeadvektion



woher kommt die Wärme ?

... aus dem Mantel

Anfangsenergie

Wärmeverlust kollidierender
Partikel bei der kalten Akkretion

30 - 50% der
Erdwärme

Kristallisationswärme bei der
Erstarrung des festen Kerns

Laufend erneuert

Radioaktiver Zerfall der Isotope
Uranium, Thorium, und Kalium

50 - 70%
 $5 \cdot 10^{-12} \text{ Wkg}^{-1}$

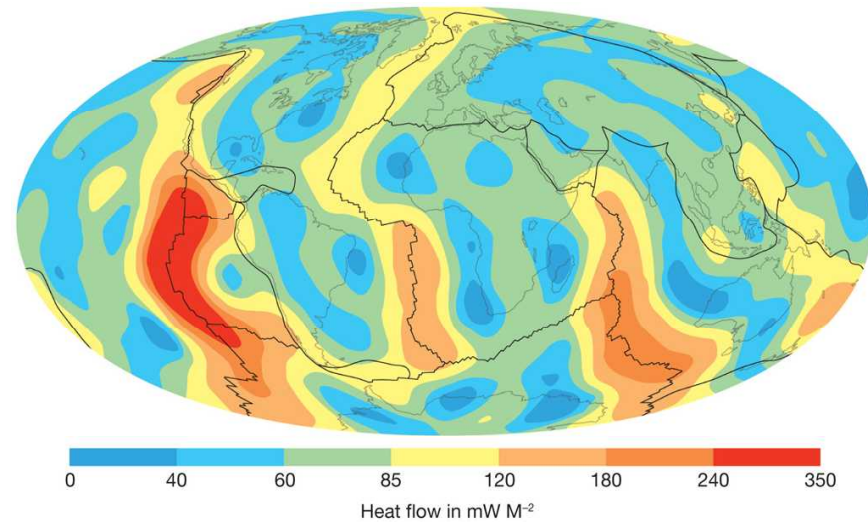
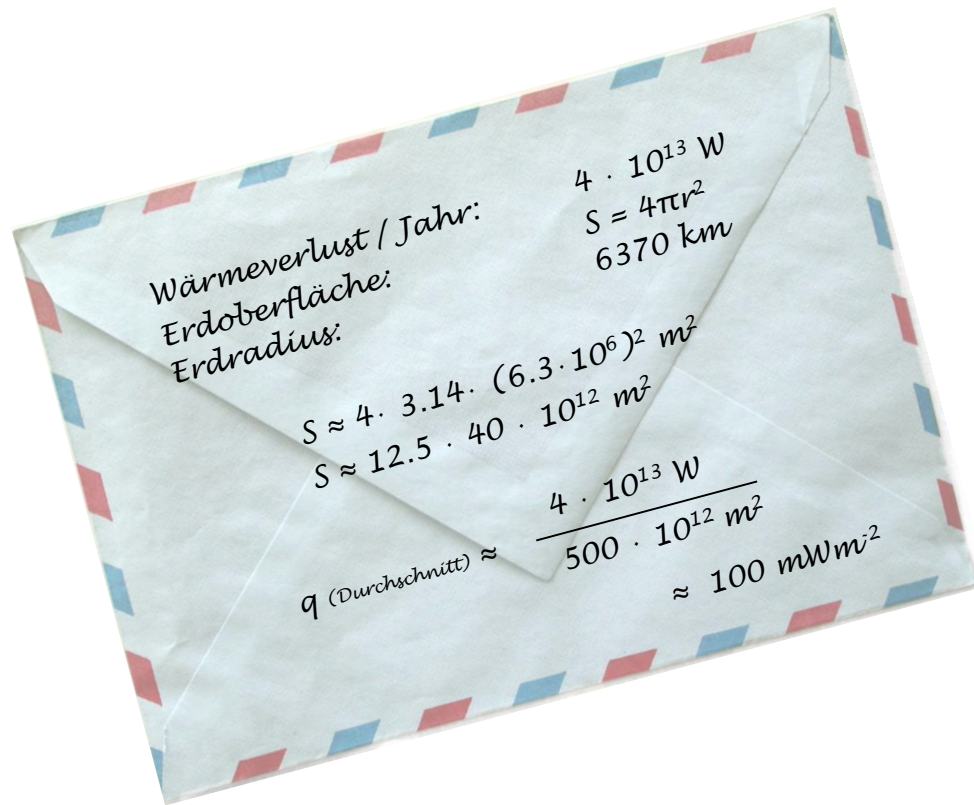
Reibungswärme durch
Gezeitenwirkung des Mondes

$2 \cdot 10^{-13} \text{ Wkg}^{-1}$

Total: $\approx 44 \text{ TW}$

Energie-Verbrauch der Menschen: $\approx 20 \text{ TW}$

Plattengrenzen erkennt man am Wärmefluss



Mittlerer Wärmefluss:

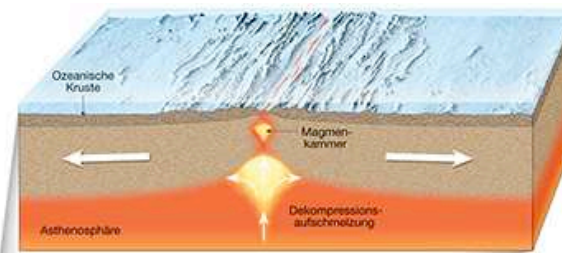
$\geq 100 \text{ mW/m}^2$ (Ozeanrücken)

$\leq 50 \text{ mW/m}^2$ (Kontinent)

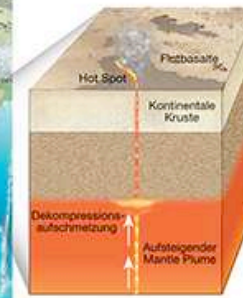
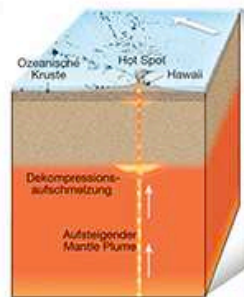
Vulkanismus an Plattengrenzen



Mount Augustine
(Alaska)



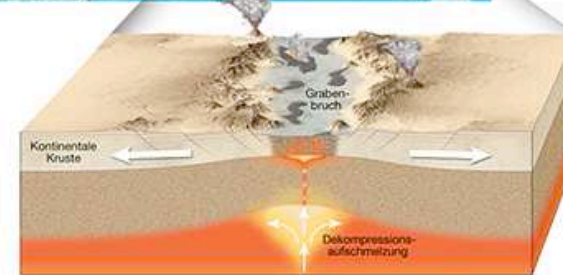
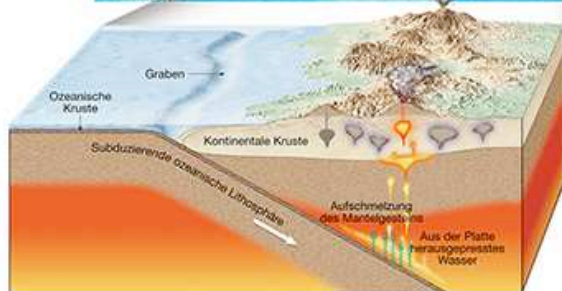
(Island)



Deccan Trapp
(Indien)



Kilauea
(Hawaii)

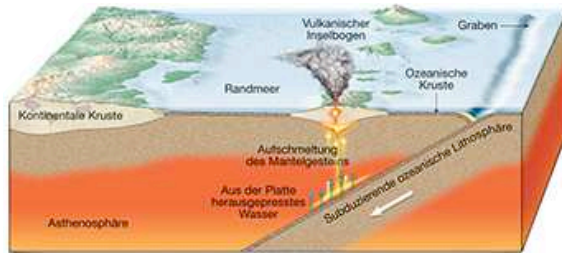


Kilimandscharo
(Tansania)

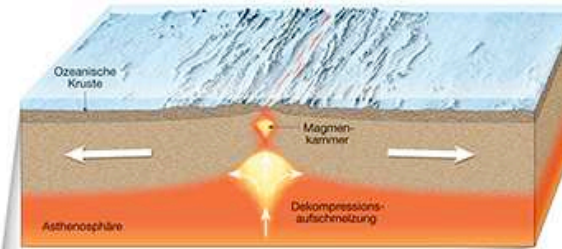


Chimborazo
(Ecuador)

Vulkanismus an Plattengrenzen

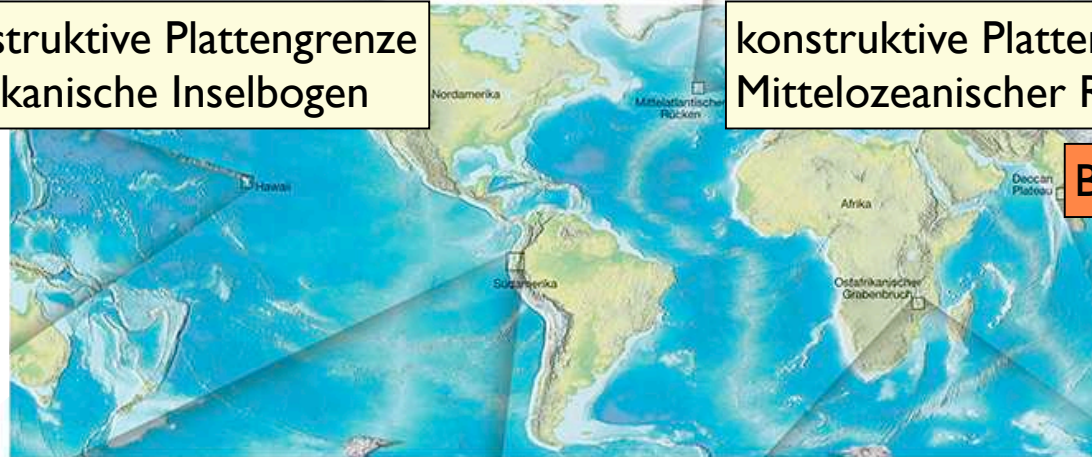


destruktive Plattengrenze
Vulkanische Inselbogen

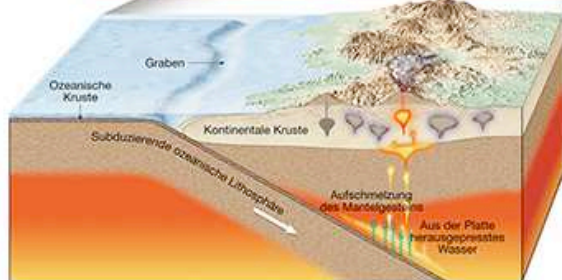


konstruktive Plattengrenze
Mittelozeanischer Rücken

Basaltische Lava

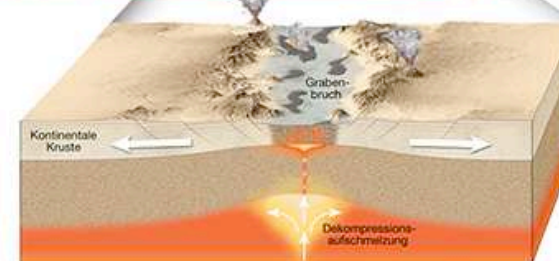


Basalte (MORB), Kissenlava



destruktive Plattengrenze
Kontinentaler Vulkanbogen

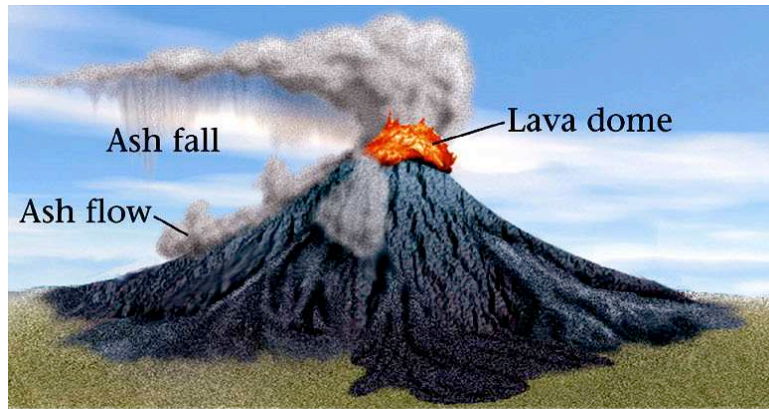
Andesitische - rhyolitische Lava



konstruktive Plattengrenze
Rifting Stadium

Flutbasalte

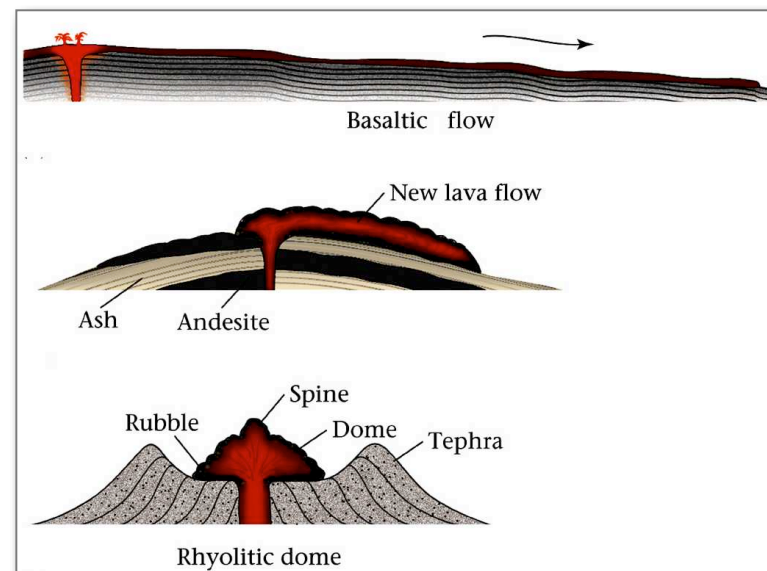
Welcher Vulkanismus an welcher Plattengrenze ?



Felsische Gesteinsschmelze (Magma)
→ Rhyolitische Lava
Zähflüssig, wenig fließfähig (hochviskös)
→ Gefährliche Explosionen
Beispiel: Mount St Helens



Mafische Gesteinsschmelze (Magma)
→ Basaltische Lava
Düninflüssig, leicht fließfähig (niederviskös)
→ Ungefährliches Ausfließen
Beispiel: Hawaii



Mafisch - Basaltisch

Intermediär - Andesitisch

Felsisch - Rhyolitisch

Die wichtigsten magmatischen Gesteine

Plutonite



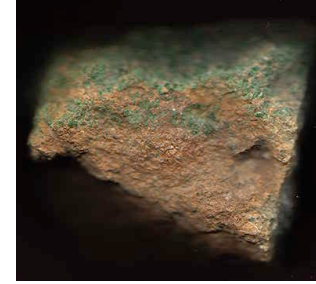
Granit



Diorit



Gabbro



Peridotit



Vulkanite



Rhyolit



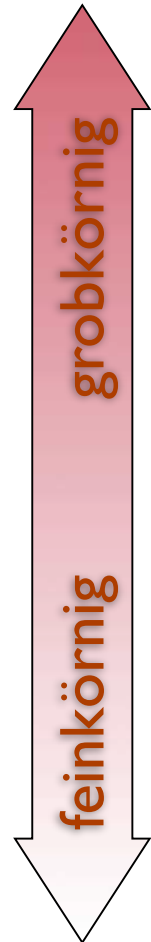
Andesit



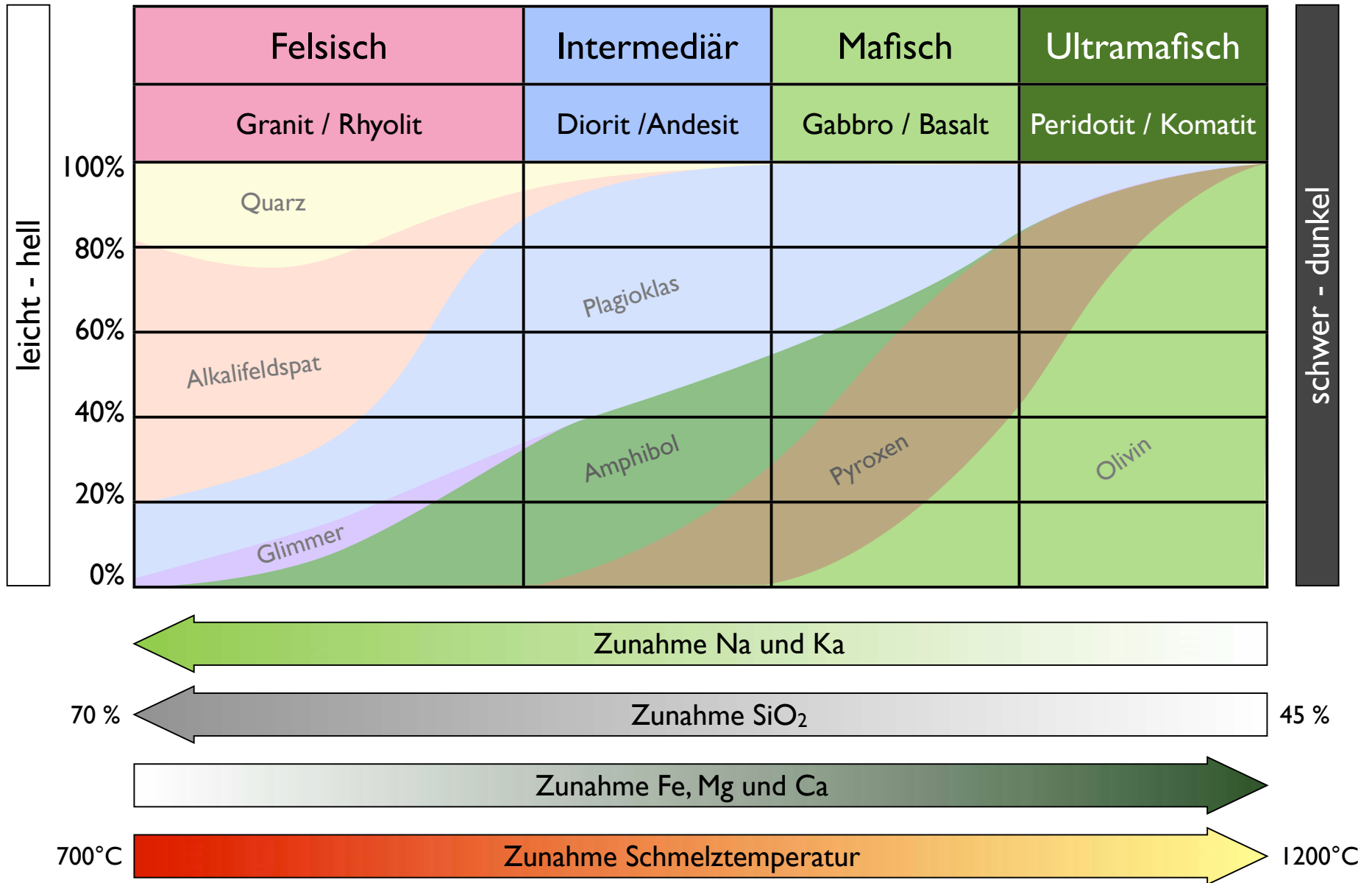
Basalt



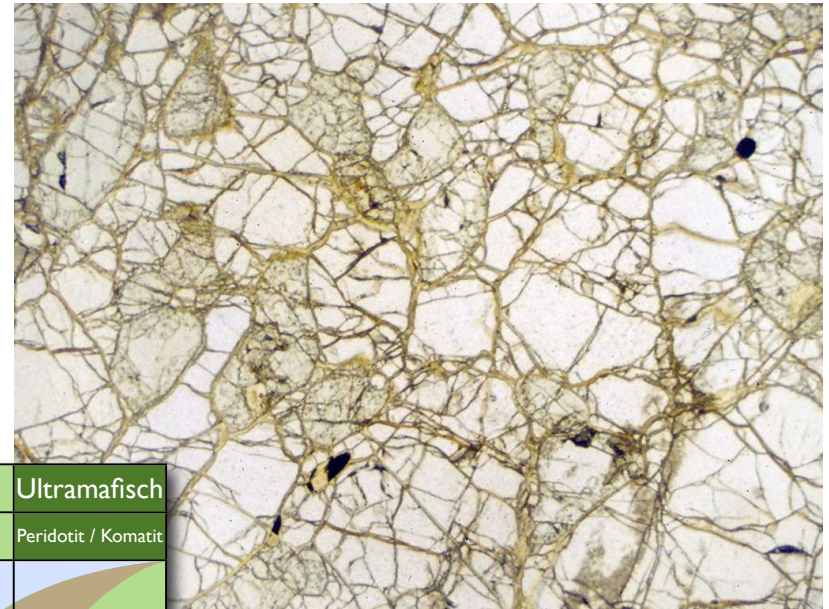
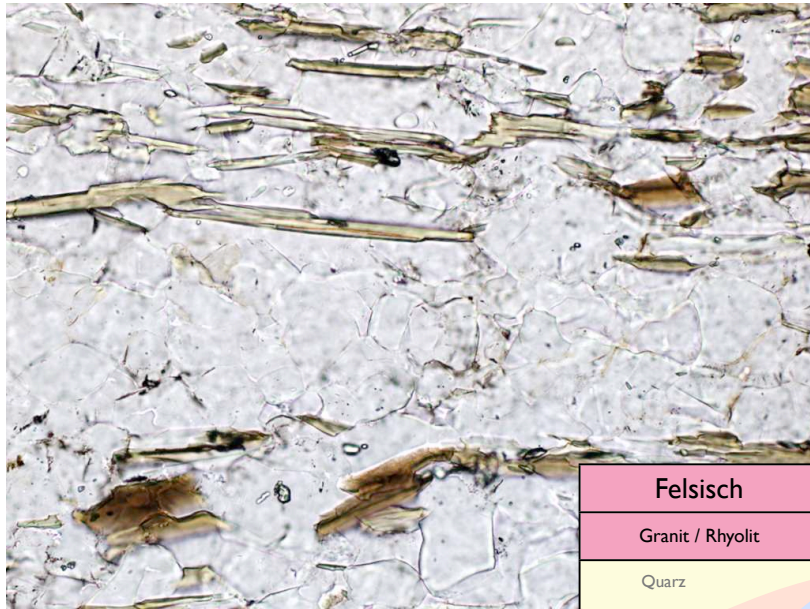
Obsidian



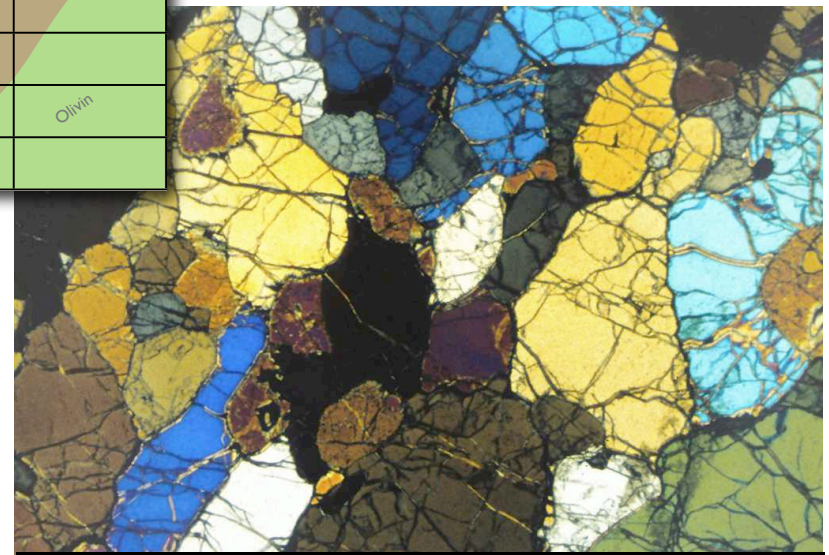
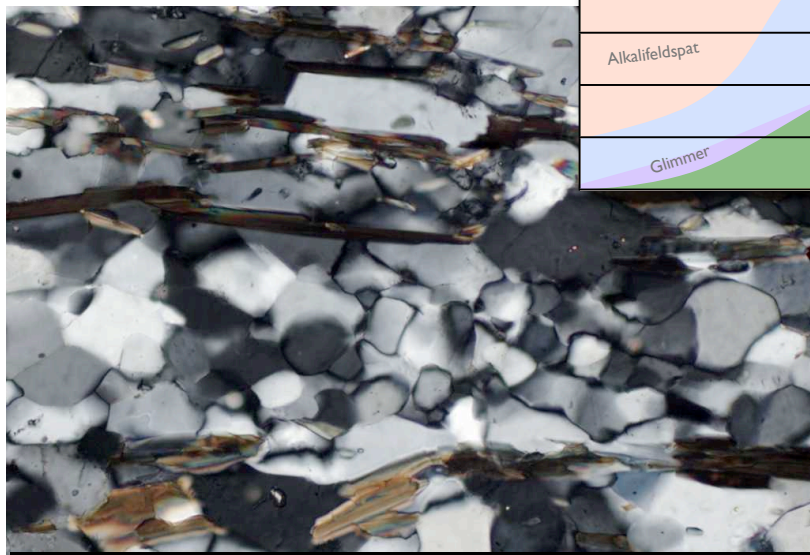
Zusammensetzung magmatischer Gesteine



Kristallingestein unter dem Mikroskop



Felsisch	Intermediär	Mafisch	Ultramafisch
Granit / Rhyolit	Diorit / Andesit	Gabbro / Basalt	Peridotit / Komatit
Quarz			
	Plagioklas		
Alkalifeldspat			
	Amphibol	Pyroxen	Olivin
Glimmer			



Granitoid: Feldspat, Quarz, Glimmer

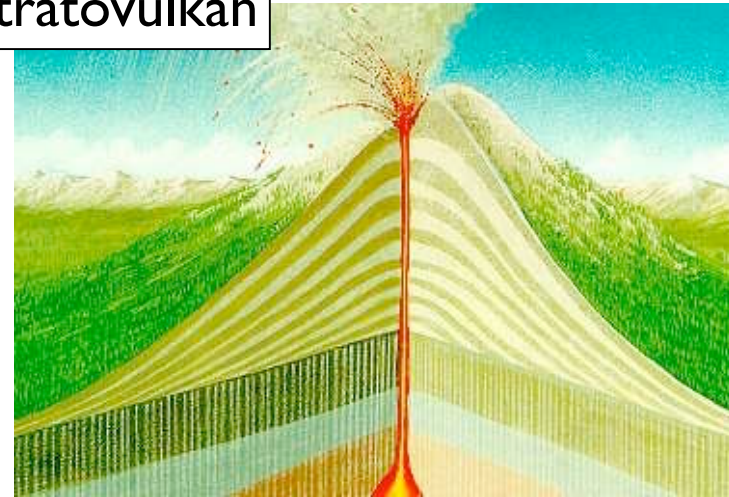
Peridotit: Olivin

Vulkan - Typen

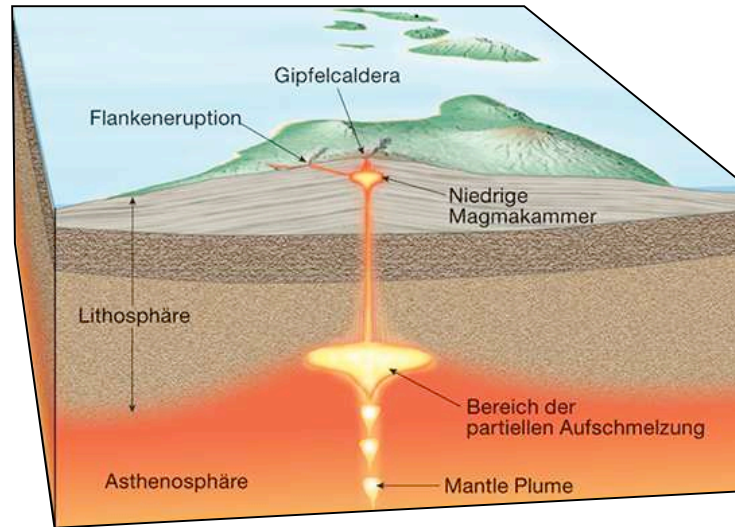
Schildvulkan



Stratovulkan

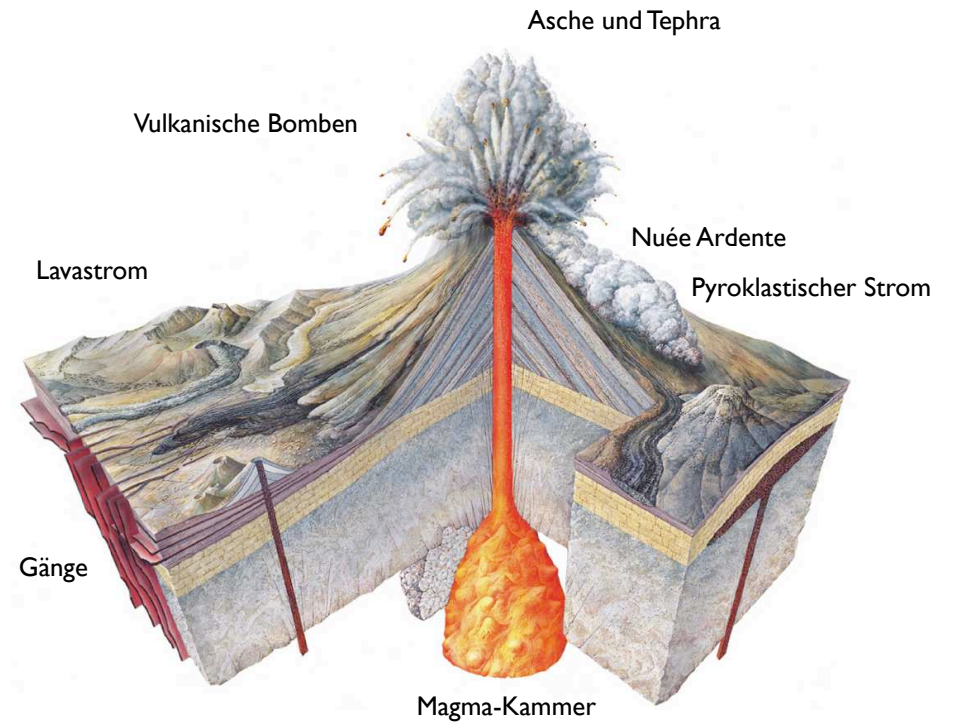


Schildvulkane

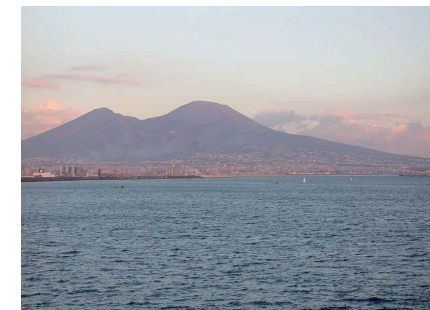


Mauna Loa
Hawaii

Stratovulkane



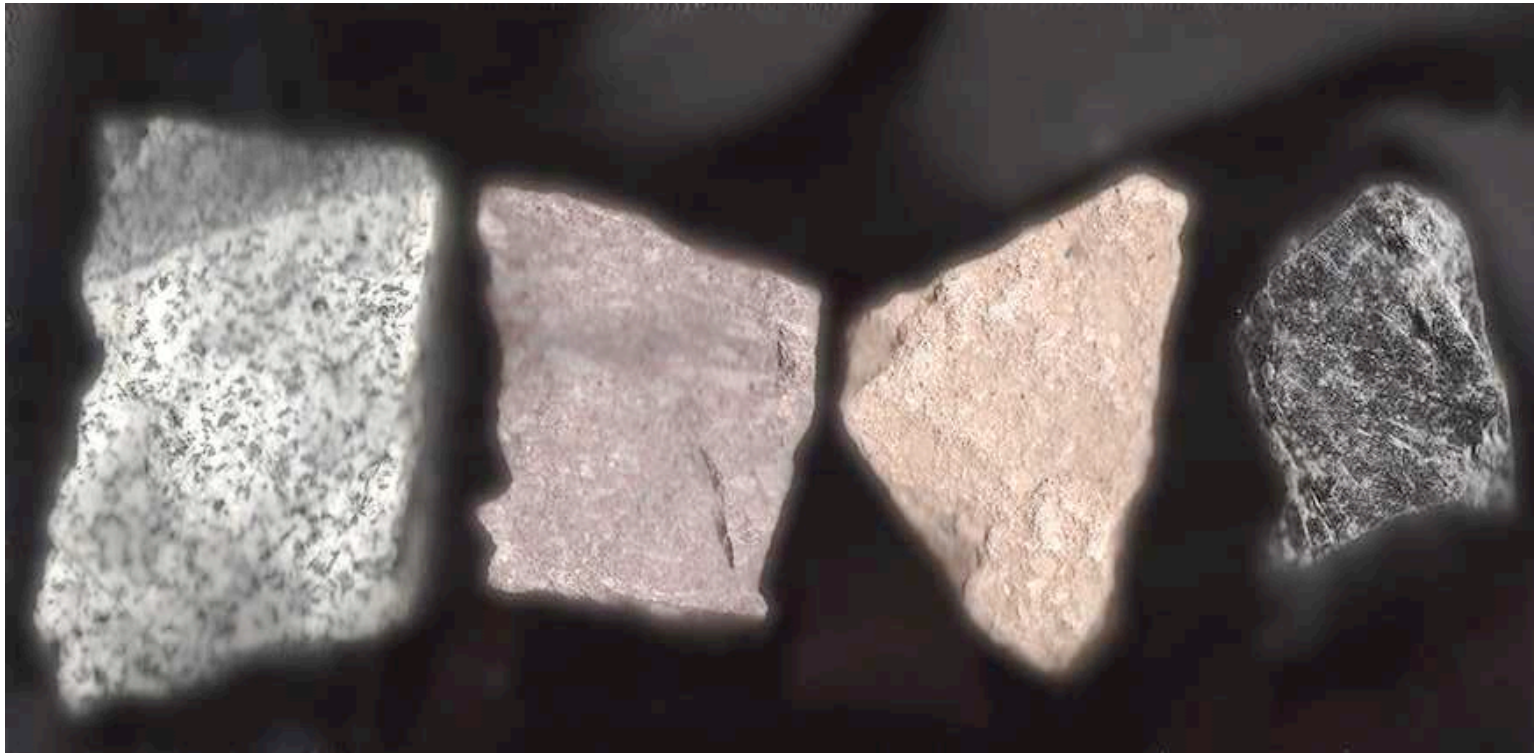
Fujiyama
Japan



Vesuvio
Italien

Pausengebäck

Erstarrungsgeschwindigkeit



Tonalit
(Adamello)

Rhyolit
(Côte d'Azur)

Tuff
(Hegau)

Obsidian
(Lipari)

Plutonit

Ignimbrit mit
Fliebsstrukturen

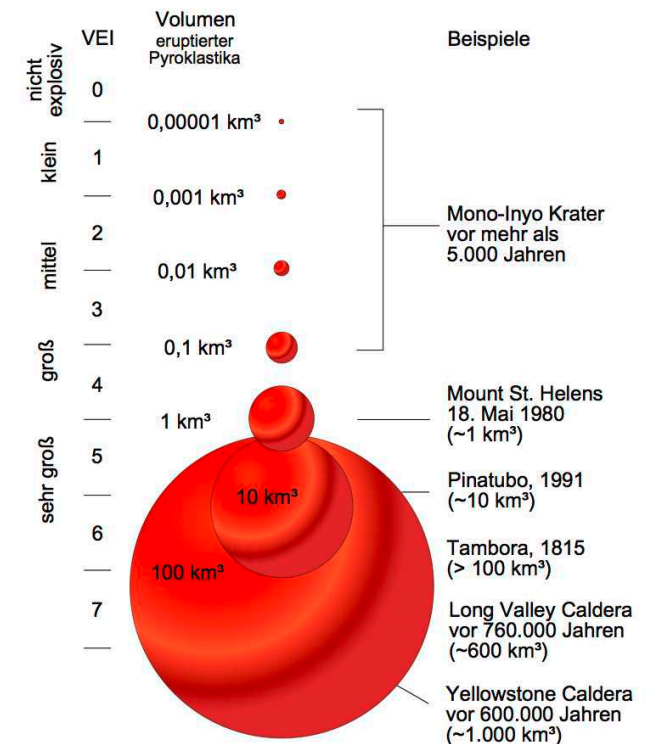
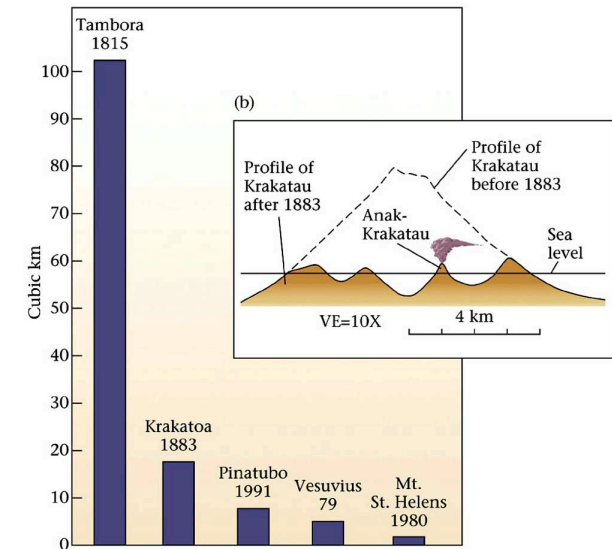
Pyroklastika

Glas

berühmte Vulkane
grosse Ausbrüche

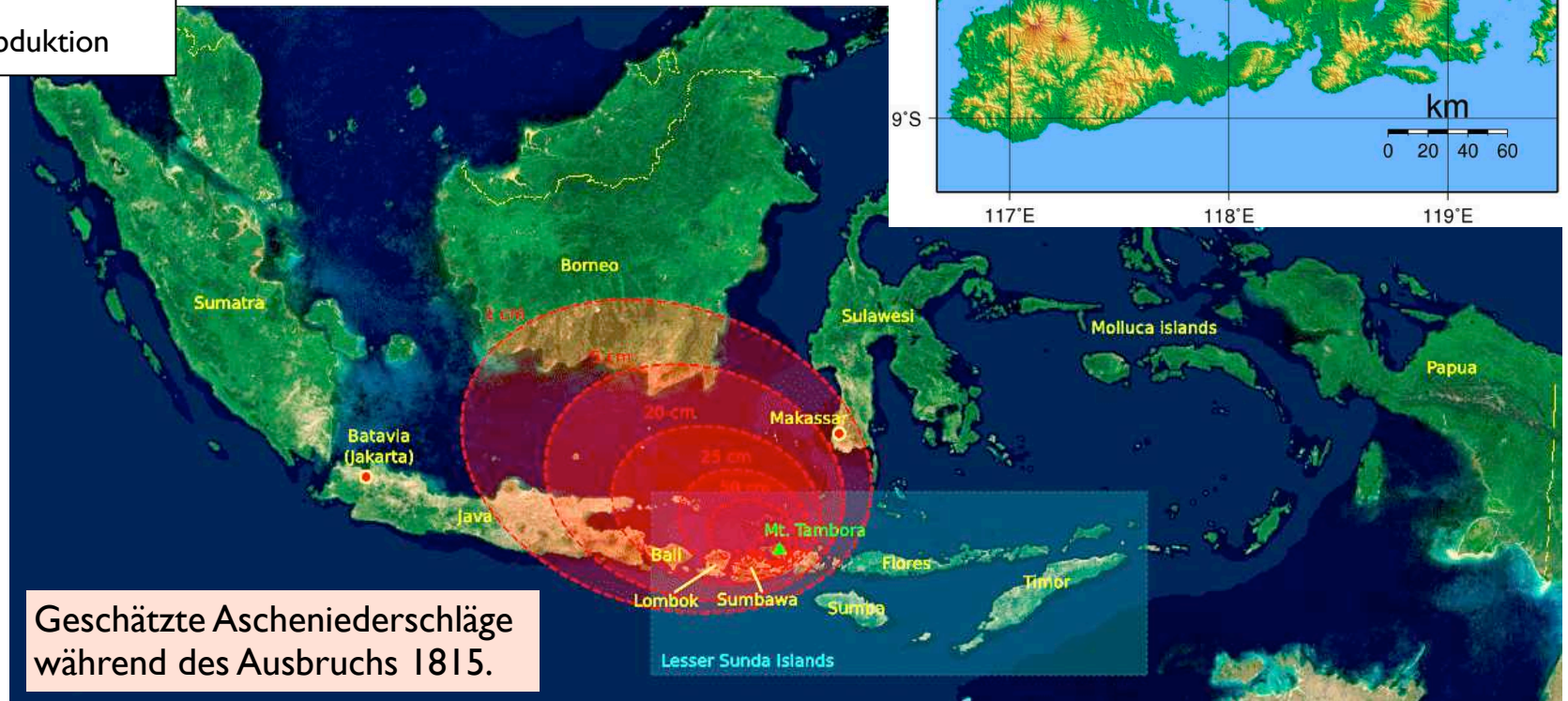
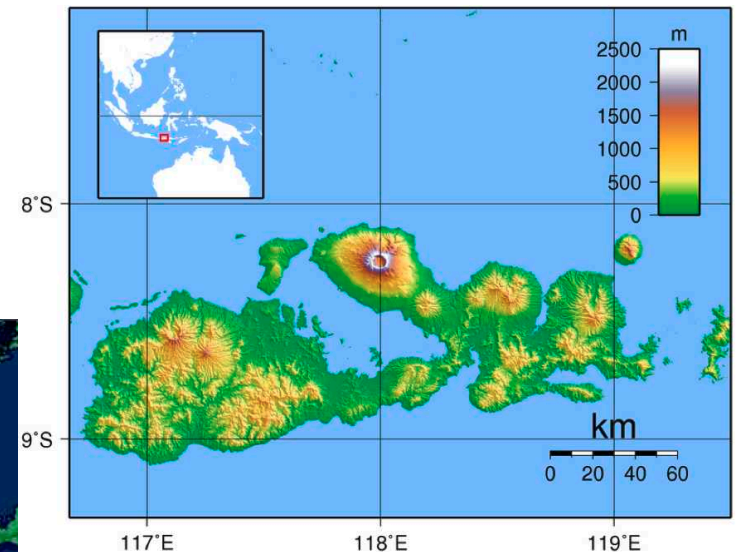
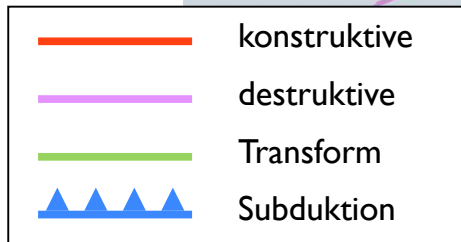
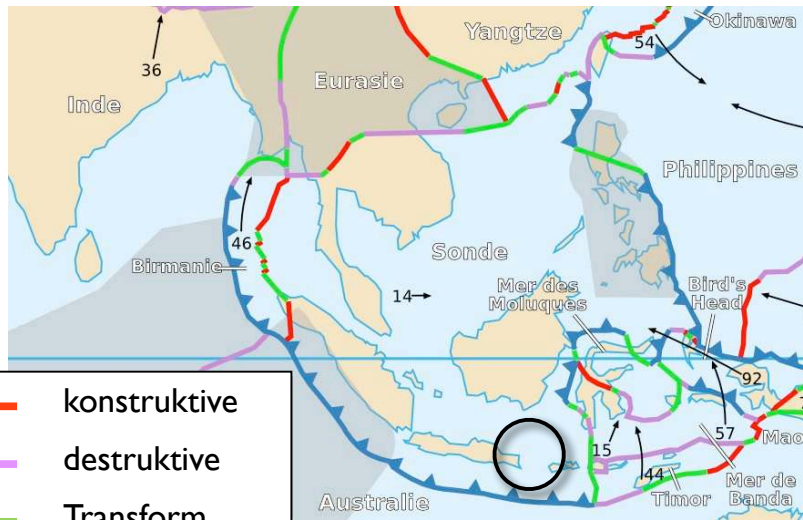
Die grössten Ausbrüche

Eruptions	Country	Location	Year	Column height (km)	Volcanic Explosivity Index
Hatepe (Taupo)	New Zealand	Pacific Ring of Fire	186	51	7
Tambora	Indonesia	Pacific Ring of Fire	1815	43	7
Baekdu	China / North Korea	Pacific Ring of Fire	969	25	6–7
Kuwae	Vanuatu	Pacific Ring of Fire	1452	?	6
Huaynaputina	Peru	Pacific Ring of Fire	1600	46	6
Krakatoa	Indonesia	Pacific Ring of Fire	1883	36	6
Santa María	Guatemala	Pacific Ring of Fire	1902	34	6
Novarupta	USA, Alaska	Pacific Ring of Fire	1912	32	6
Pinatubo	Philippines	Pacific Ring of Fire	1991	34	6
Mount Vesuvius	Italy	Mediterranean	79	30	5
Mt. St. Helens	USA, Washington	Pacific Ring of Fire	1980	19	5



http://de.wikipedia.org/wiki/Liste_großer_historischer_Vulkanausbrüche

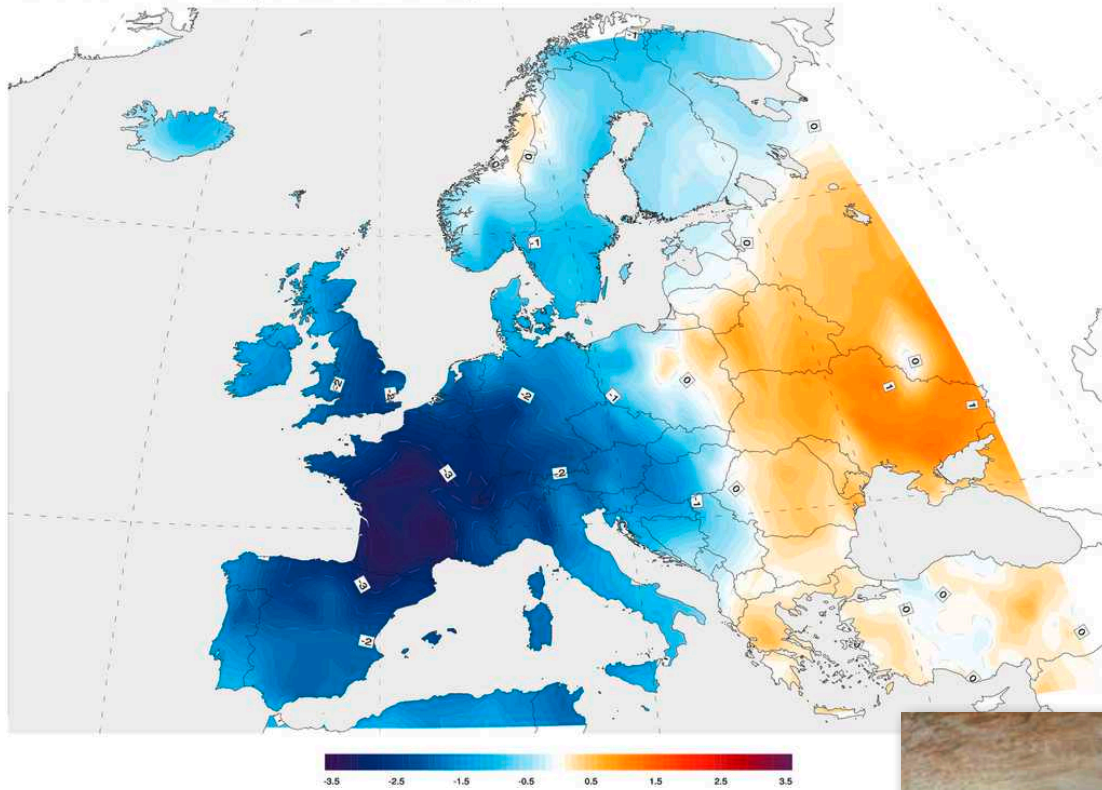
Tambora - Subduktionszone



Geschätzte Ascheniederschläge während des Ausbruchs 1815.

Tambora, 10. April, 1815

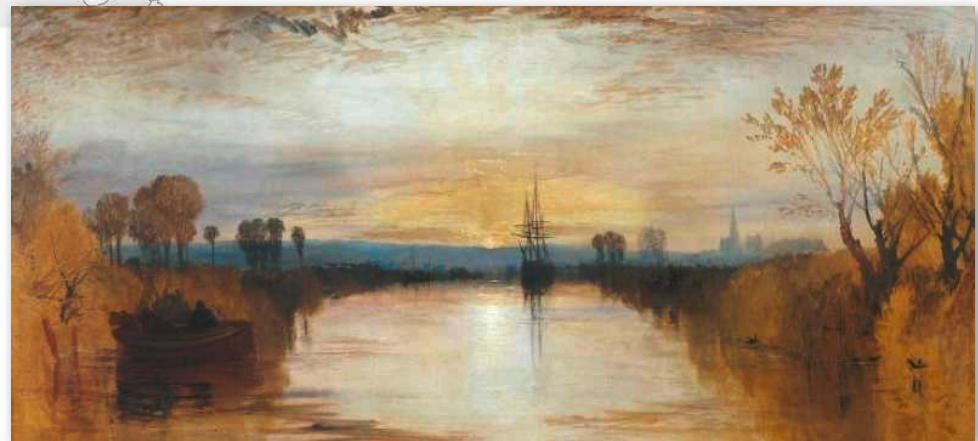
1816 Summer Temperature Anomaly



Das Jahr ohne Sommer:
"Eighteen hundred and froze to death"

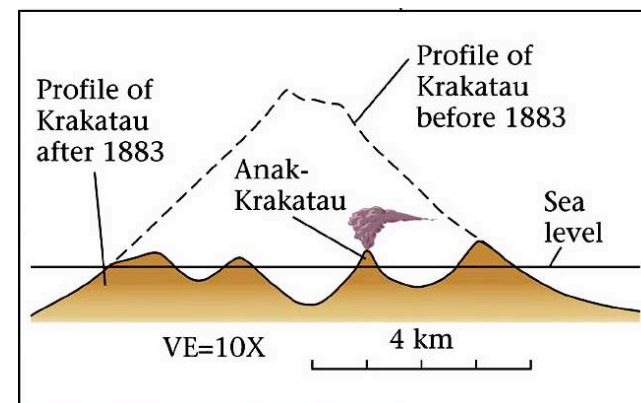
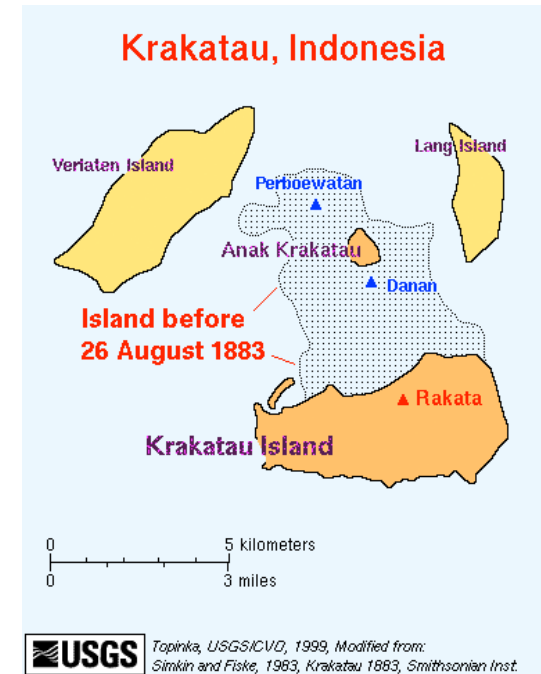
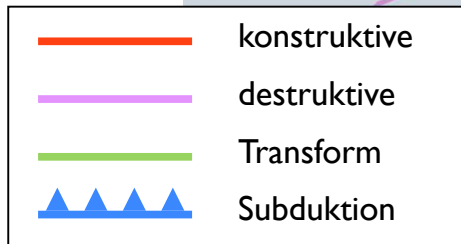
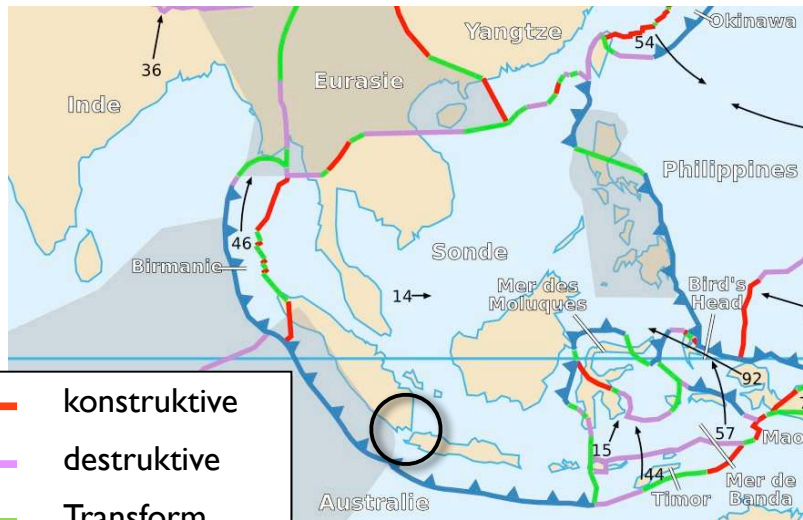


Flint Castle 1838
J. M.W. Turner (1775-1851)

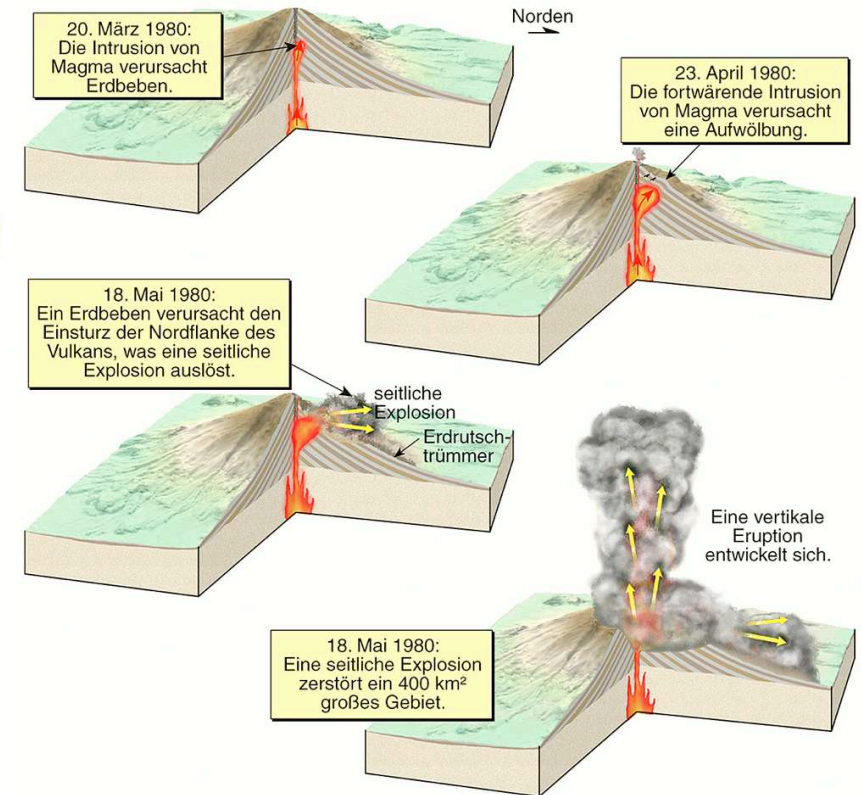


Chichester Channel 1828
J. M.W. Turner (1775-1851)

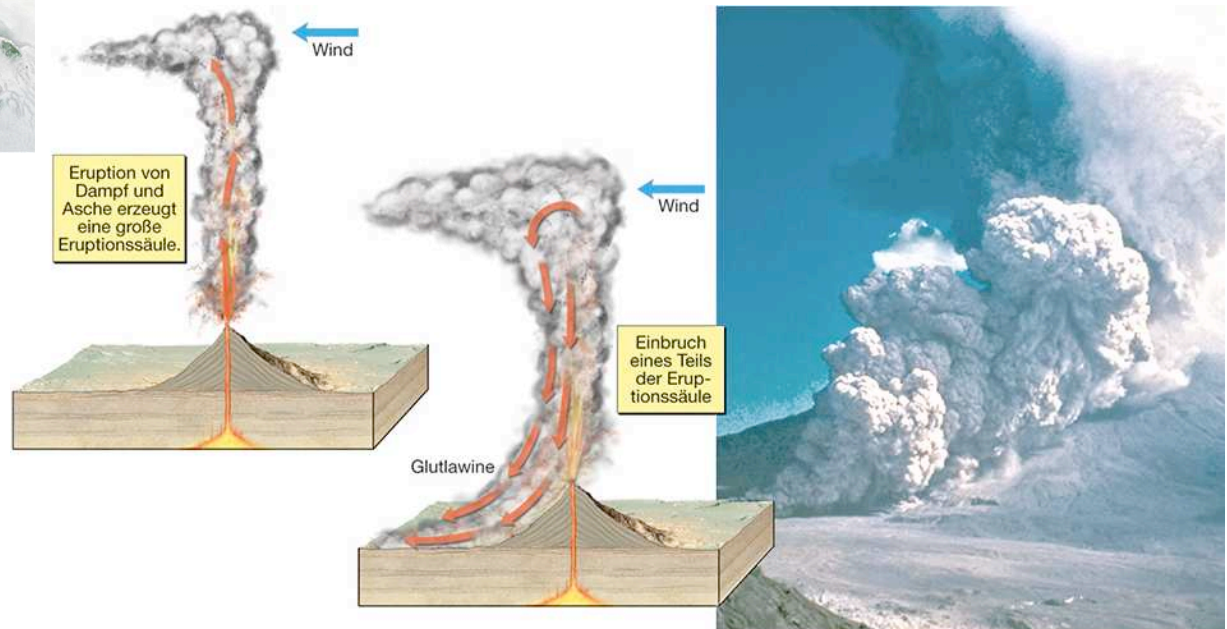
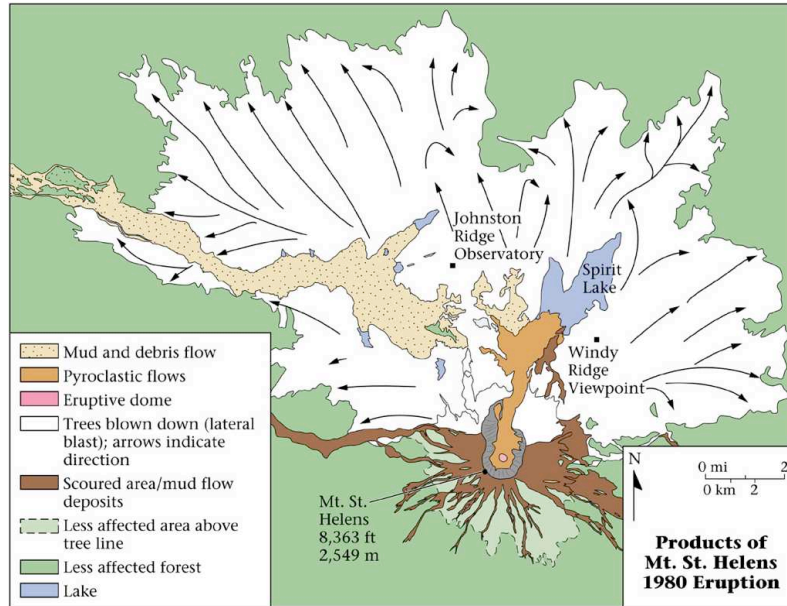
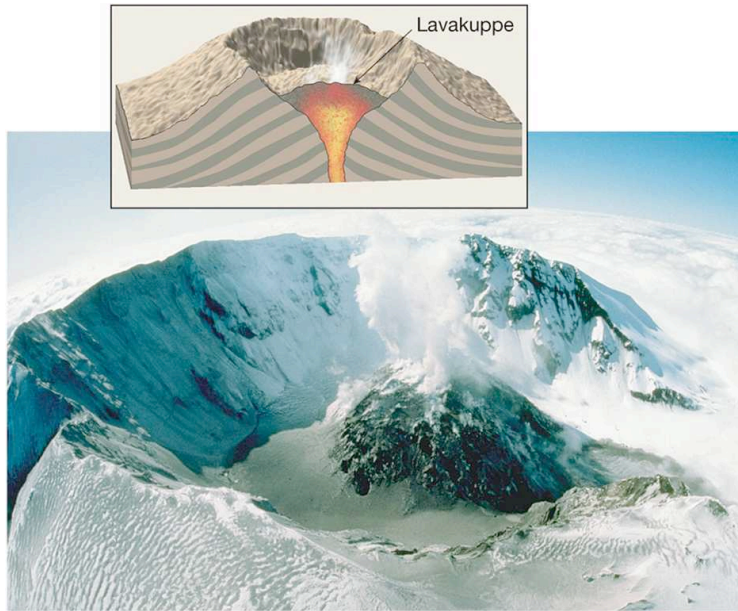
Krakatau, 22. August 1883



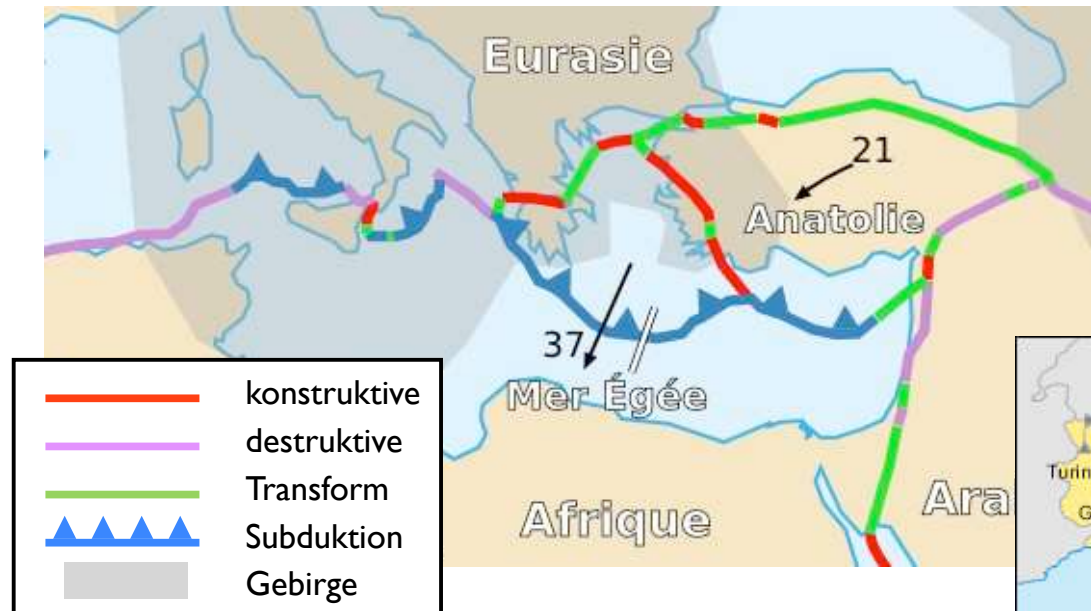
Mount St. Helens - kontinentaler Vulkanbogen



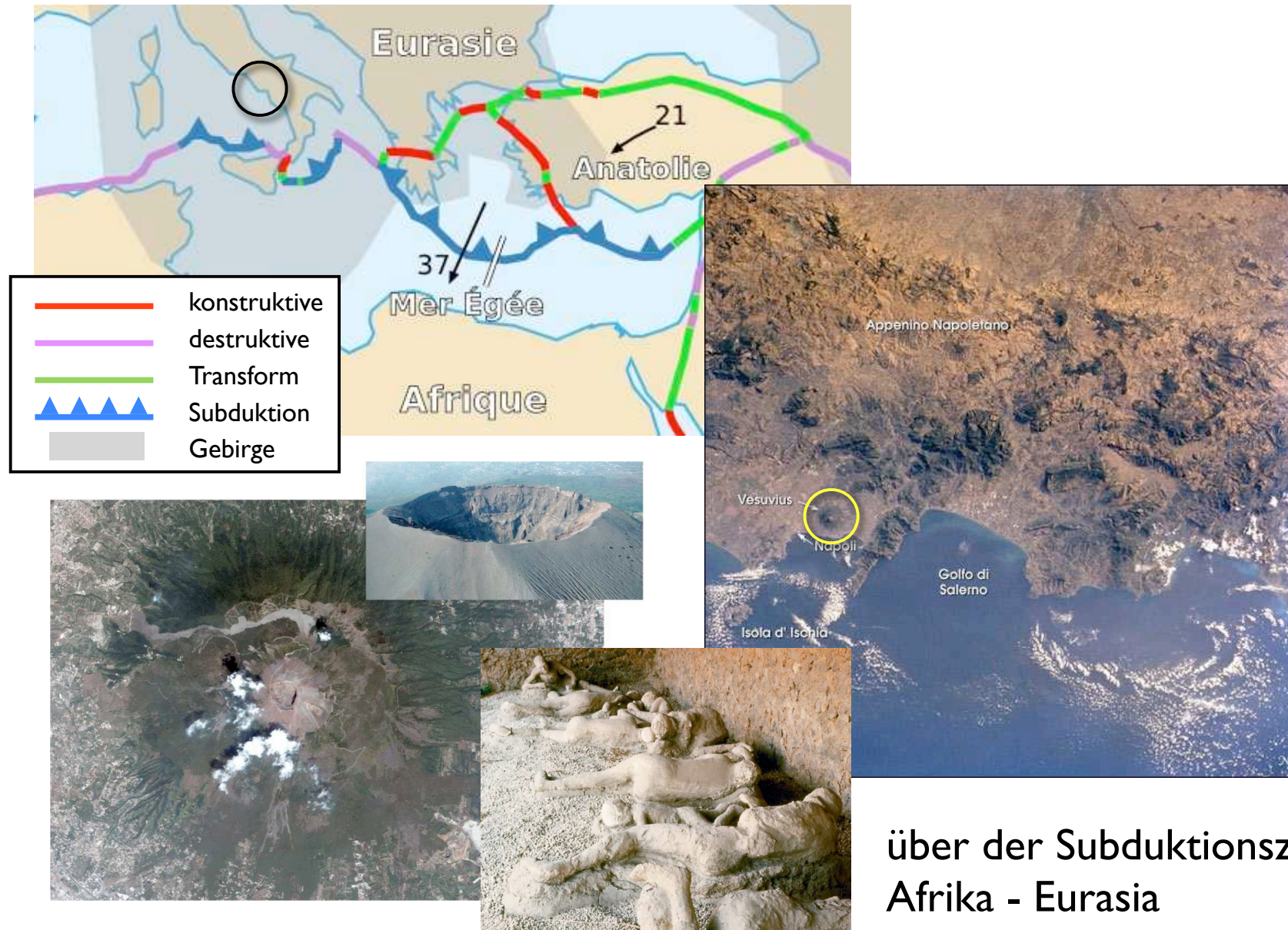
Mount St. Helens, 18. Mai 1980



Vesuv und Ätna - Subduktionszone

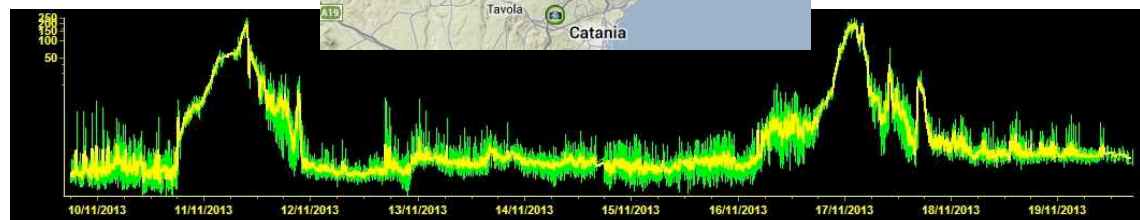
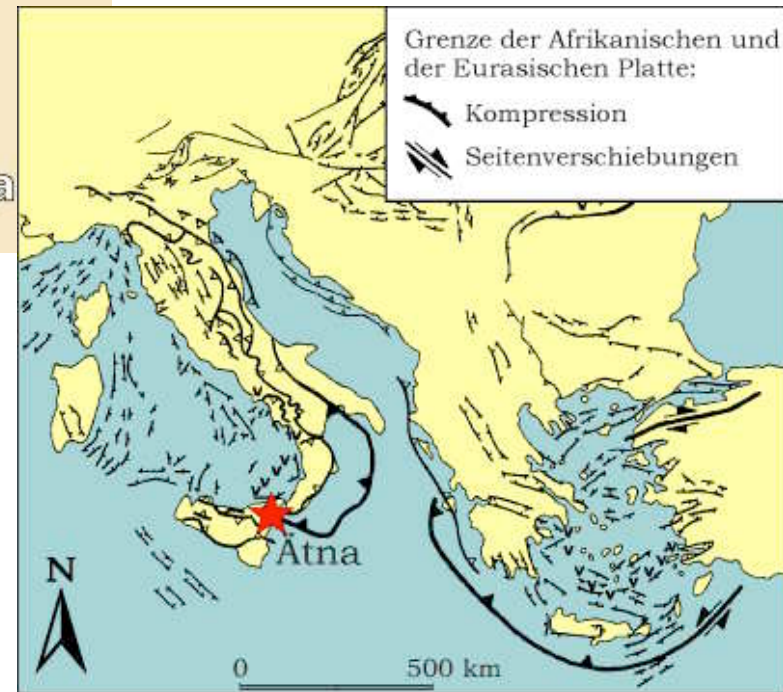


Vesuv, 24. August, 79 n. Chr.



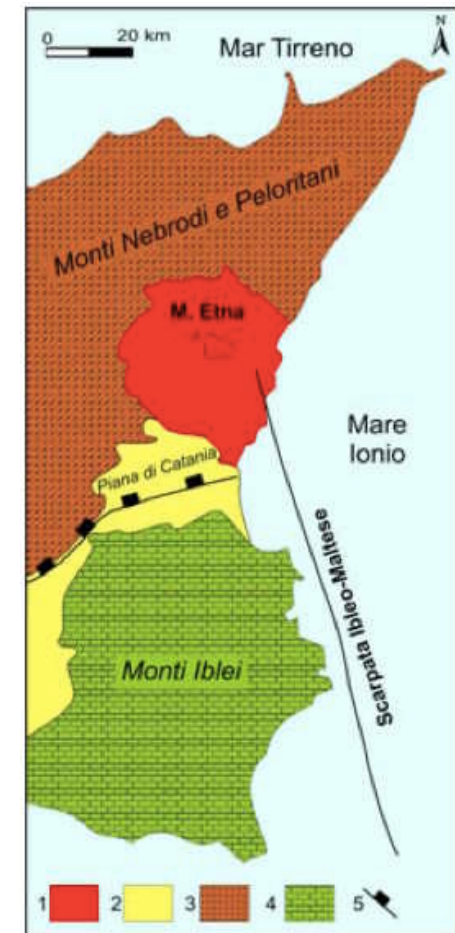
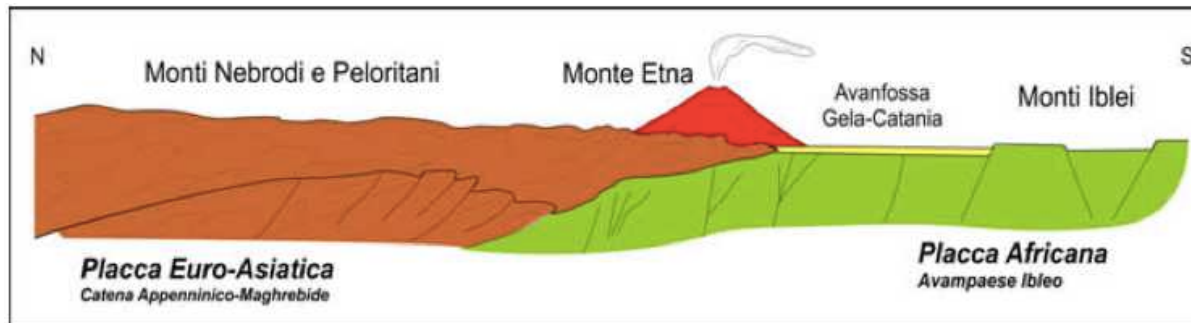
über der Subduktionszone
Afrika - Eurasia

Ätna - Subduktionszone



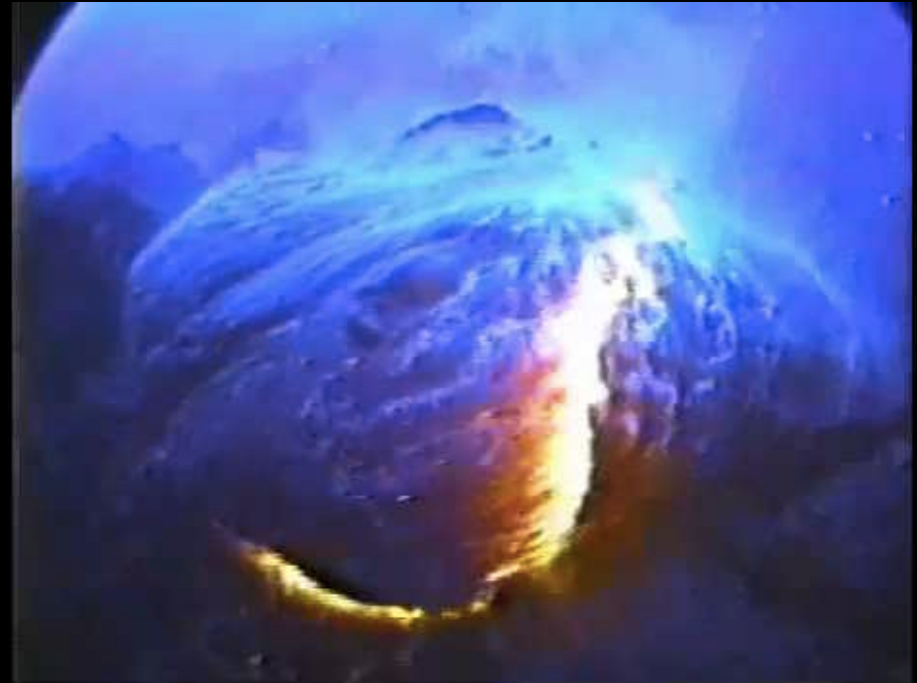
über der Subduktionszone
Afrika - Eurasia

Ätna, 26. Okt. 2013

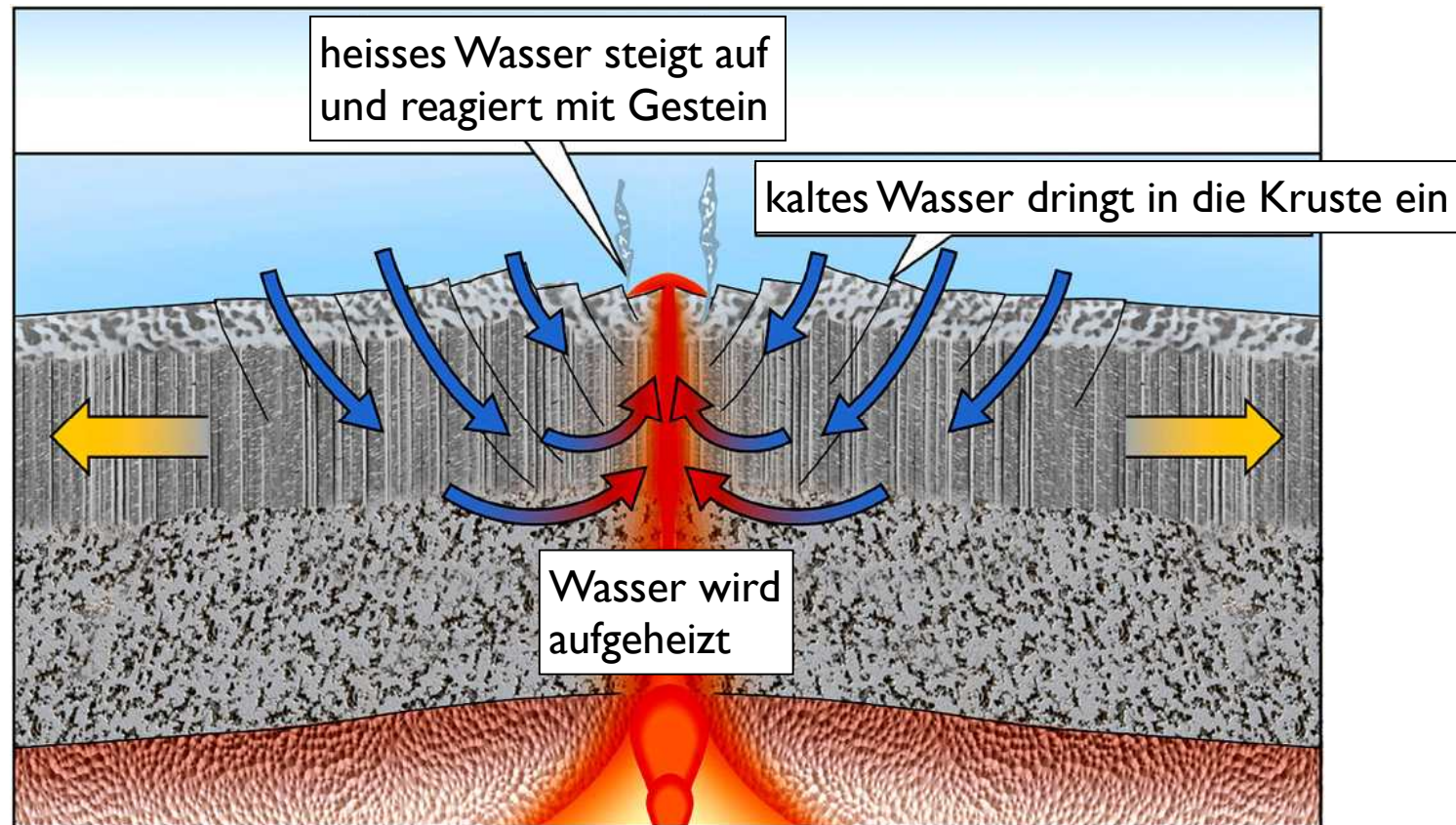


Leben am mittelozeanischen Rücken

Bildung von Kissenlava (pillow lava)



Interaktion Meerwasser - Kruste



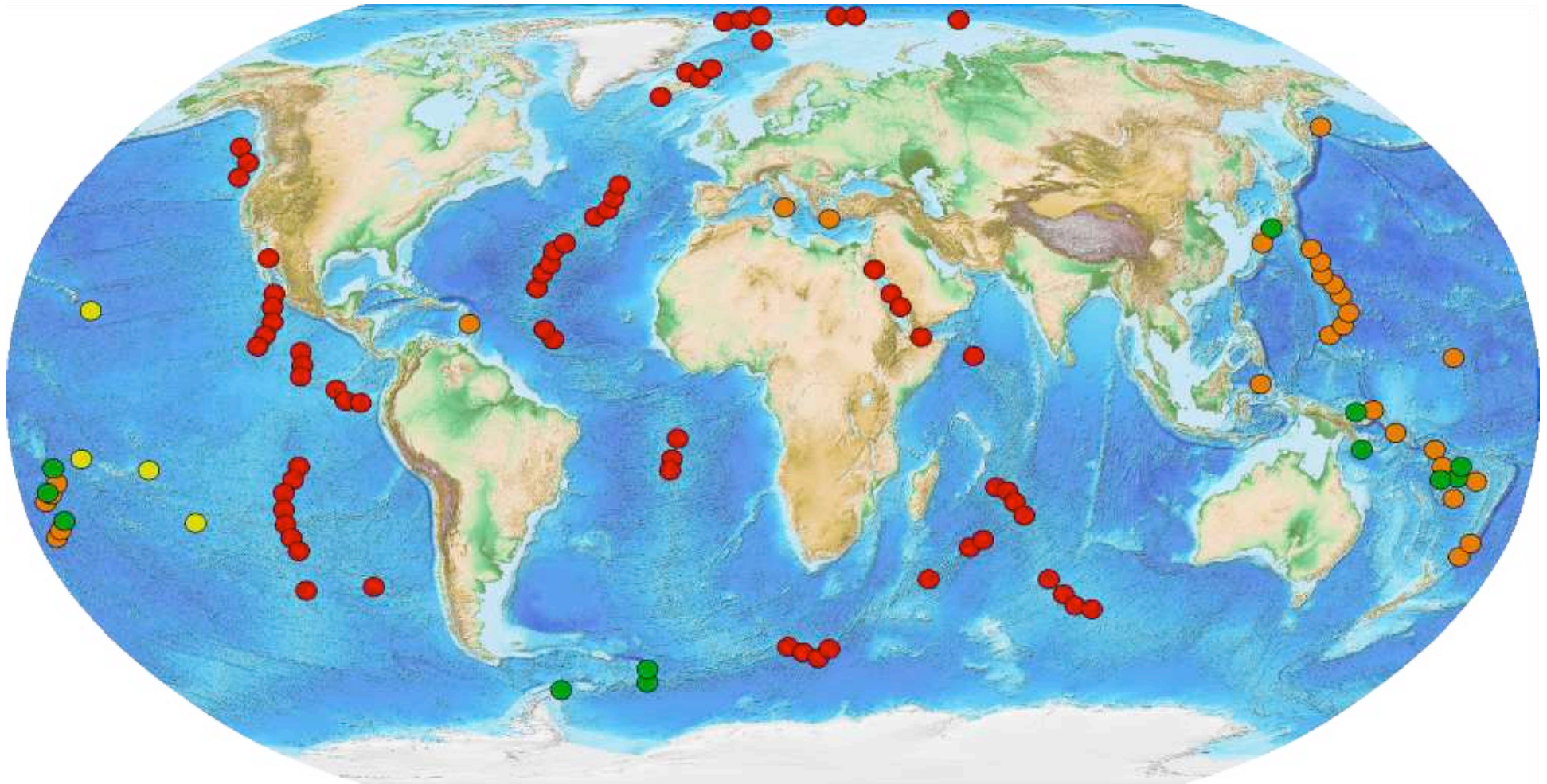
- Basaltisches Gestein erfährt Hydrothermalmetamorphose
- Hydrothermale Fluids steigen auf und bilden schwarze Raucher (black smokers)

Serpentinisierung



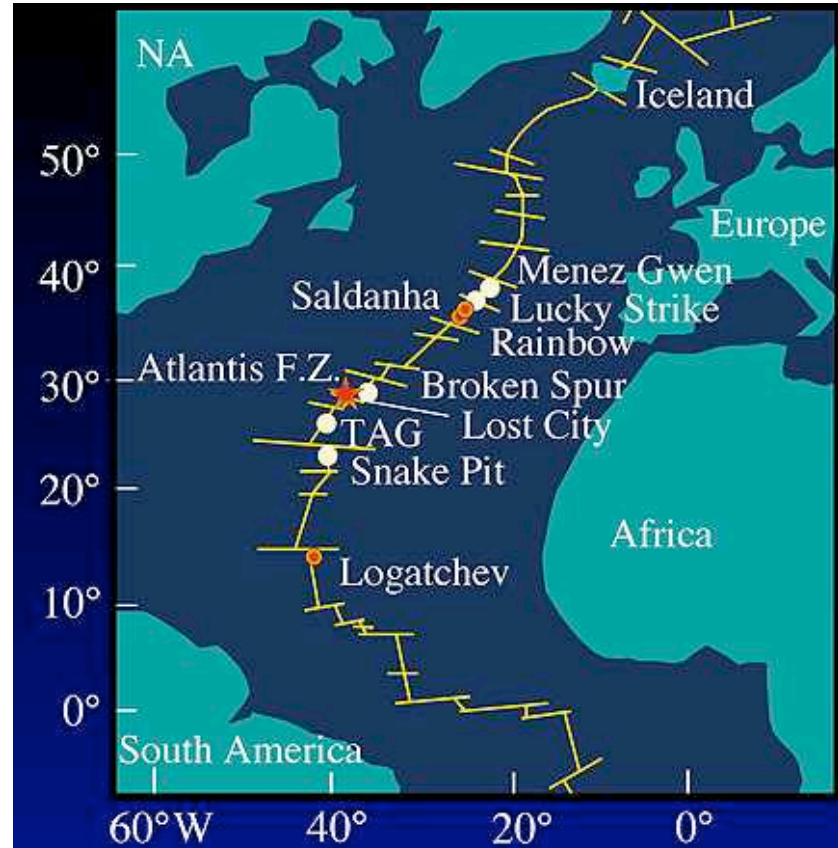
Ophikalzitbildung
Totalp Peridotit, Davos
D. Bernoulli

Hydrothermalfelder



gelb = Hotspot
rot = Mittelozeanische Rücken
grün = Back-arc Spreizungsrücken
orange = Vulkanbögen

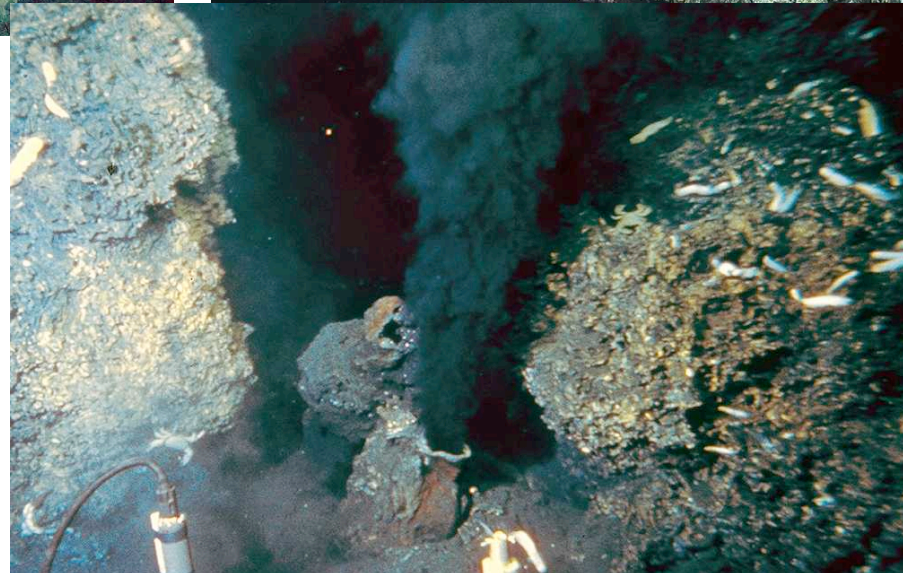
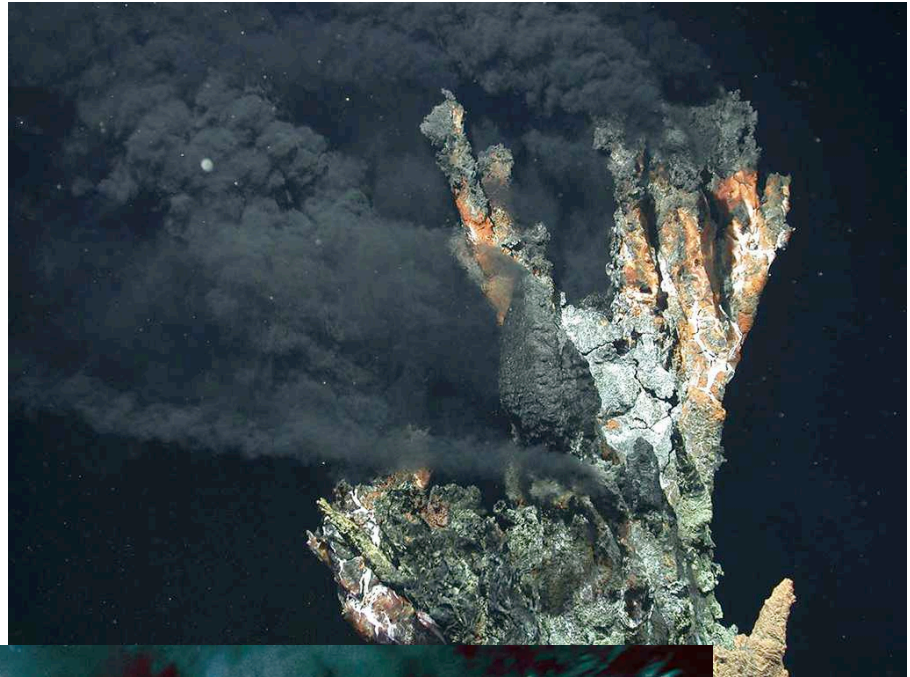
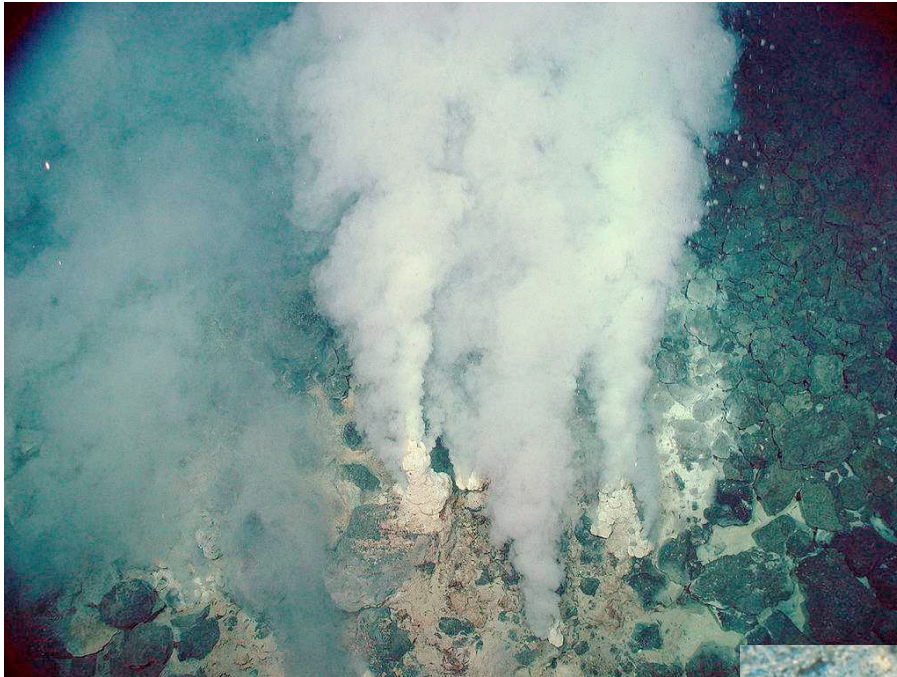
Lost City Expedition



Gretchen L. Früh-Green
Petrologist and Geochemist
Department of Earth Sciences
ETH-Zurich, Switzerland
shore-based



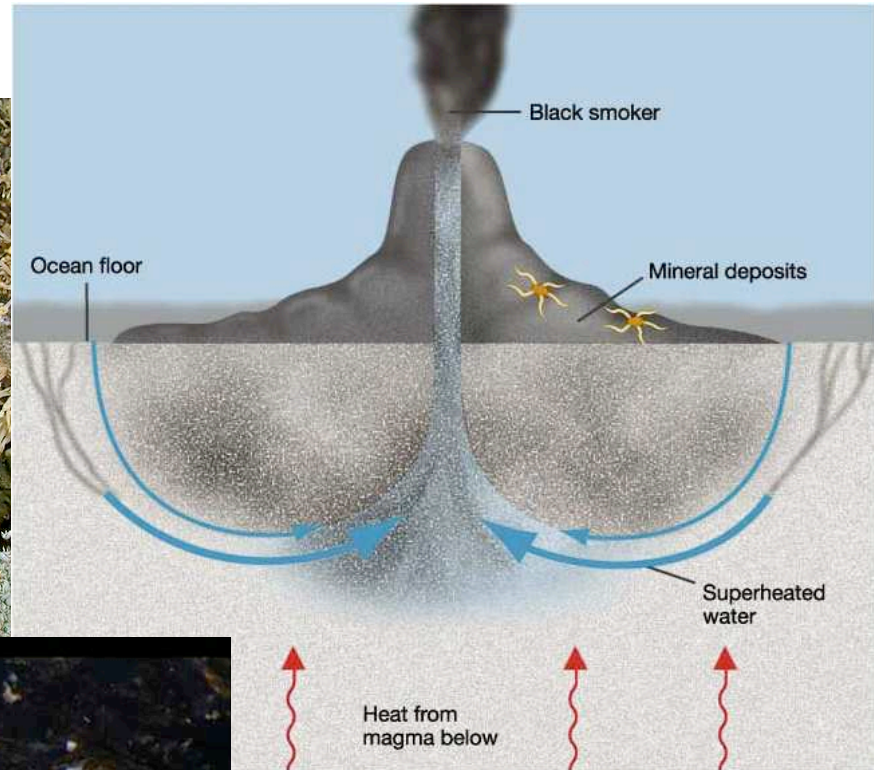
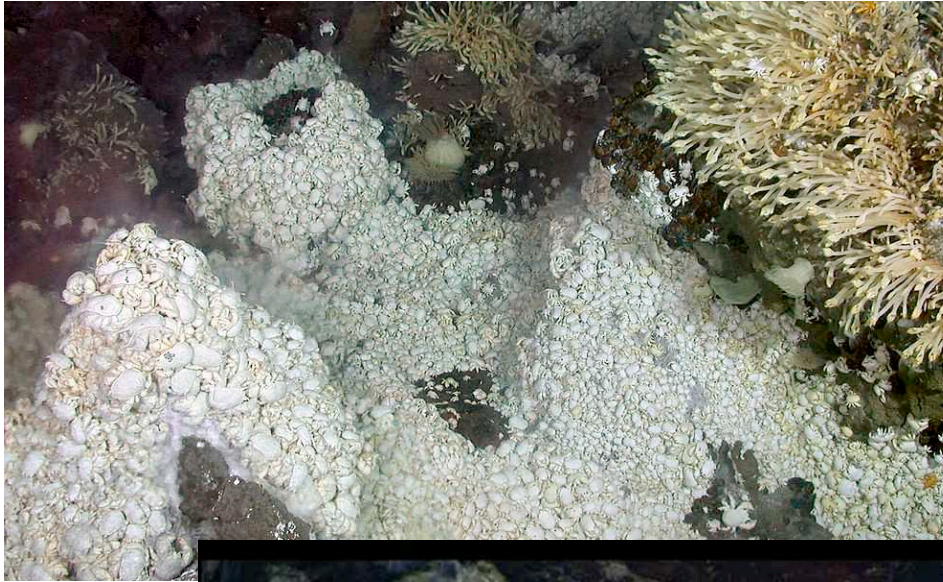
Schwarze und weisse Raucher



ROV Kiel nach Twin Sisters



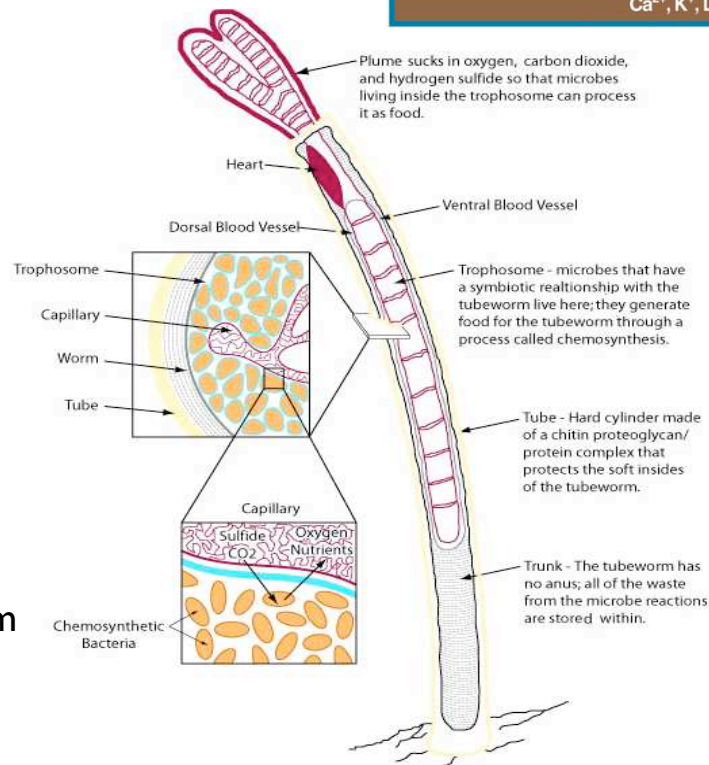
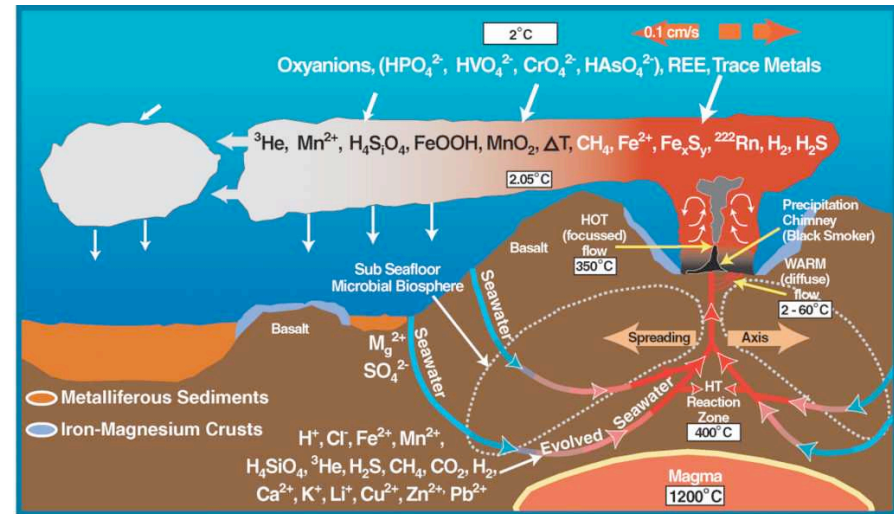
Chemosynthese versus Photosynthese



Thermophile Biotope



Riftia pachyptila (Bartwurm)
bis zu 3m lang (nur im Pazifik)
Symbiose mit Schwefelbakterium
Filamente (rot=Hämoglobin)

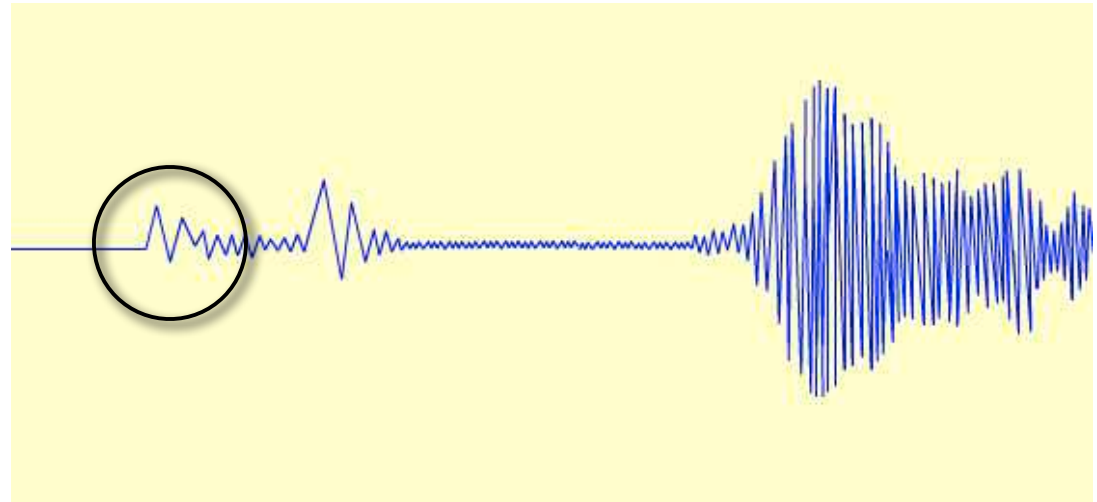


Erdbeben

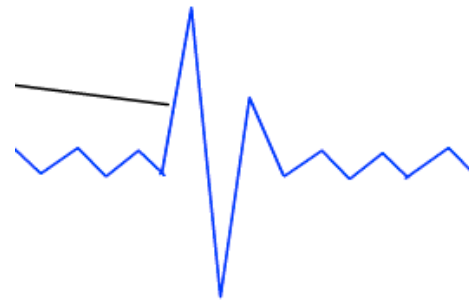
Erstausschläge

Herdflächen

Erdbeben - Erstausschlag

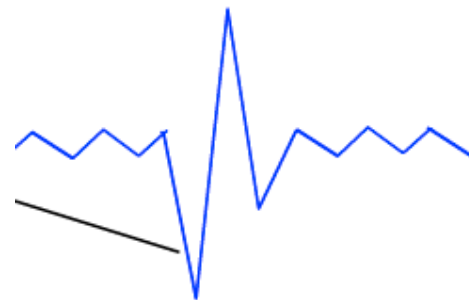


Kompression an der Messtation



= weg vom Epizentrum

Tension an der Messtation

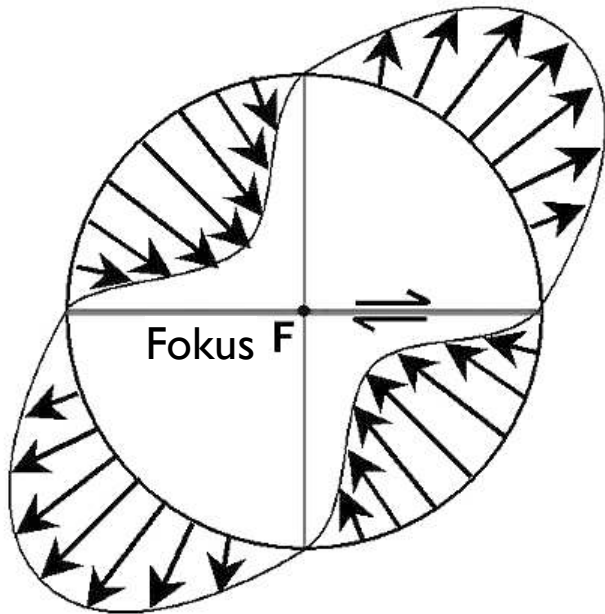


= hin zum Epizentrum

Erdbeben Bruchfläche

Bewegungssinn der
abgestrahlten Welle:

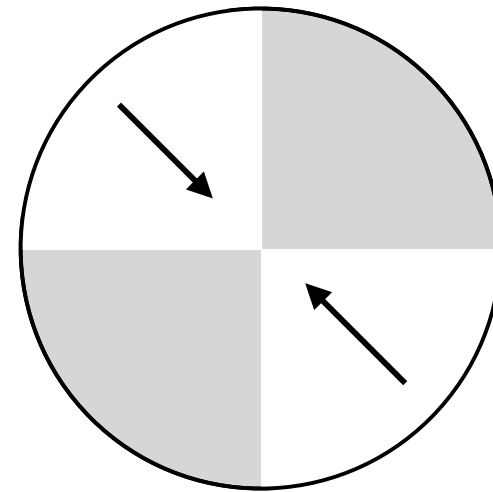
Kontraktion (hin zum Epizentrum)



Dehnung (weg von der Epizentrum)

Bewegungssinn der
eintreffenden Welle:

Tension

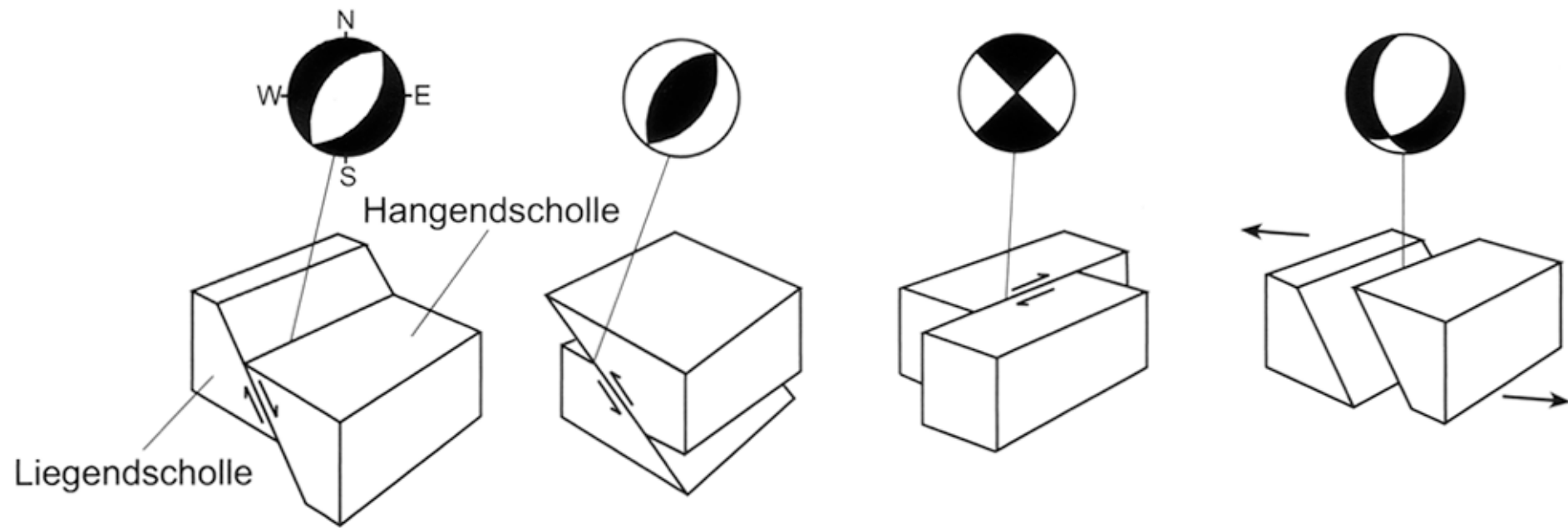


Kompression

σ_1

Haupt-
spannungs-
richtung

Erdbeben - Herdflächenlösung



Abschiebung

Aufschiebung

Blattverschiebung

Transtension

Überschiebung

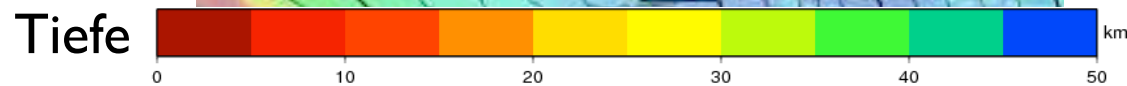
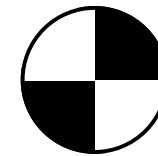
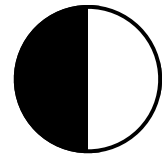
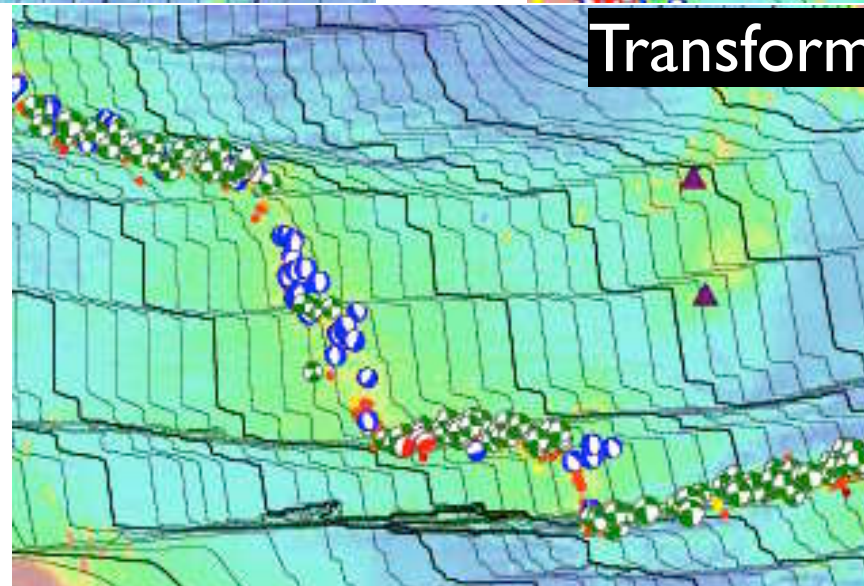
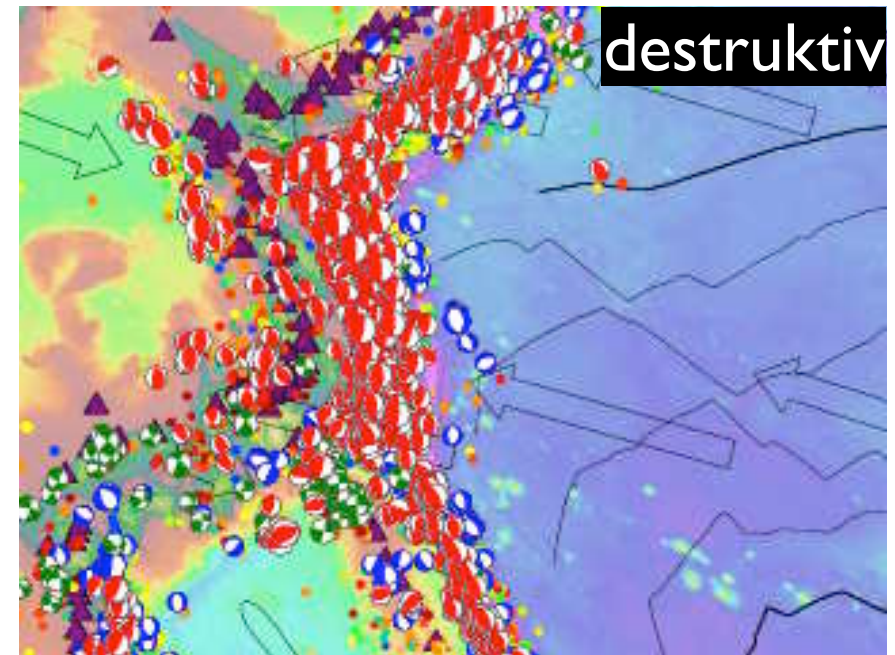
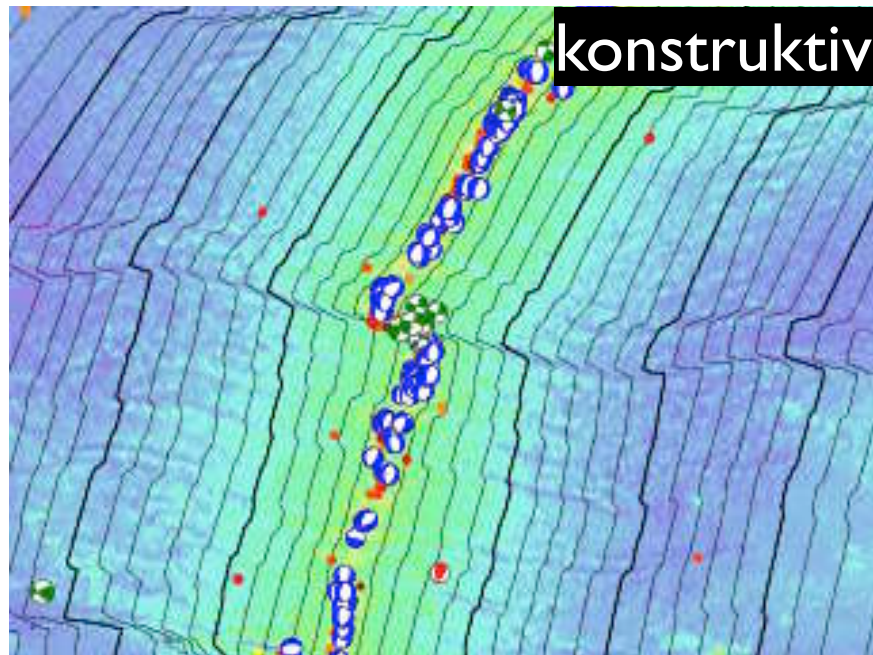
Seitenverschiebung

Konstruktive

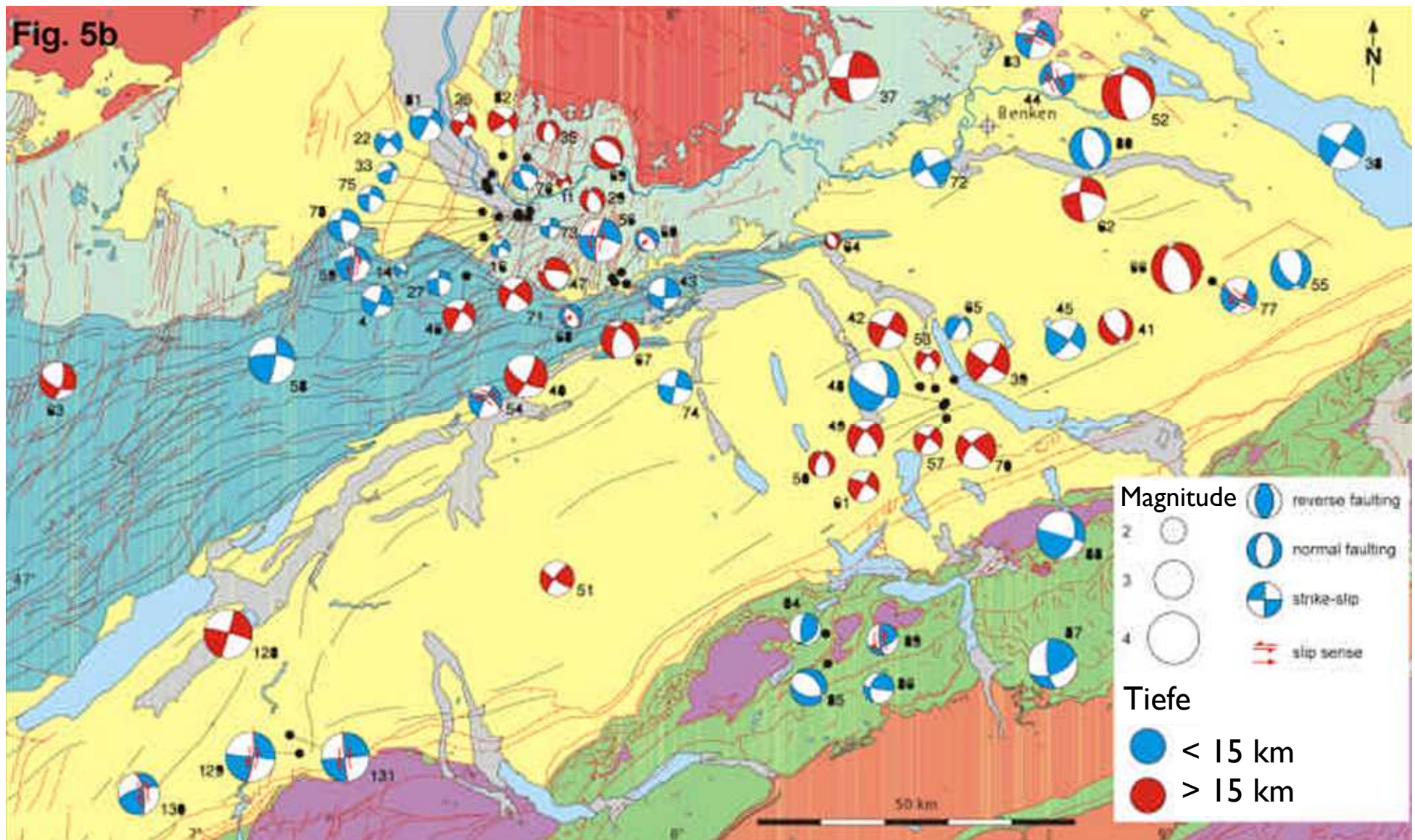
Destruktive

Transform- Plattengrenze

Typische Herdflächenlösungen für Plattengrenzen



Spannungsfeld in der Schweiz



<http://pages.unibas.ch/earth/tecto/images/Hazard.pdf>

S.M. Schmid¹), K. Ustaszewski¹), N. Deichmann²), W.H. Müller³), D. Slejko⁴)



Ende 4. Stunde

Kataklasit aus einer Bruchfläche, Sacramento Mountains