ASTR430 Quiz #1 (18 points) Name ____________________

Be the professor! First circle **True** or **False** for each statement below (there may be several correct statements or none at all). Then, for all **False** statements, cross out the part of the sentence that is wrong. Finally, for Extra Credit, provide a one or two word correction for the **False** statements, if possible.

Chapter 5: Planetary Atmospheres

3 **True** or **False** The exponential change in atmospheric pressure with height derived in class also applies to the interiors of ~~of~~ gas giant planets. +1

3 **True** or **False** Ozone absorbs ultraviolet light and is the primary molecule responsible for heating Earth's ~~Mesosphere~~ stratosphere +1

3 **True** or **False** Water clouds are found on the following planets: ~~Mercury, Venus,~~ Earth, Mars, Jupiter, and Saturn.

3 **True** or **False** Carbon Dioxide clouds are found on the following planets: ~~Mercury~~, ~~Venus~~, ~~Earth~~, Mars, ~~Jupiter~~, and ~~Saturn~~.

3 **True** or **False** Gas molecules high in a planetary atmosphere have a Maxwellian distribution of speeds; the fastest ones undergo Thermal, or Jeans, escape.

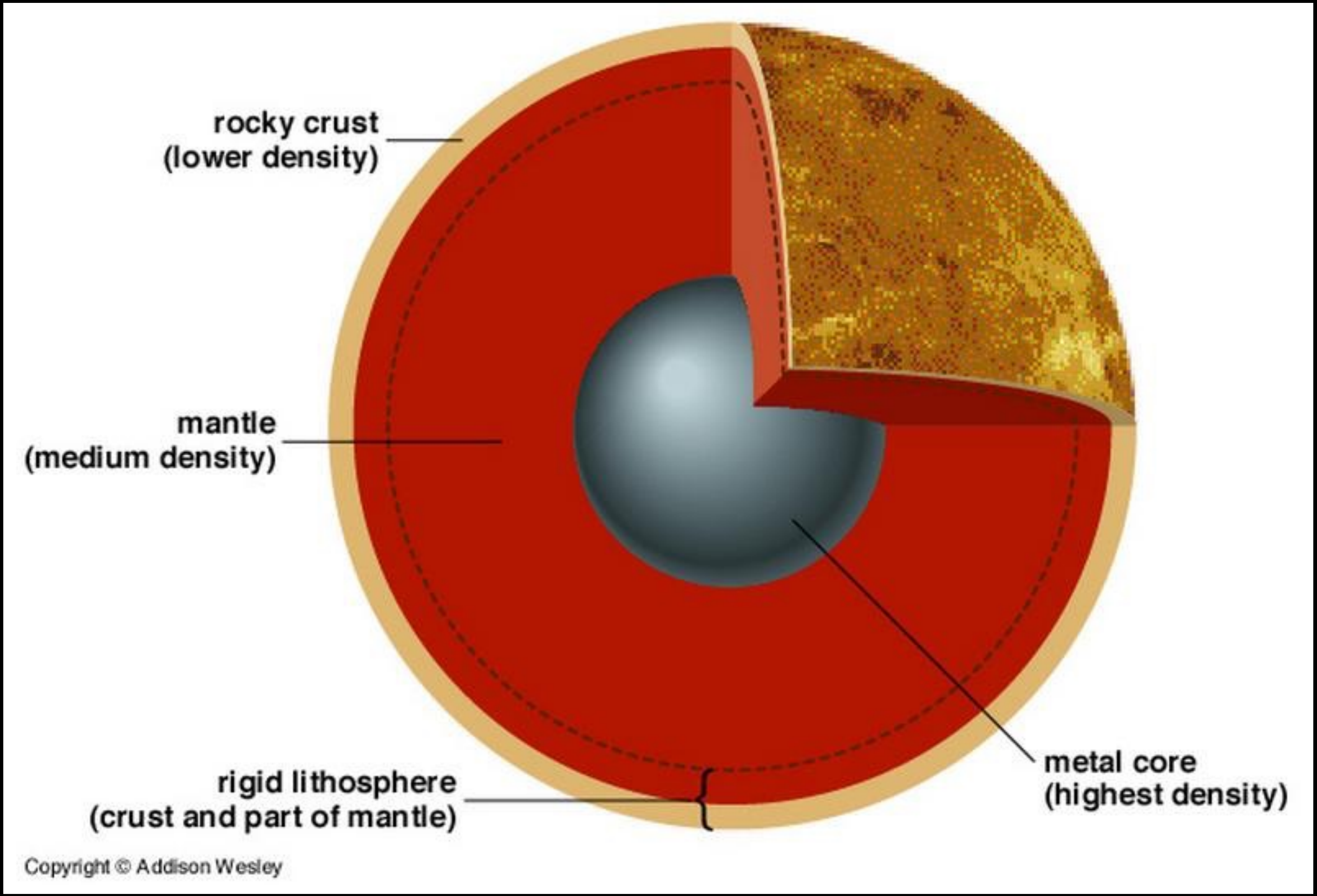
3 **True** or **False** Giant planet atmospheres are composed primarily of H and He; other abundant gases include H_2O, ~~O_2, CO_2~~, H_2S, CH_4, and NH_3.

18

Planetary Interiors

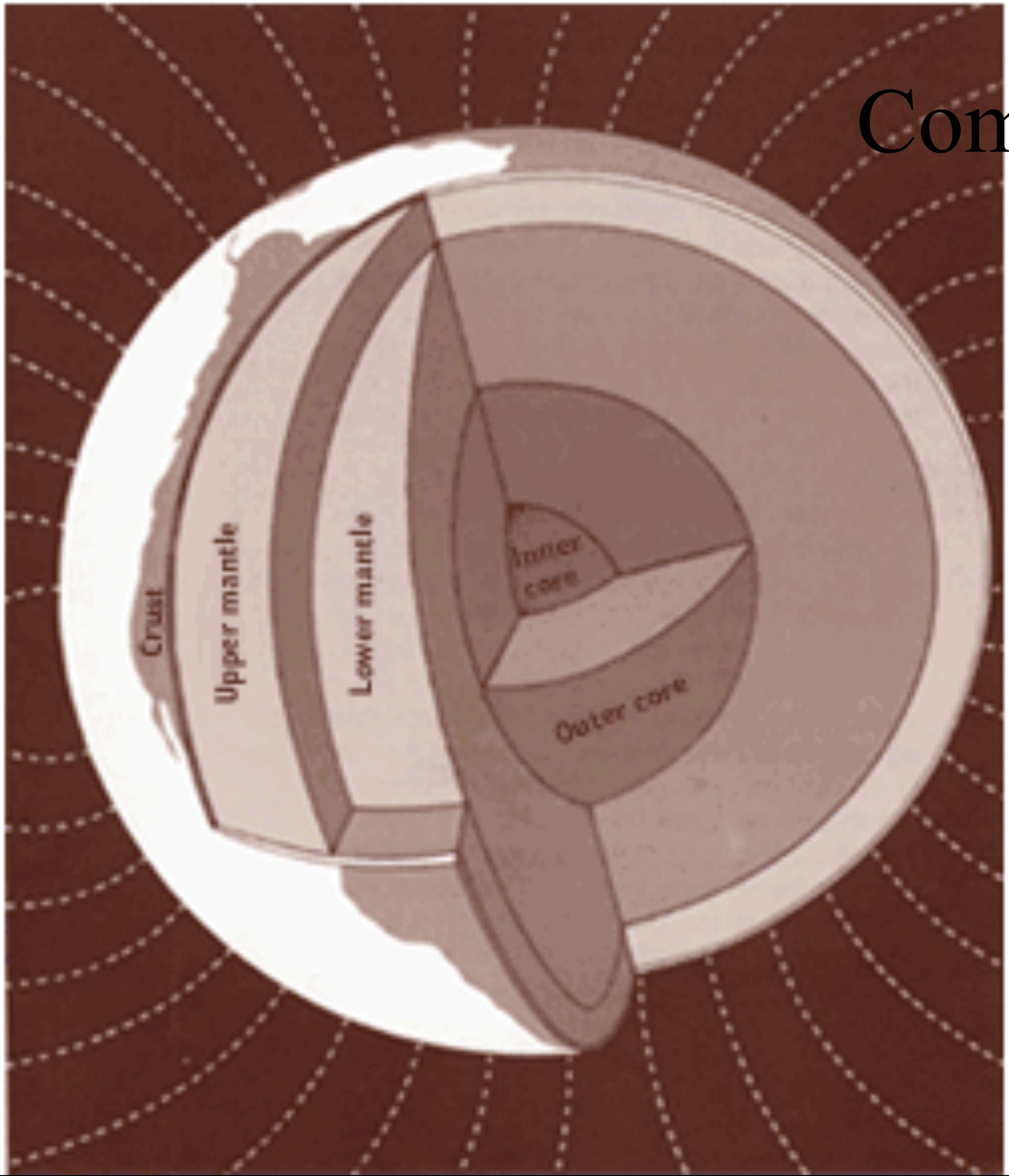
1. Interior Structure of the Earth
2. Interiors of Other Planetary Bodies
3. Accretion and Radioactive Heating
4. Plate Tectonics

Earth's Interior

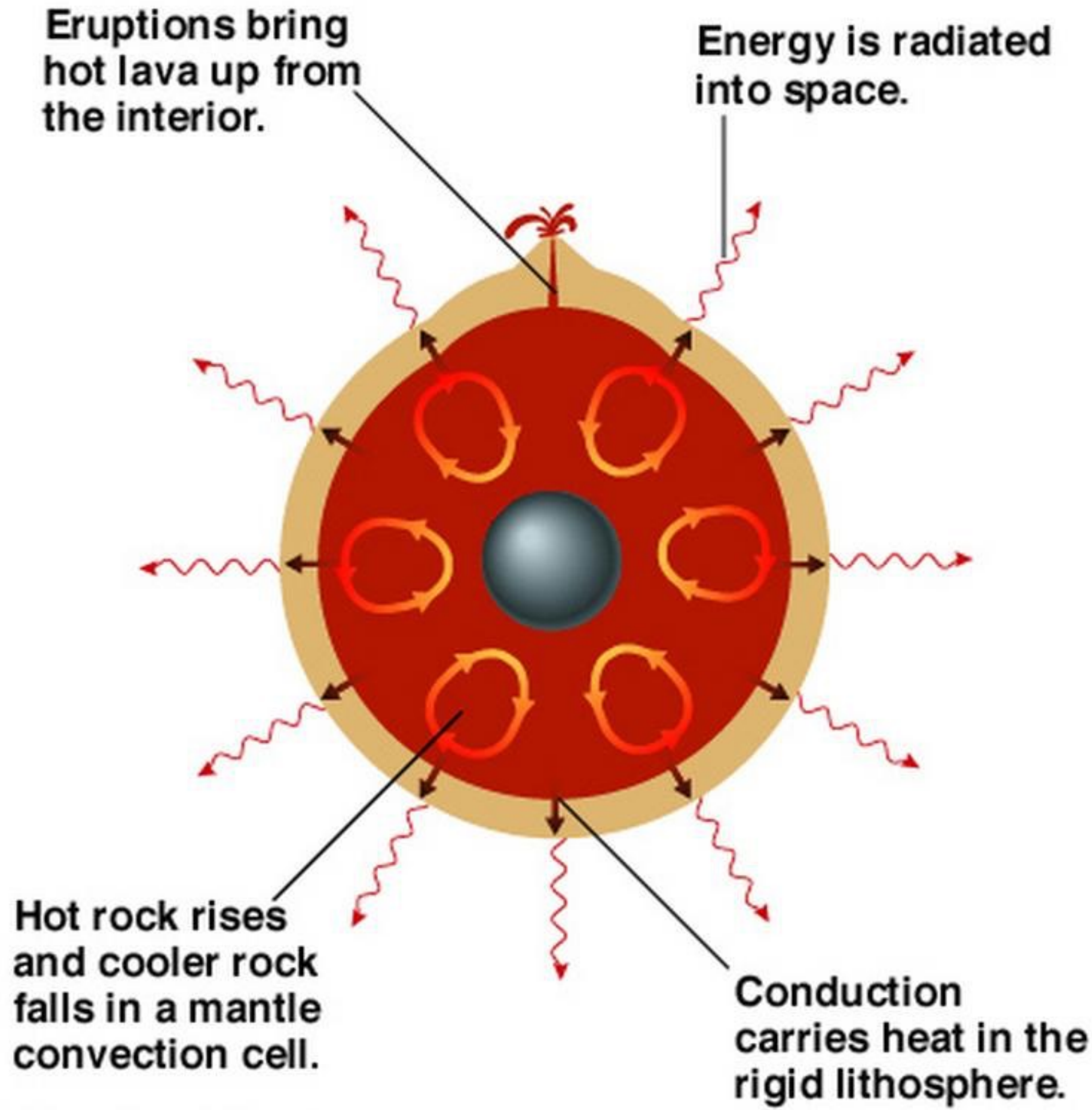


The Interior of the Earth

by Eugene C. Robertson



Components:
Crust
Mantle
Core


Eruptions bring hot lava up from the interior.
Energy is radiated into space.
Hot rock rises and cooler rock falls in a mantle convection cell.
Conduction carries heat in the rigid lithosphere.

Earthquake Waves

1. P Waves and S Waves

2. Planetary Size vs. Cooling Rate

or 'Moho' (Box 2.4). This important seismic boundary provides excellent evidence for a fundamental compositional layering structure within our planet.

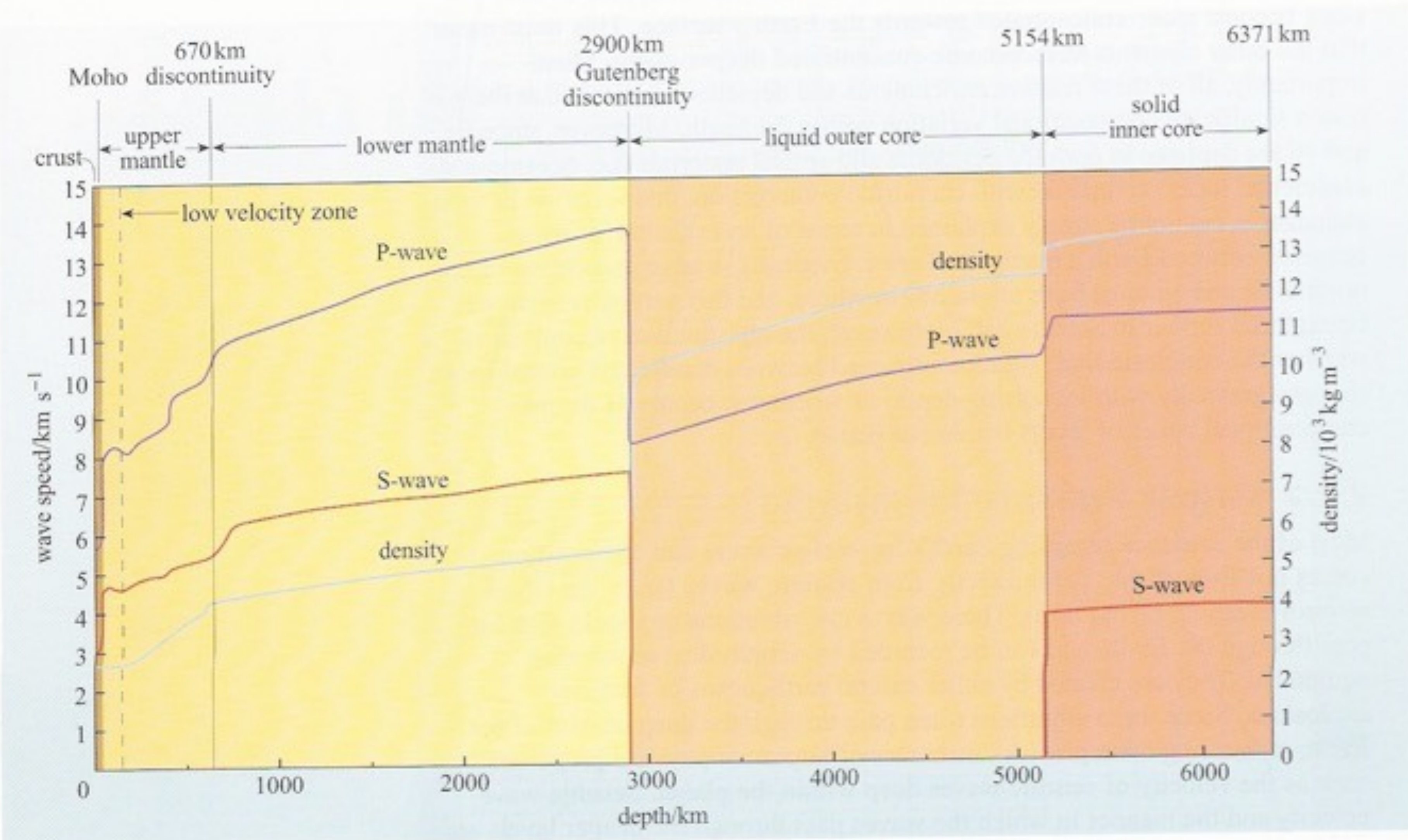
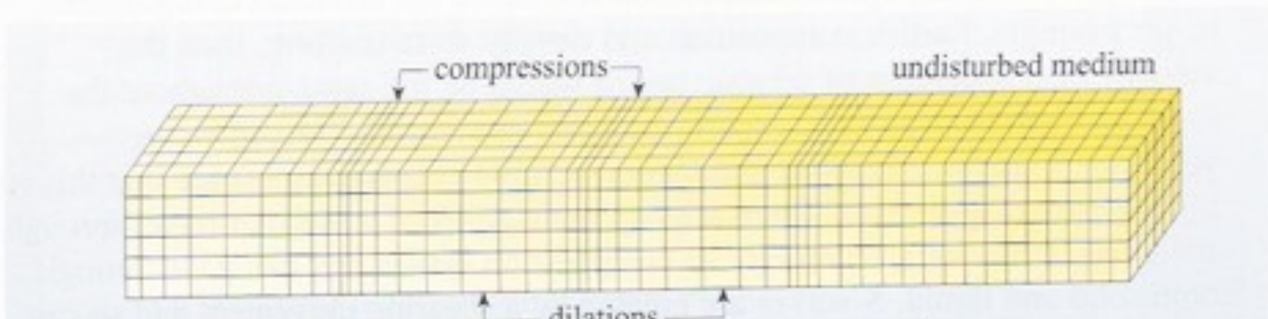
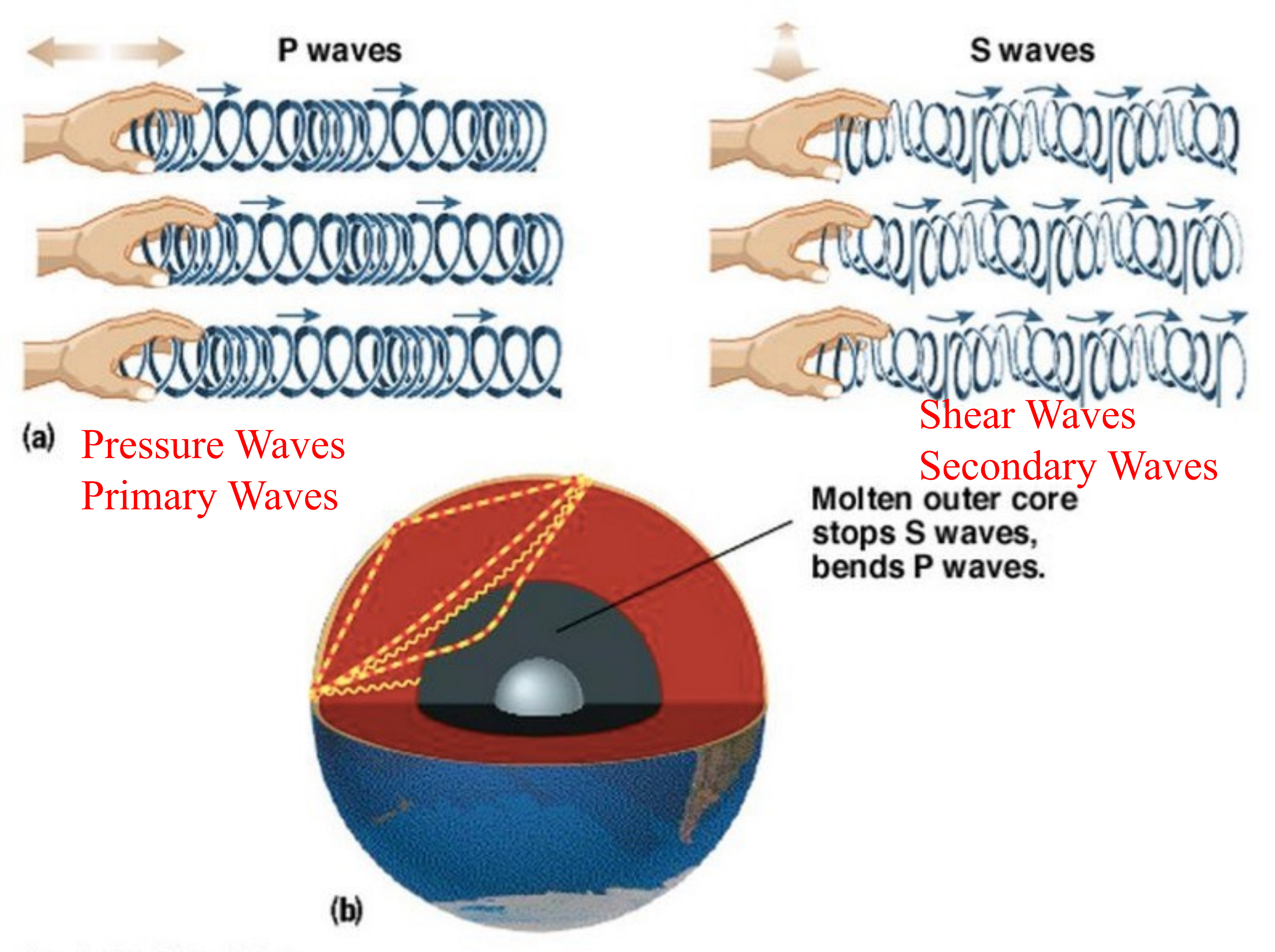


Figure 2.4 Velocity profiles of P-waves and S-waves within the Earth, and inferred densities. The term 'velocity profile' refers to the changes in velocity of seismic waves with increasing depth.



P Waves and S Waves

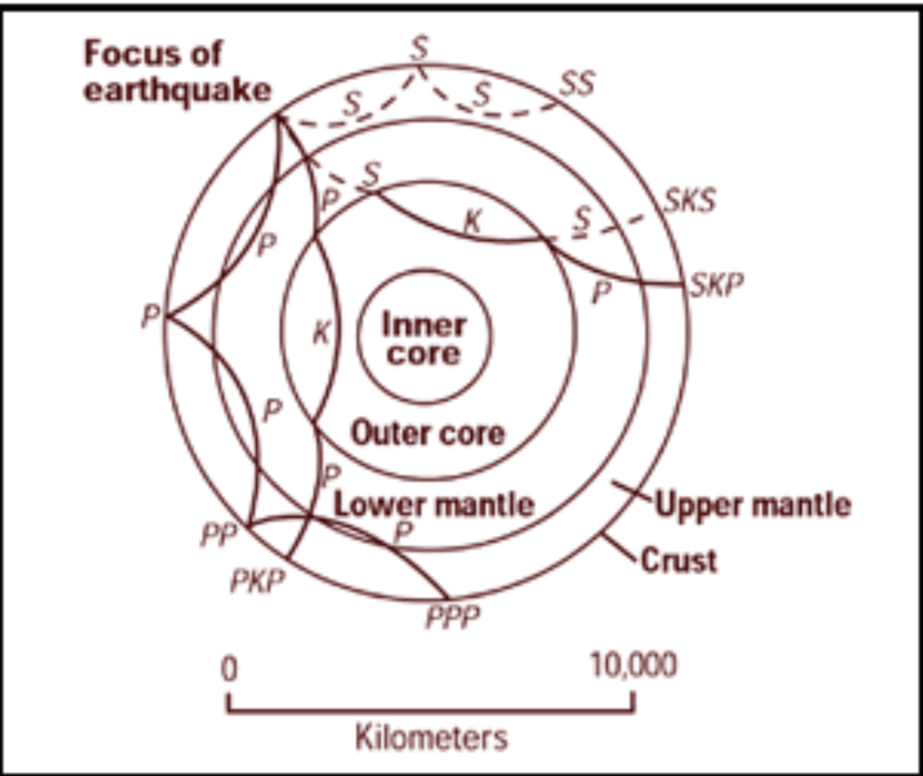


How do we know this?

Data on the Earth's Interior

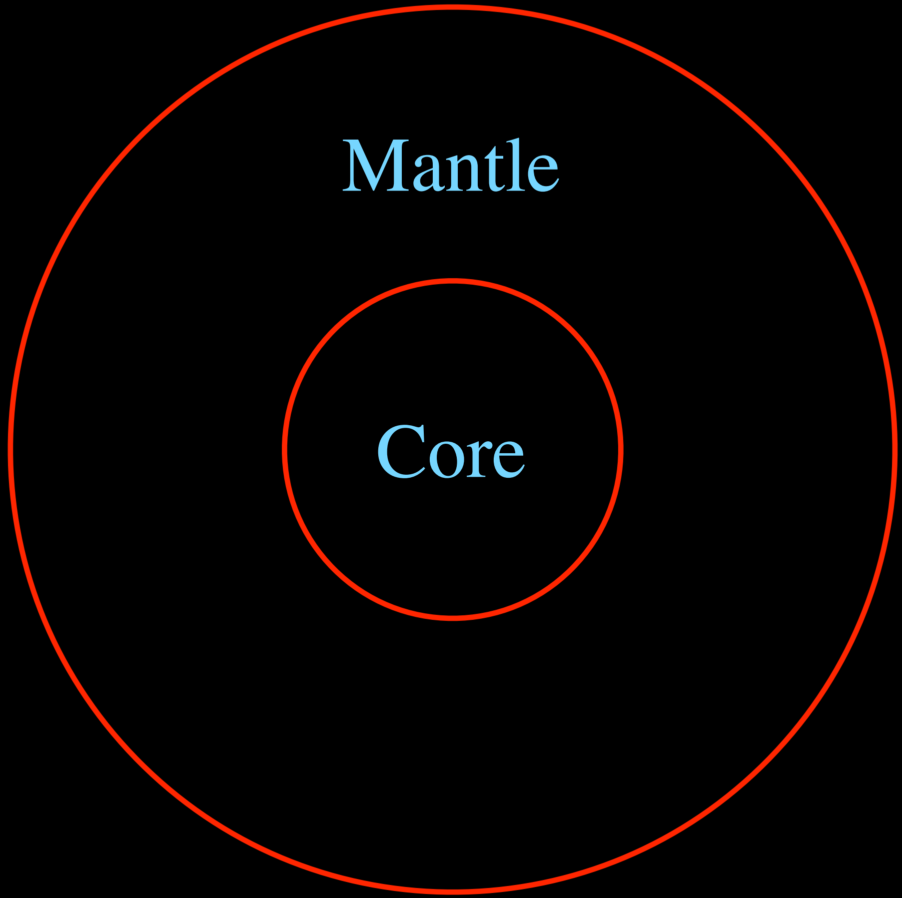
	Thickness (km)	Density (g/cm³) Top	Density (g/cm³) Bottom	Types of rock found
Crust	30	2.2	—	Silicic rocks.
		—	2.9	Andesite, basalt at base.
Upper mantle	720	3.4	—	Peridotite, eclogite, olivine, spinel, garnet, pyroxene.
		—	4.4	Perovskite, oxides.
Lower mantle	2,171	4.4	—	Magnesium and
		—	5.6	silicon oxides.
Outer core	2,259	9.9	—	Iron+oxygen, sulfur,
		—	12.2	nickel alloy.
Inner core	1,221	12.8	—	Iron+oxygen, sulfur,
		—	13.1	nickel alloy.
Total thickness	6,401			

Our accurate thickness and composition data comes mainly from monitoring earthquakes

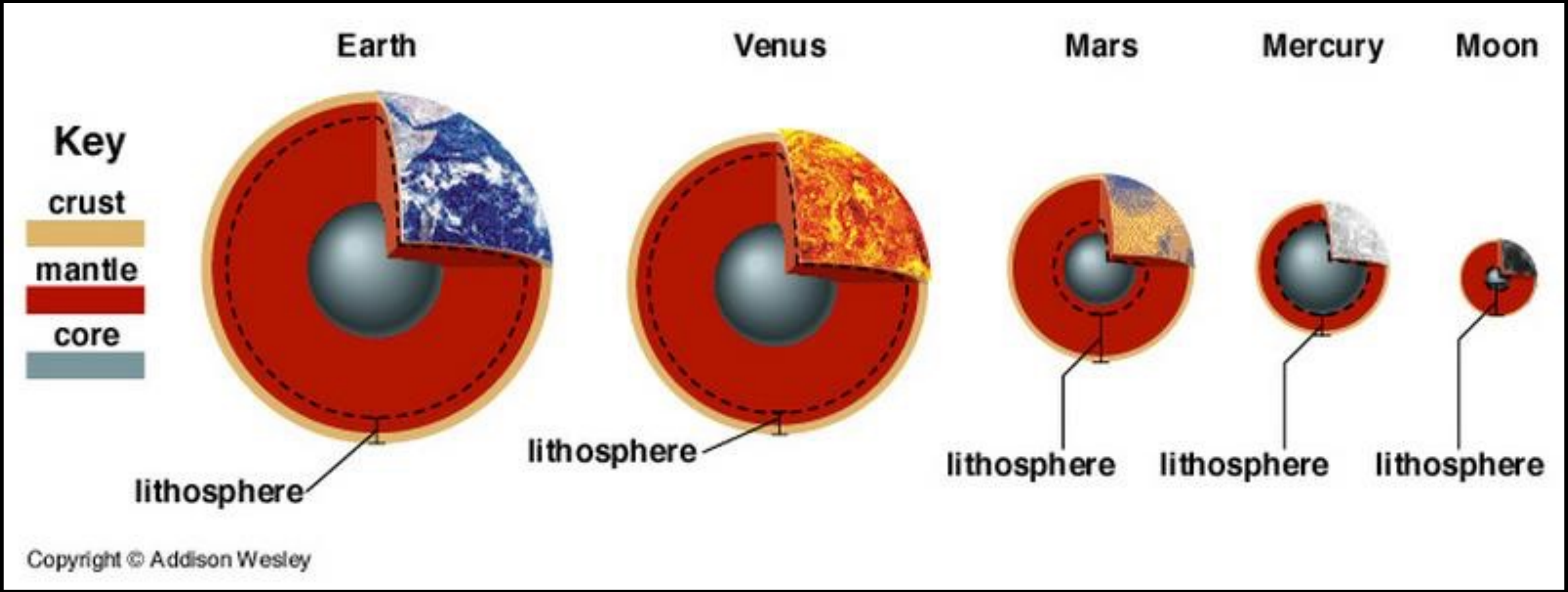


Dealing with Core/Mantle

$$V_{mantle} = \frac{4}{3}\pi r_{outer}^3 - \frac{4}{3}\pi r_{inner}^3$$

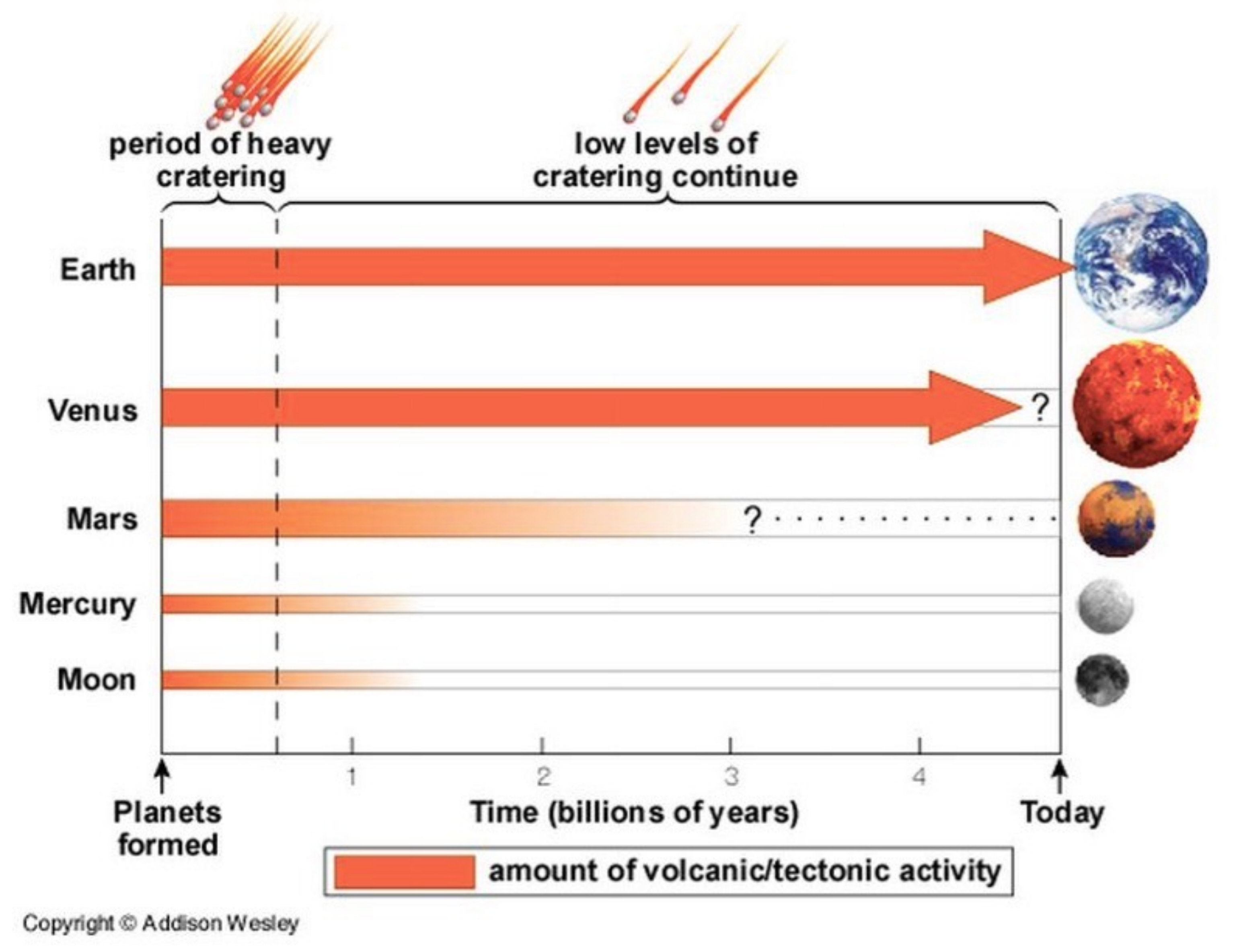


Compositions of the Terrestrial Bodies

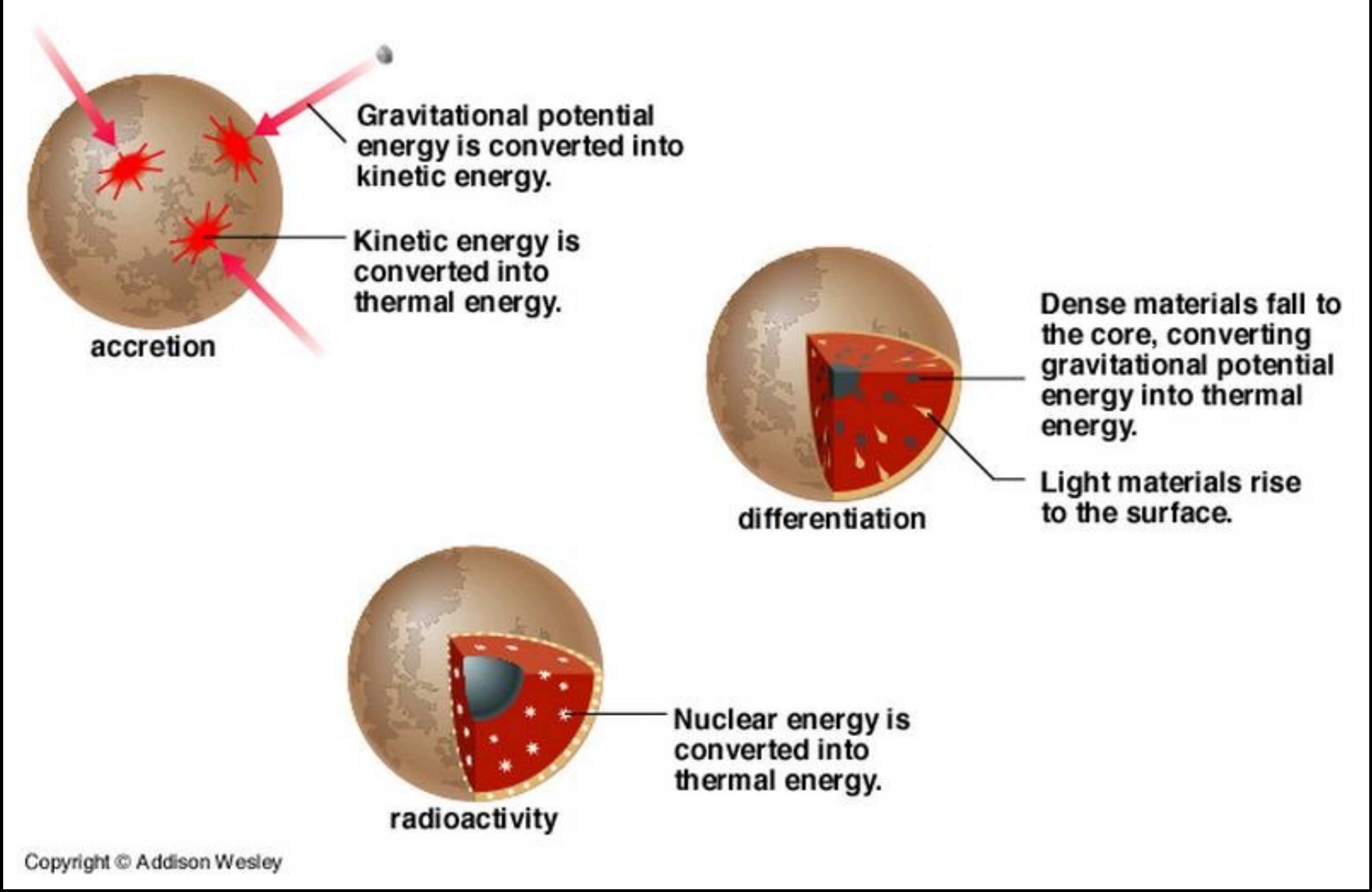


How do we know this?

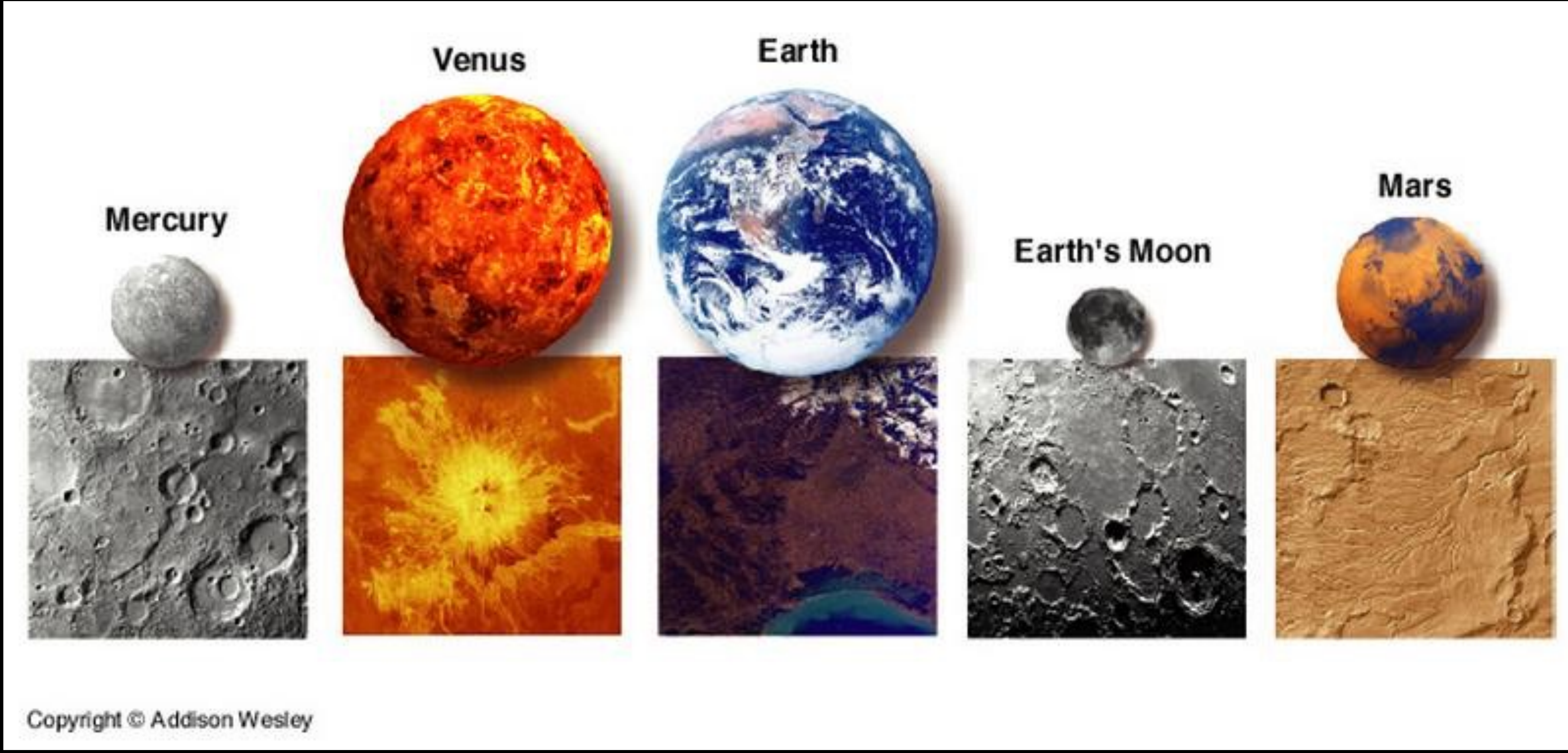
A Planet's Size Correlates with its Tectonic Activity



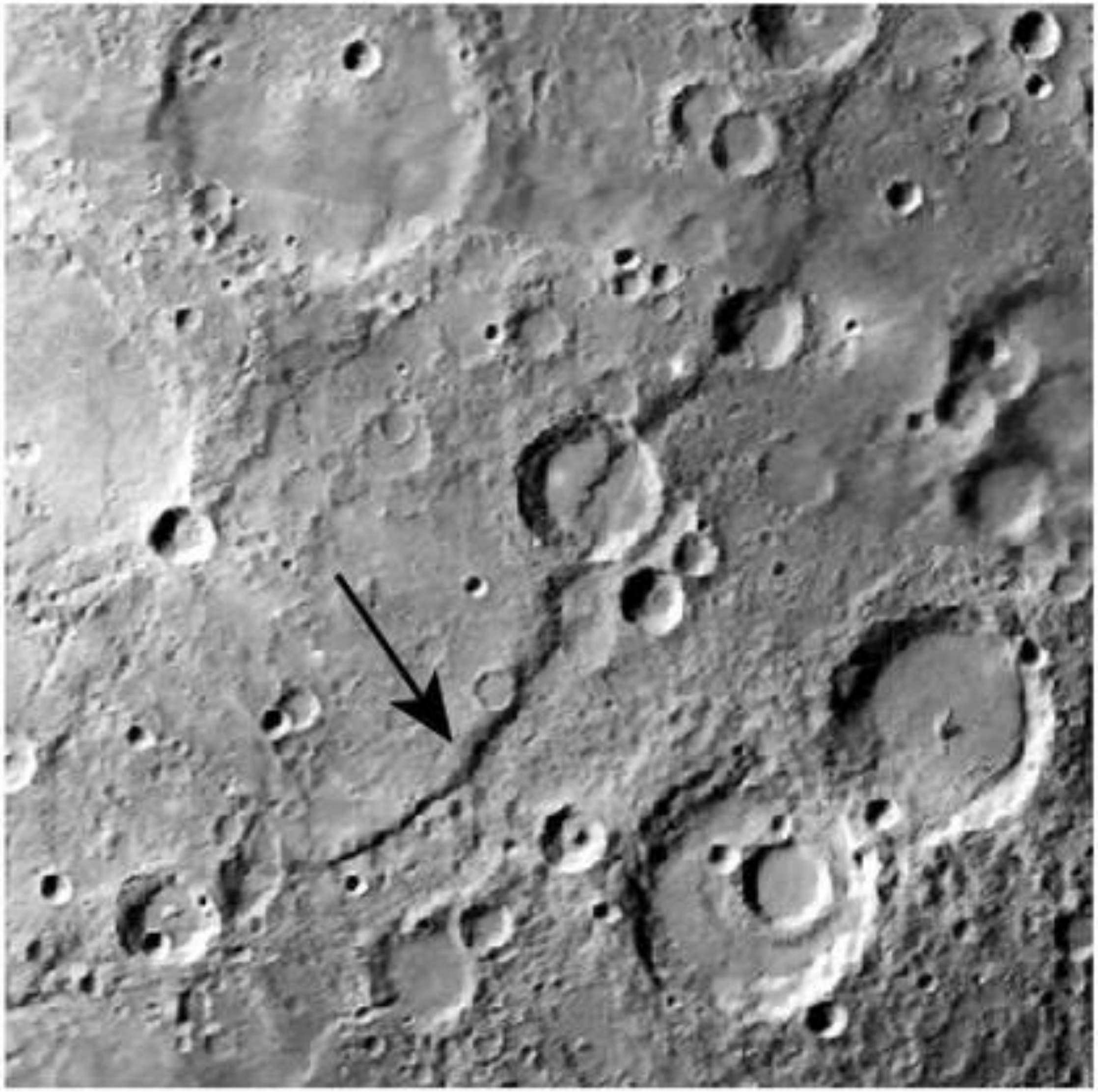
Processes leading to core formation



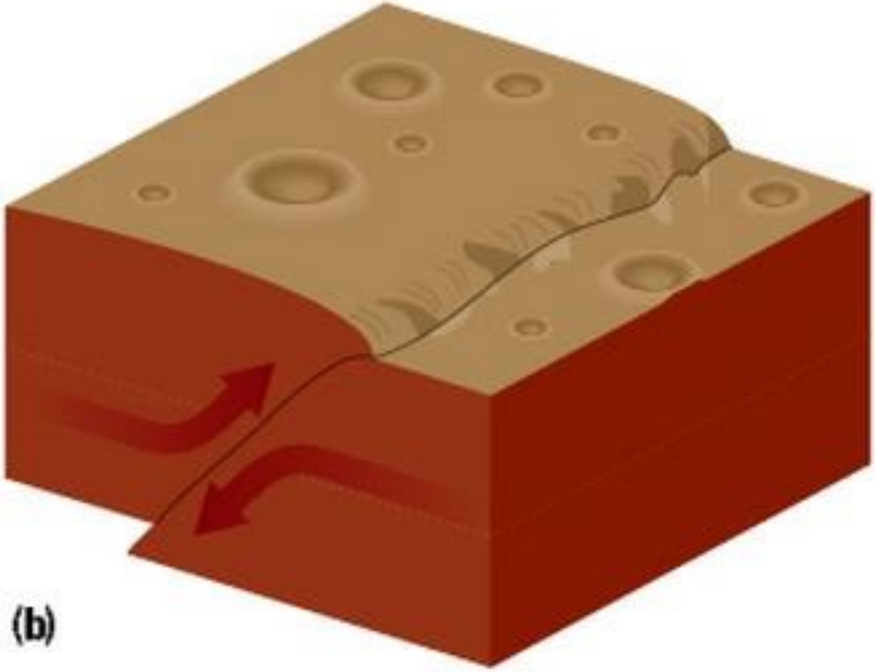
Planetary Surfaces



Contraction of Mercury

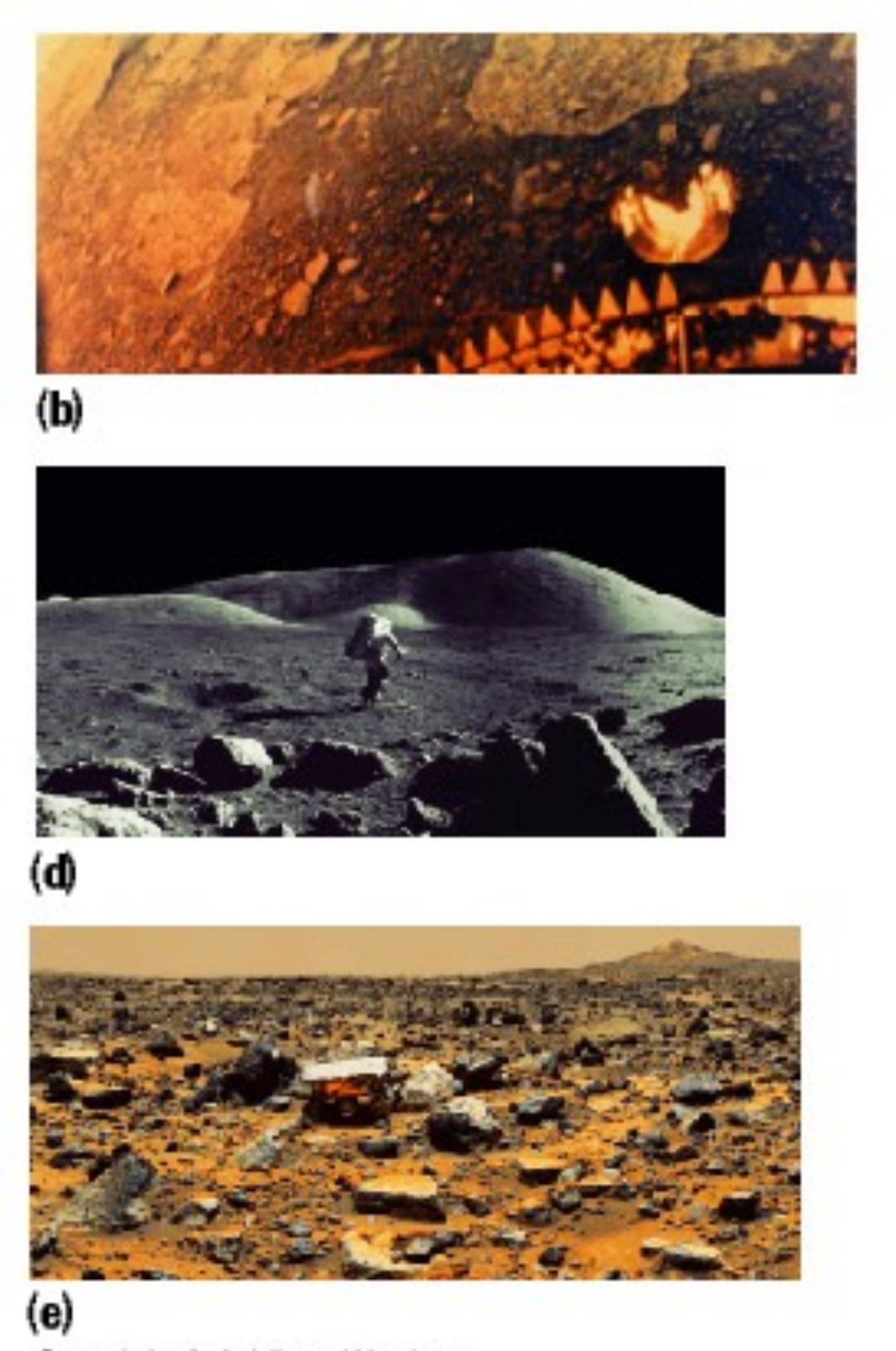


(a)



(b)

Planetary Surfaces



Question:

What evidence do we have to support Plate Tectonics?

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What evidence do we have to support Plate Tectonics?

1. Mid Atlantic ridge, new seafloor, hydrothermal vents
2. Subduction zones
3. Fossils
4. Locations of volcanos, ring of fire + hotspots
5. Earthquakes
6. Mountain ranges

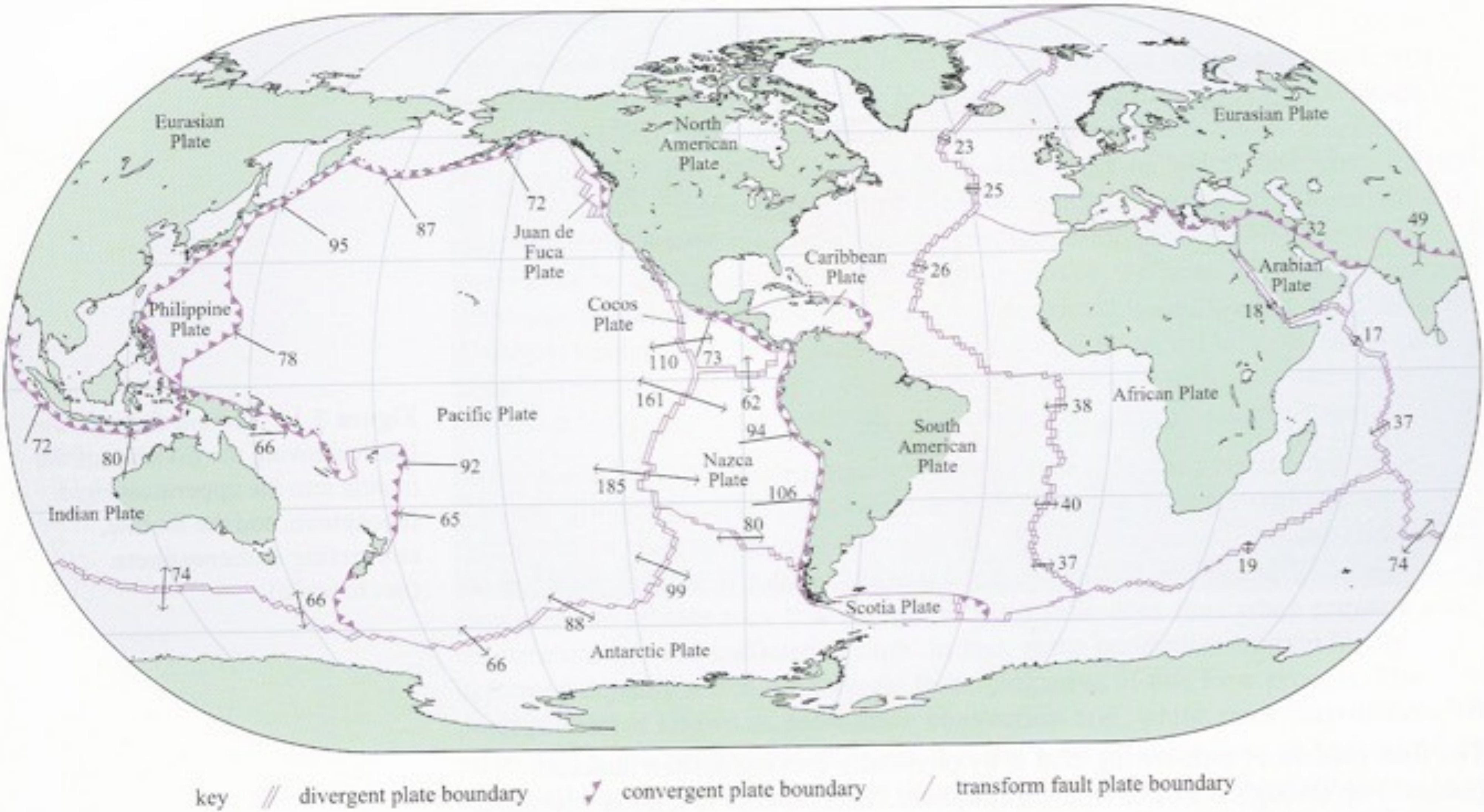

Figure 2.15 Map showing the global distribution of plates and plate boundaries. The black arrows and numbers give the direction and speed of relative motion between plates. Speeds of motion are given in mm yr^{-1}.

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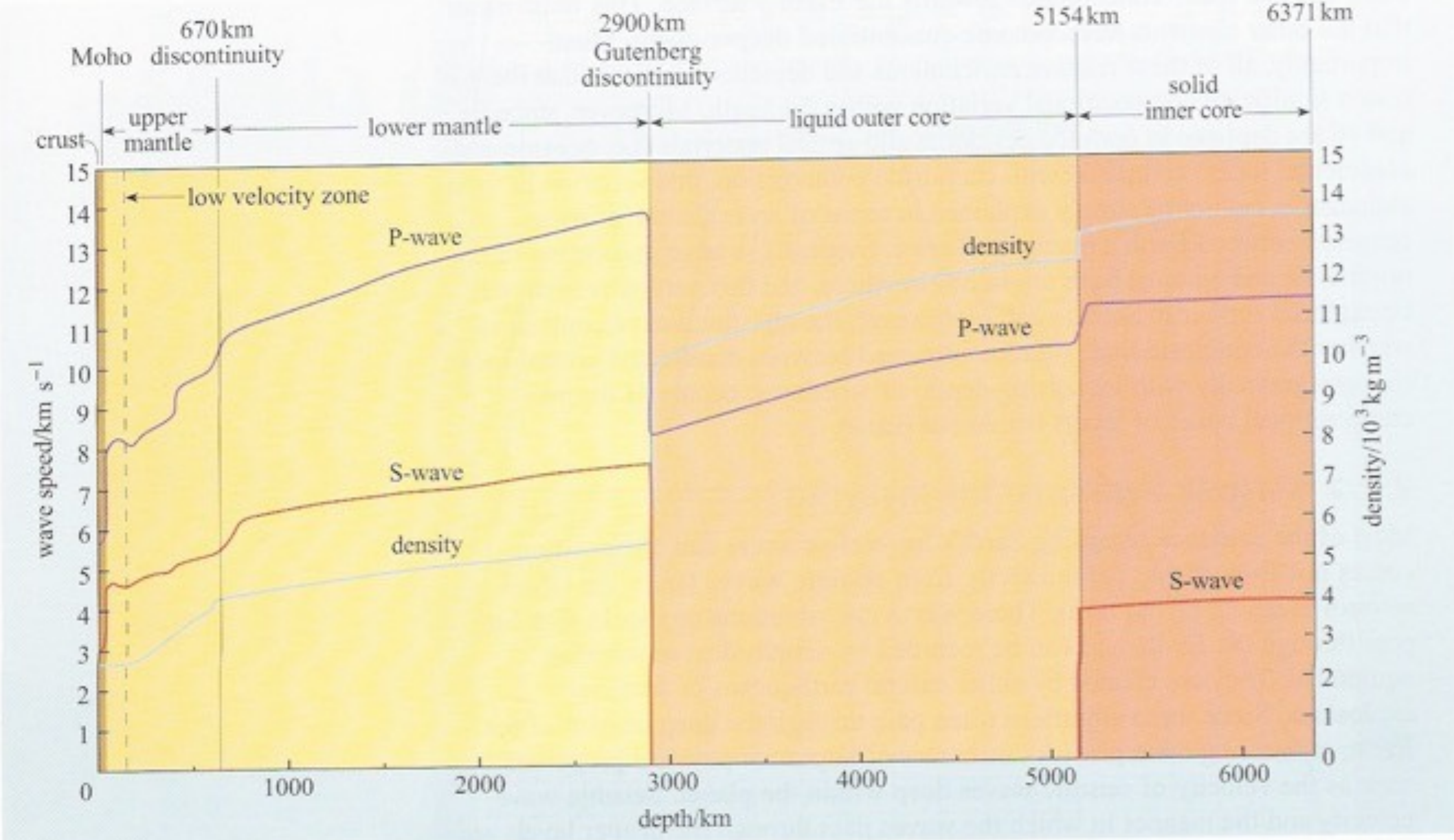

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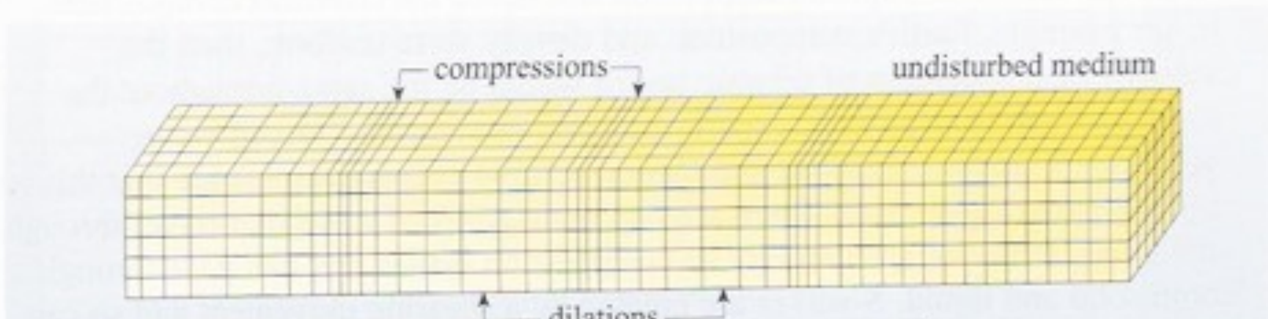
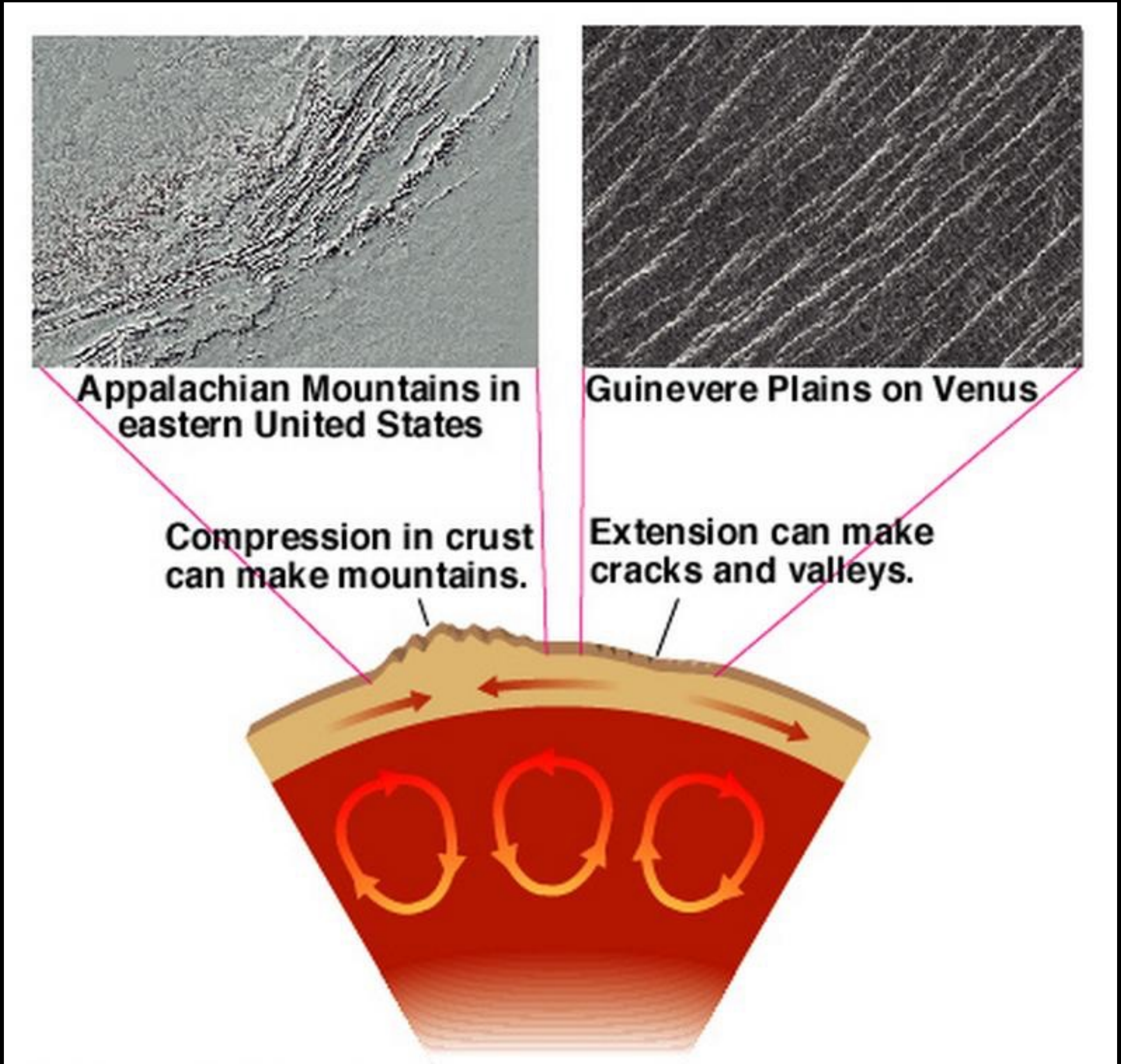
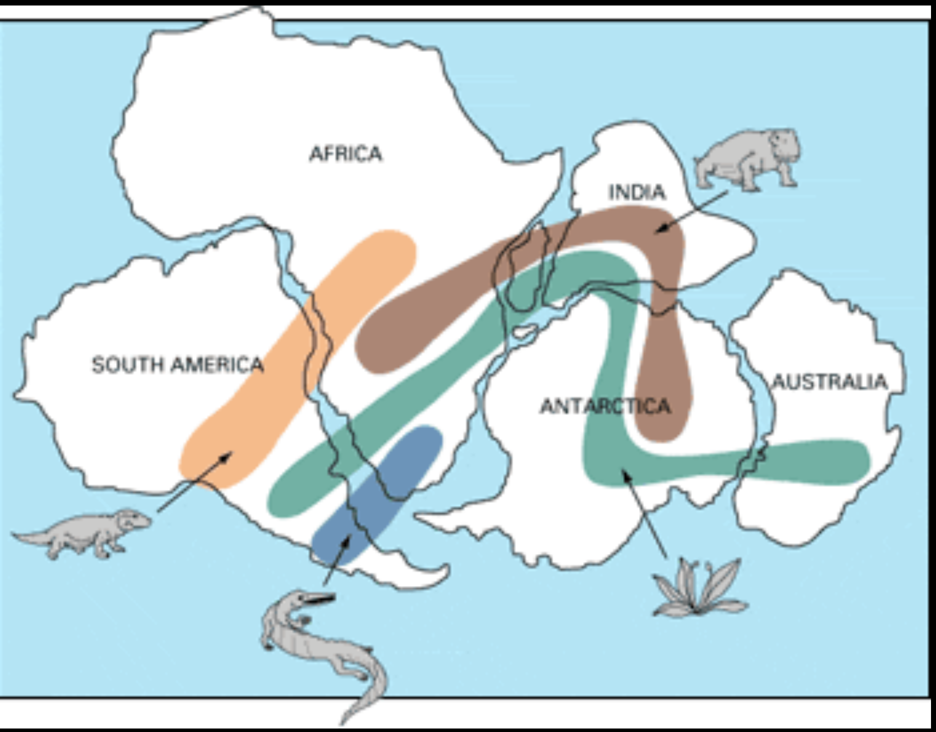


Features due to Plate Motions



Evidence for Plate Tectonics

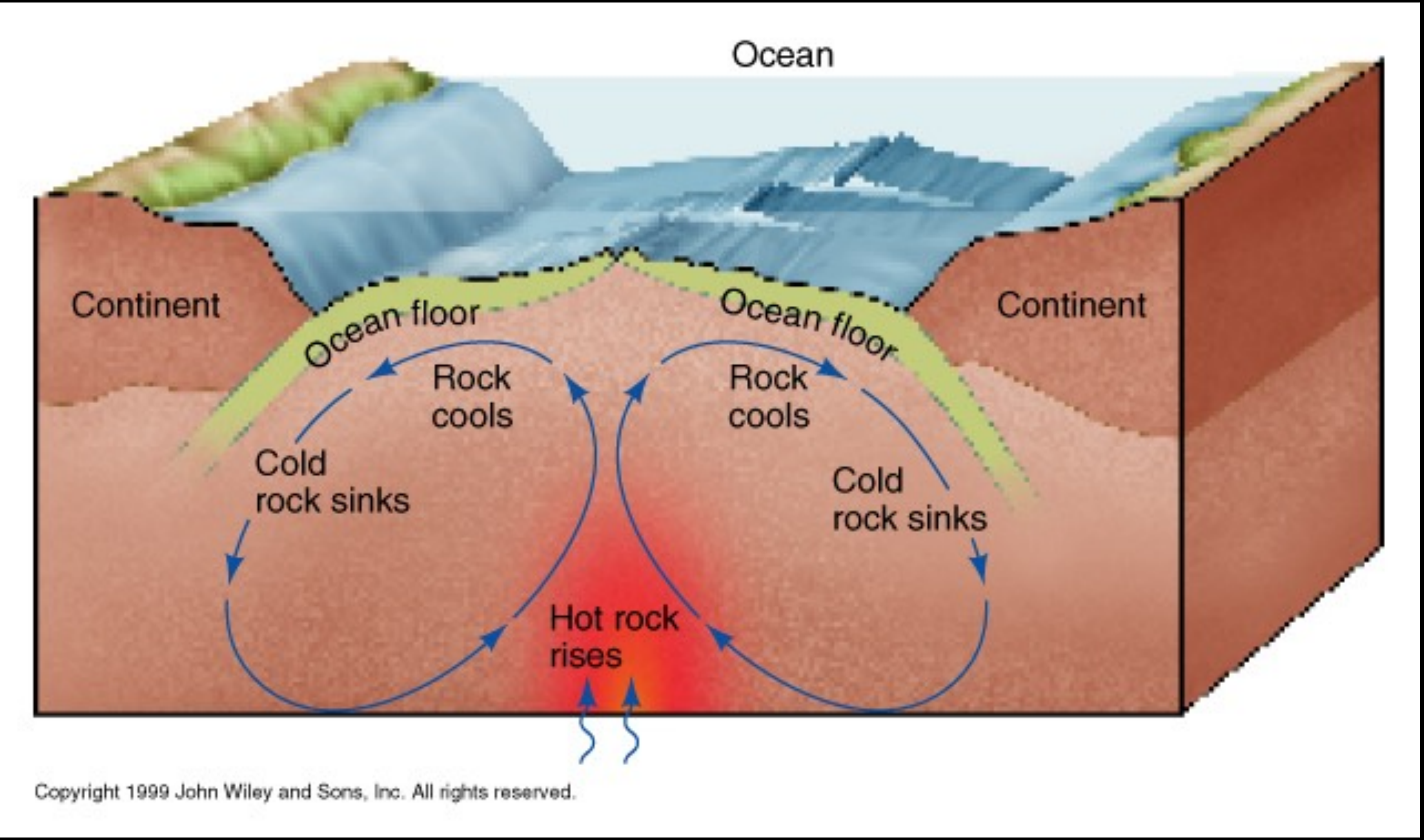


Shape Evidence: The continents look like they can be fit together like a jigsaw puzzle

Biological Evidence: The similarities between some types of ancient plants and animals can be best explained by continental motions.

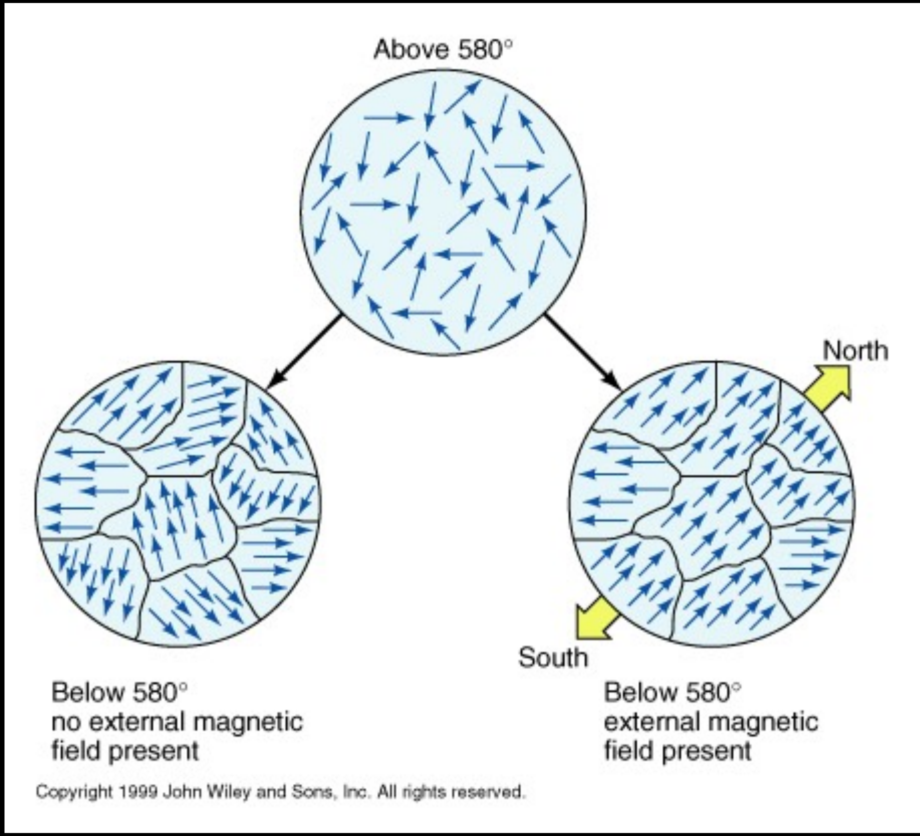
Glacial Evidence: the white parts of each continent had glacial epochs at around the same time.

Evidence for Plate Tectonics

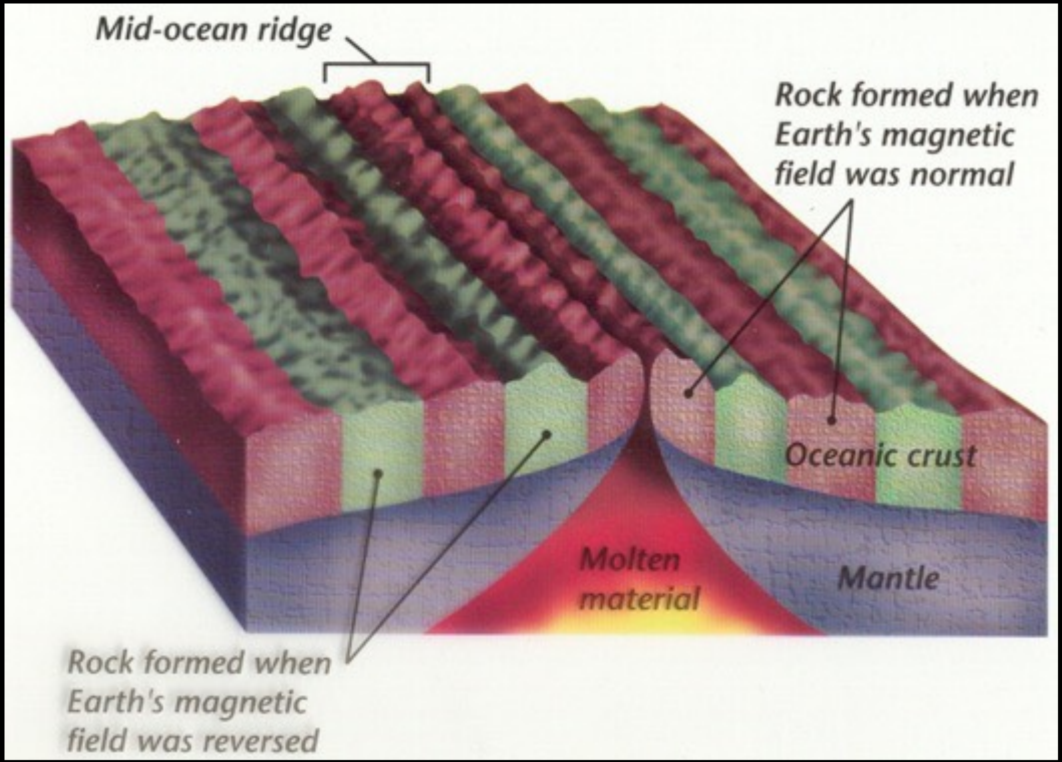


Seafloor Spreading: The Atlantic ocean is spreading as new molten material is raised from depth. This explains why the seafloor rock is basalt, a volcanic rock.

Evidence for Plate Tectonics

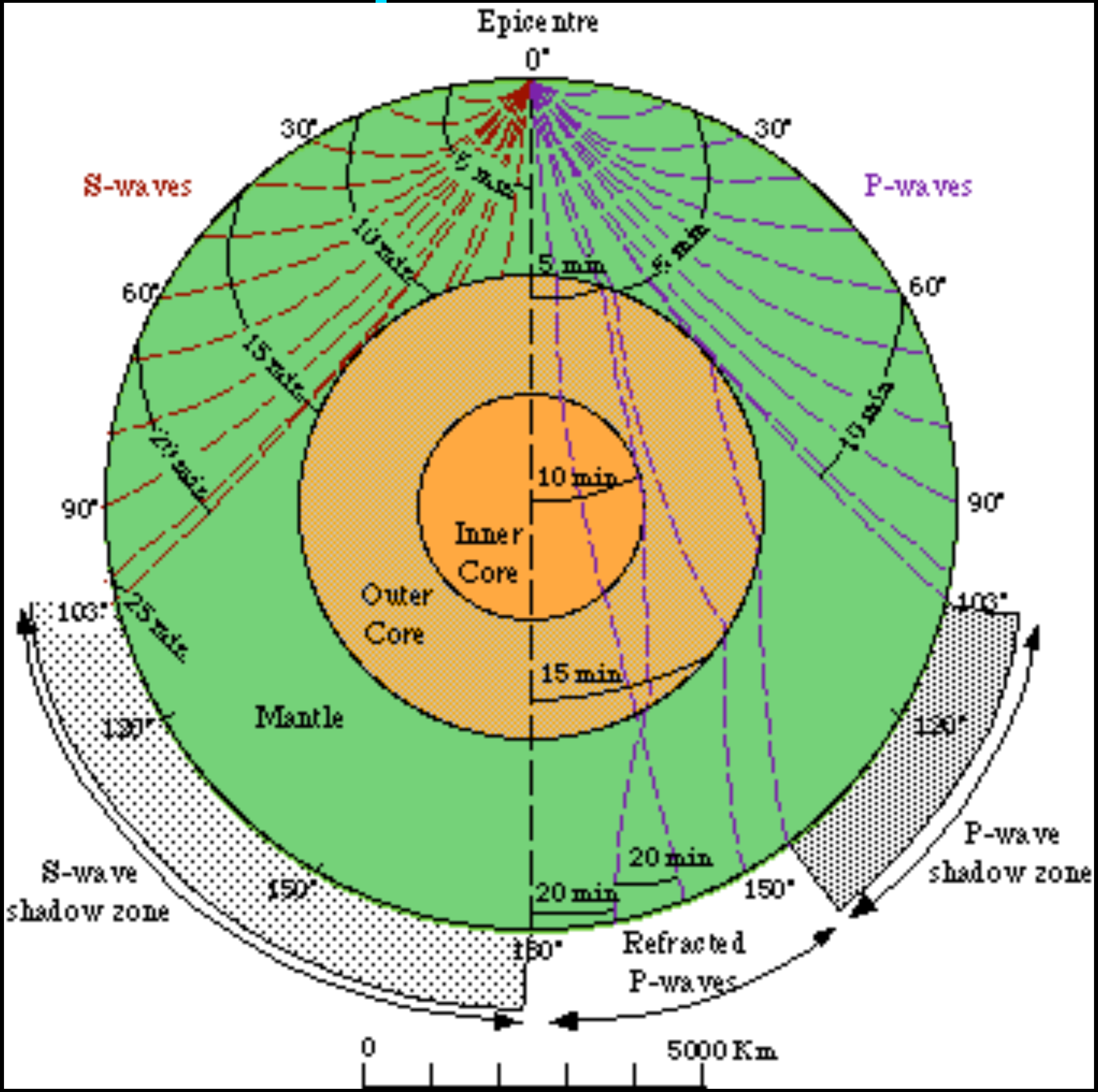


Rock Magnetic Fields: The alignment of magnetic grains in rock depends on the orientation of the Earth's magnetic field

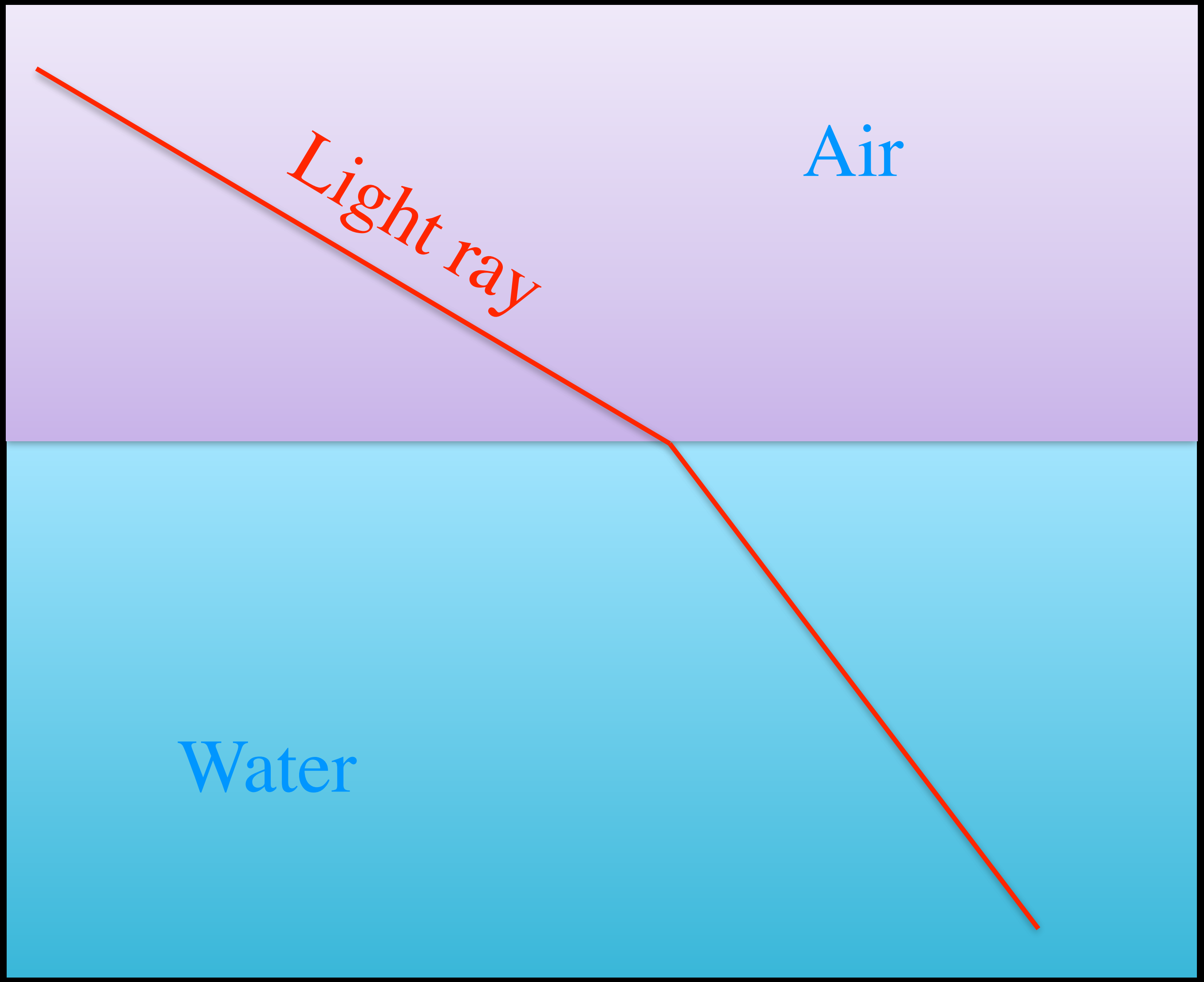


Seafloor Evidence: The rocks in the Atlantic ocean display bands of differently-oriented magnetic grains implying a "conveyer belt" motion

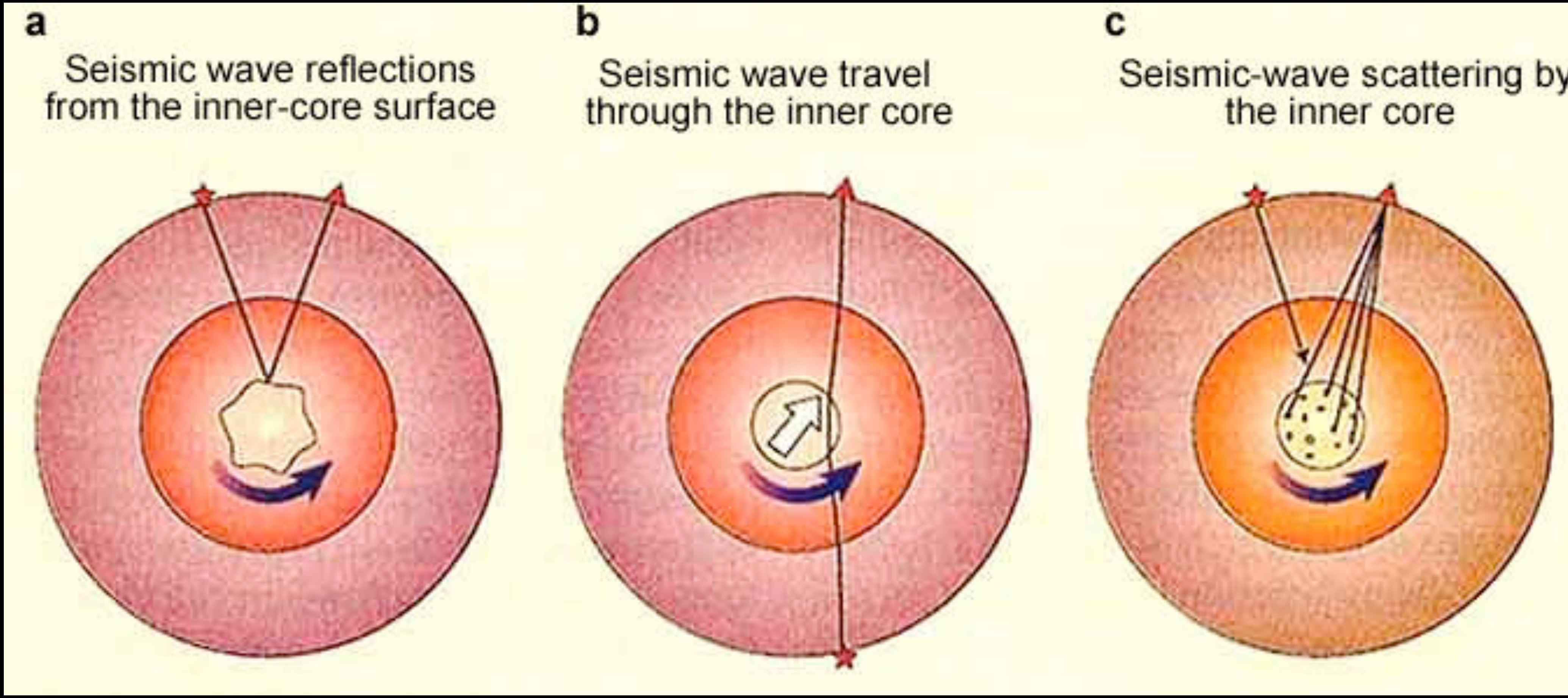
Earthquake Waves



Refraction of Waves



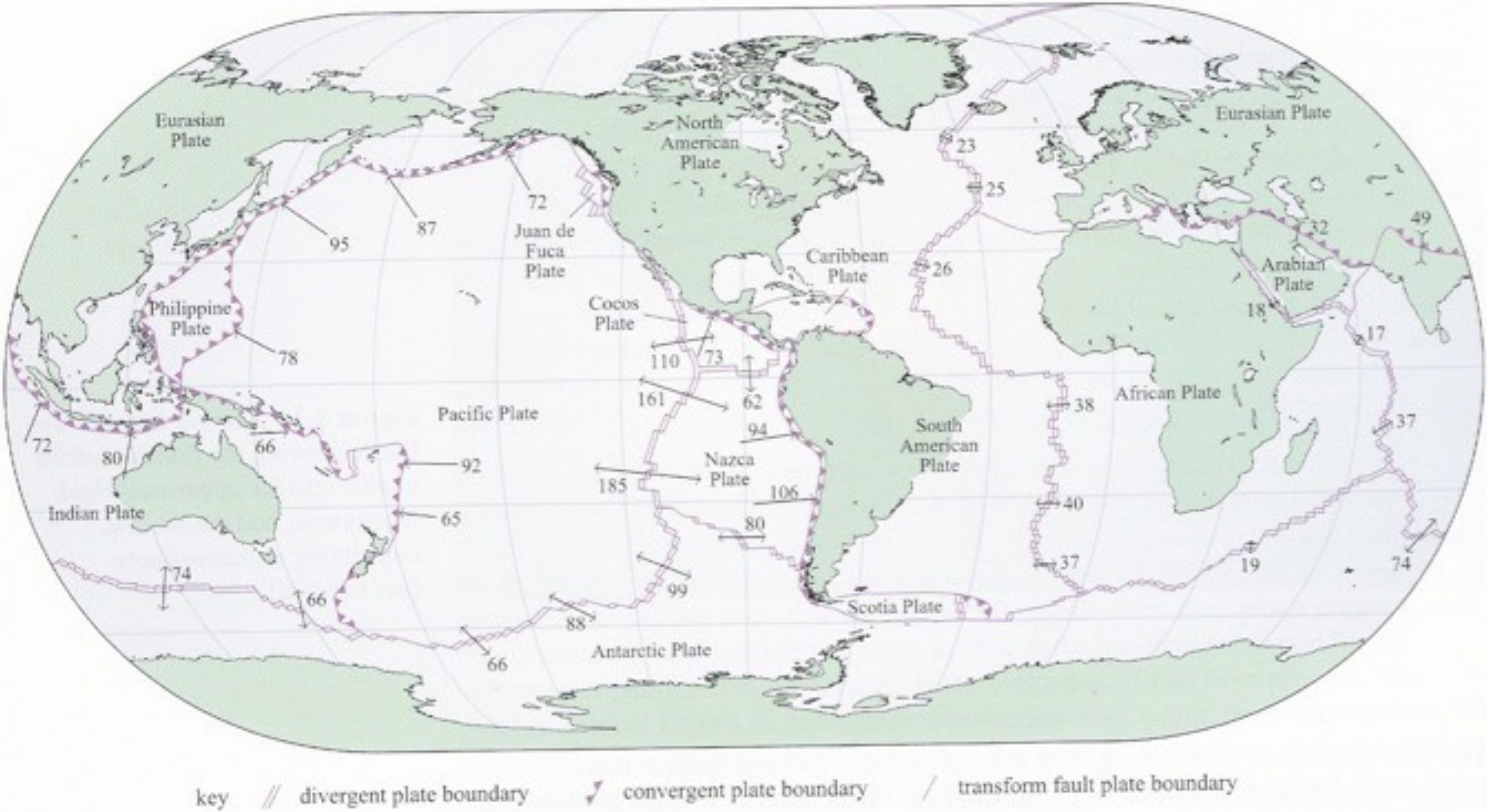
Detecting the Spin of the Core



Two Kinds of Volcanic Activity on Earth

1. Along Plate Boundaries

2. Mantle Hot Spots



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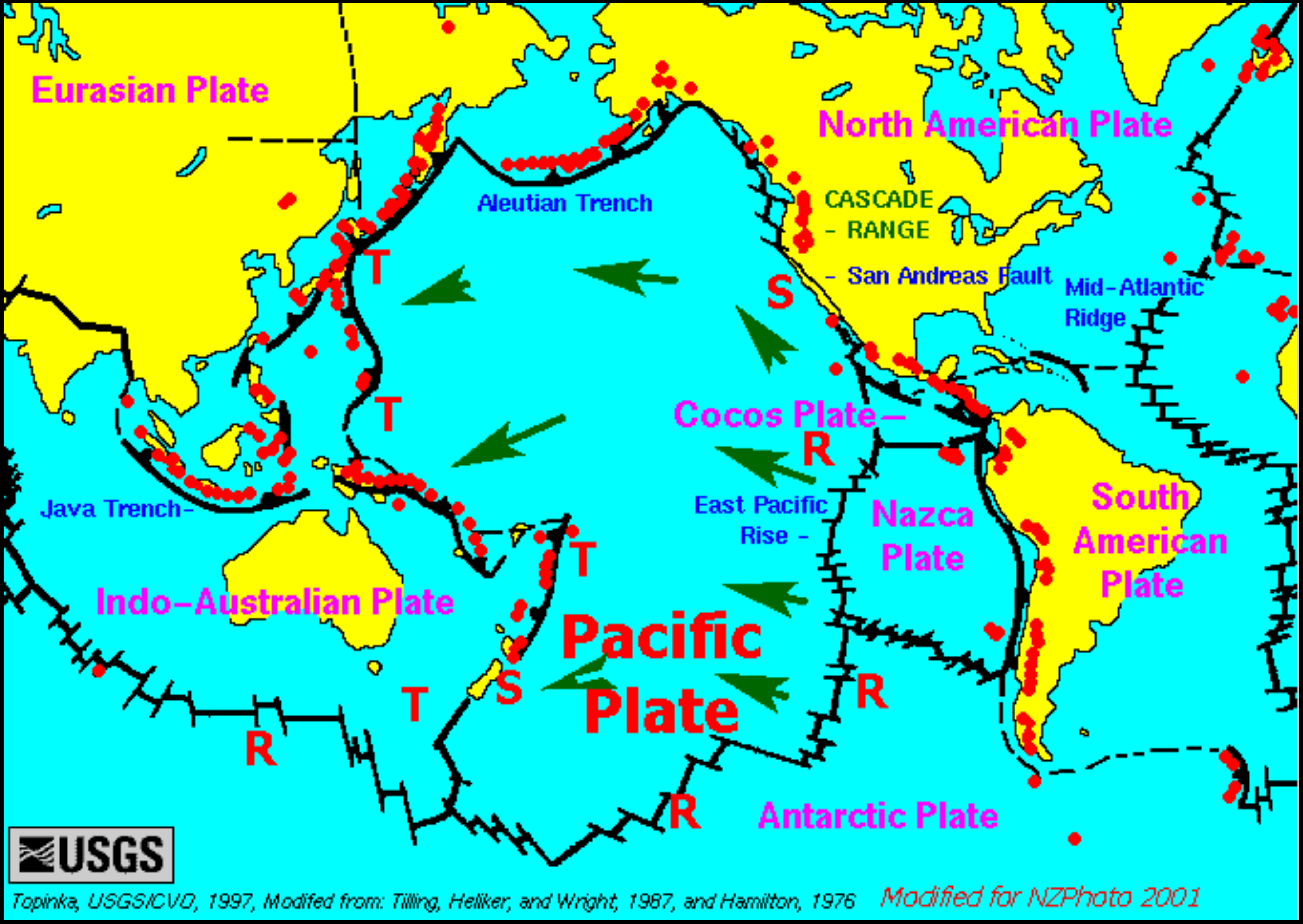
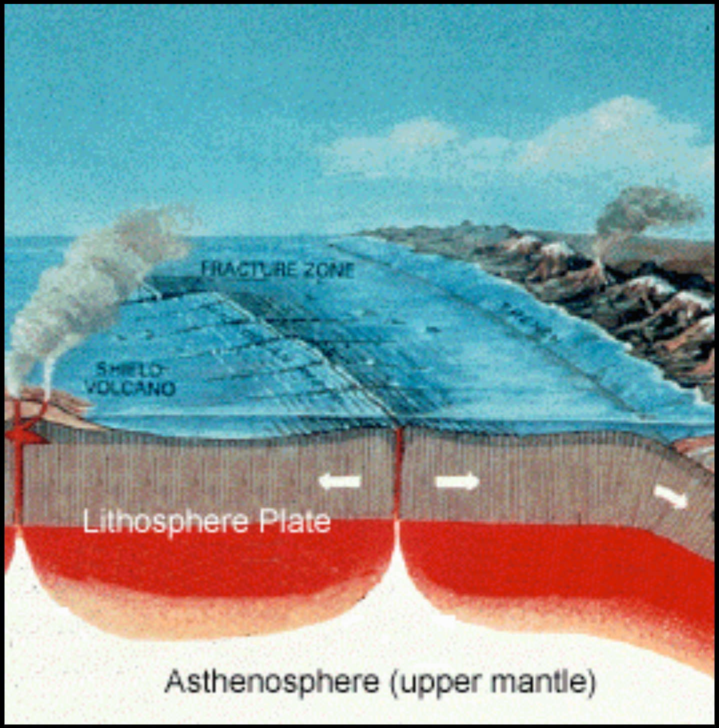
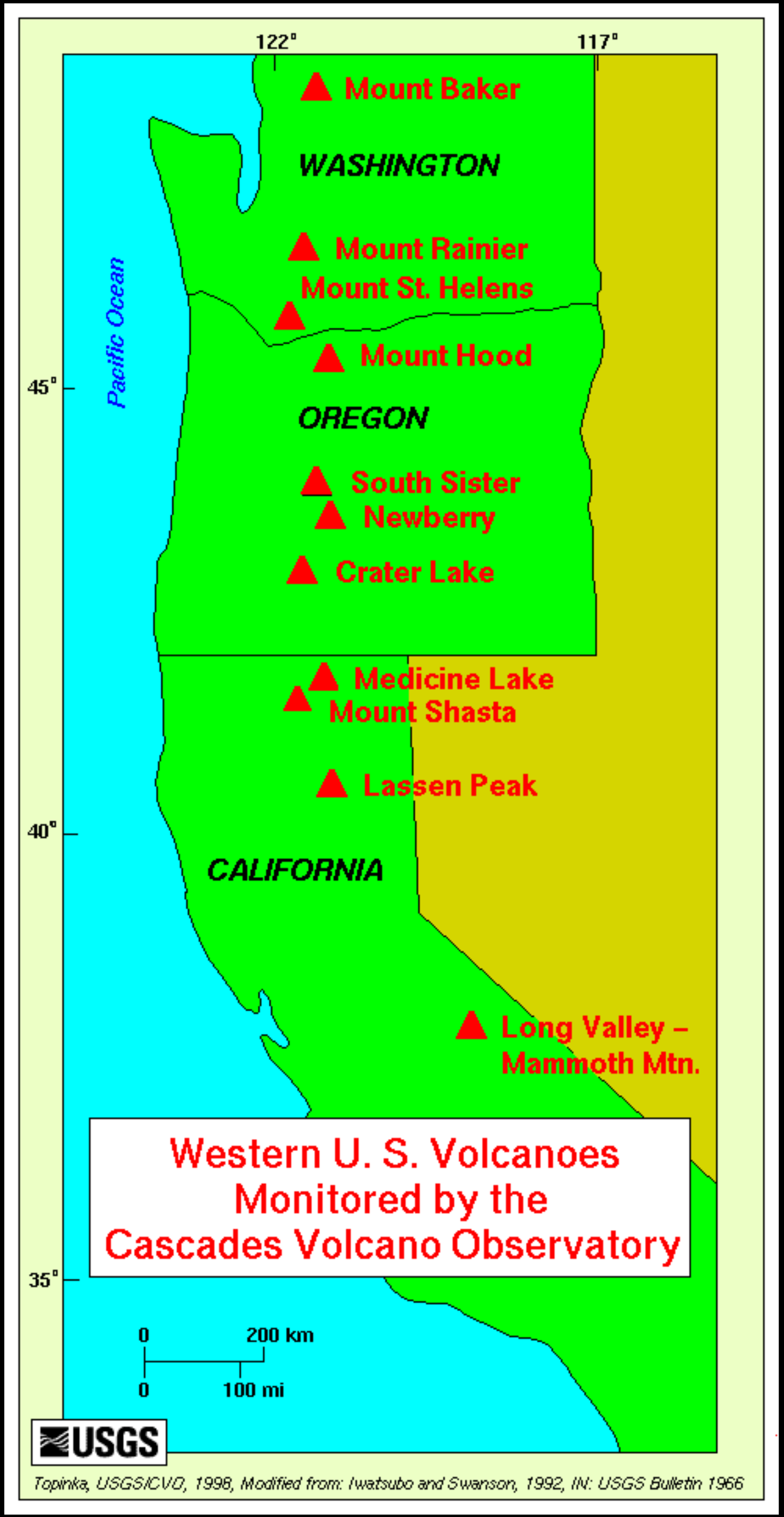
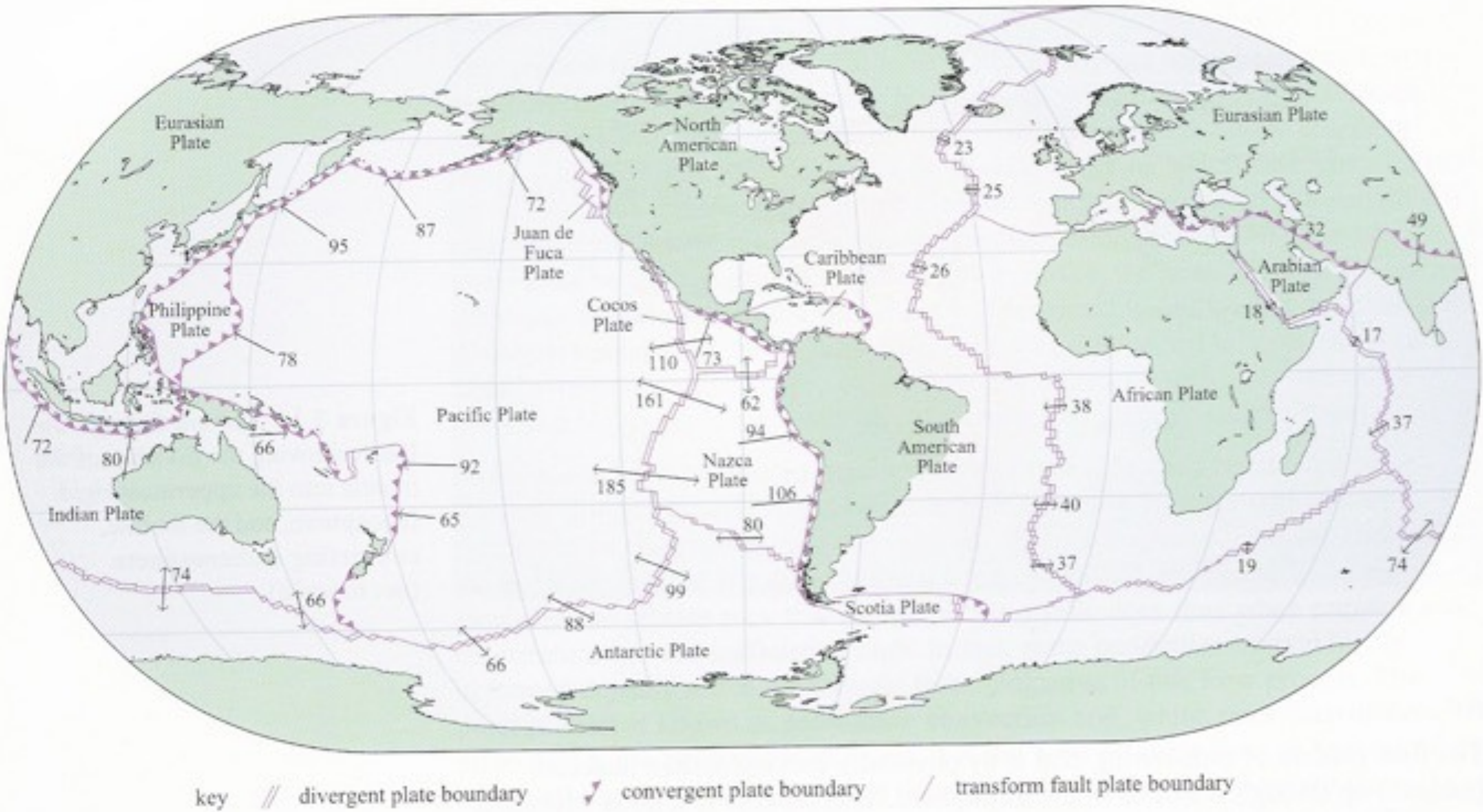
Volcanic Locations



Volcano Locations







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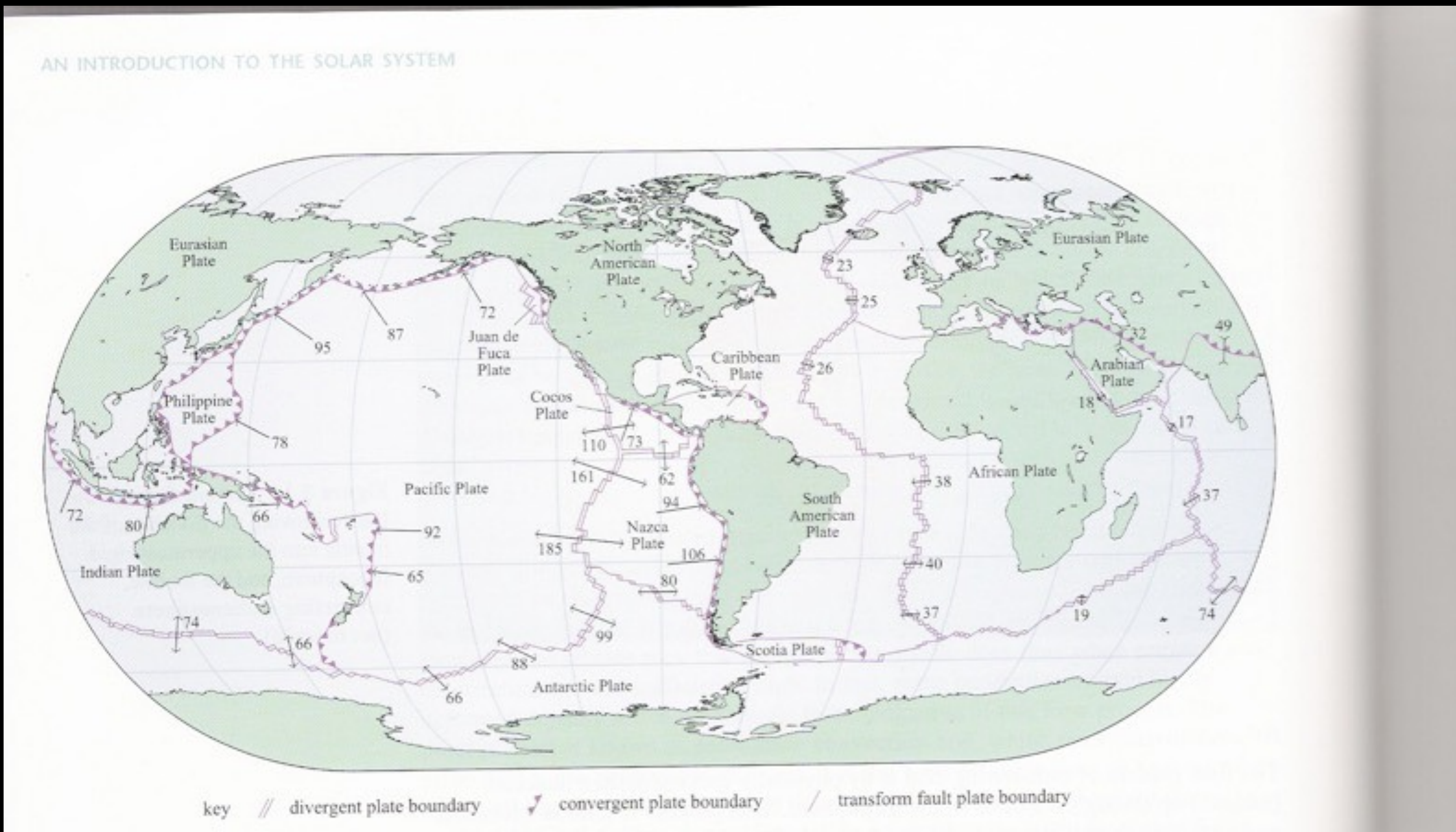
Earthquake Locations

Work in Groups

20 km^3/yr new basalt in oceans.

Try to estimate this from measured plate motions!



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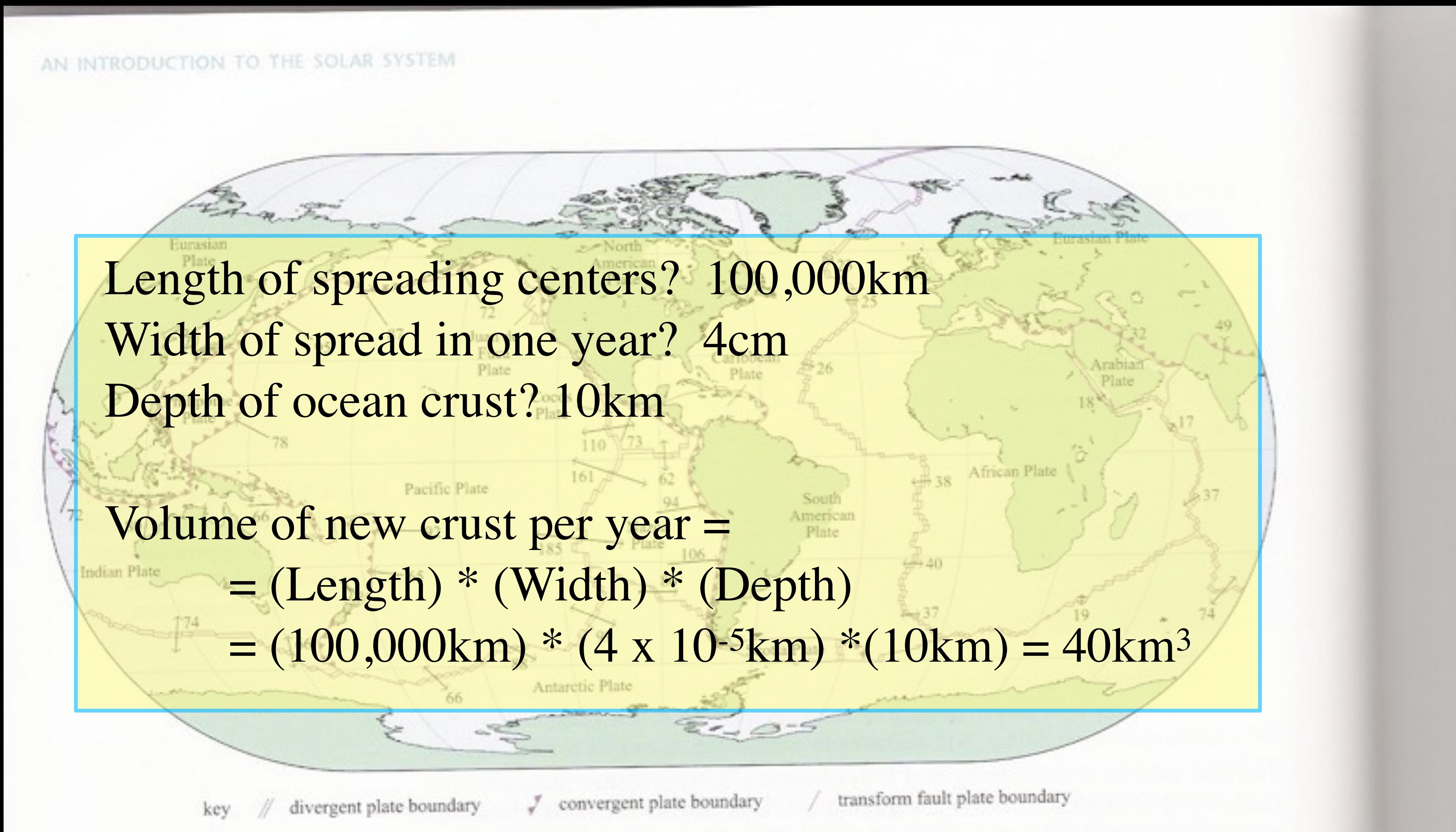


Length of spreading centers? 100,000km

Width of spread in one year? 4cm

Depth of ocean crust? 10km

Volume of new crust per year =

= (Length) * (Width) * (Depth)

= (100,000km) * (4 x 10^{-5}km) *(10km) = 40km^3

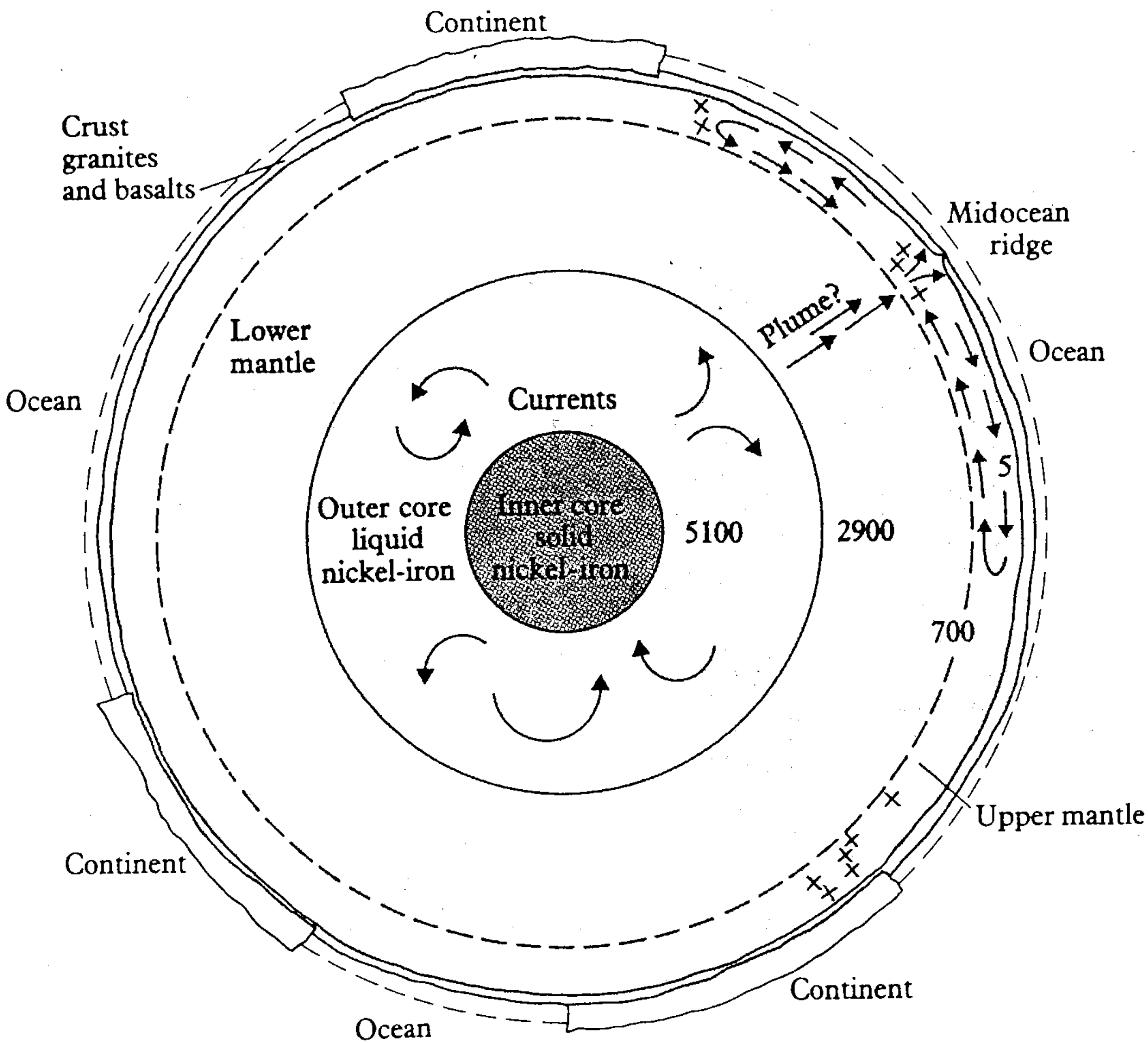
Volcanoes!

1. Mantle Hot Spots on Earth and elsewhere

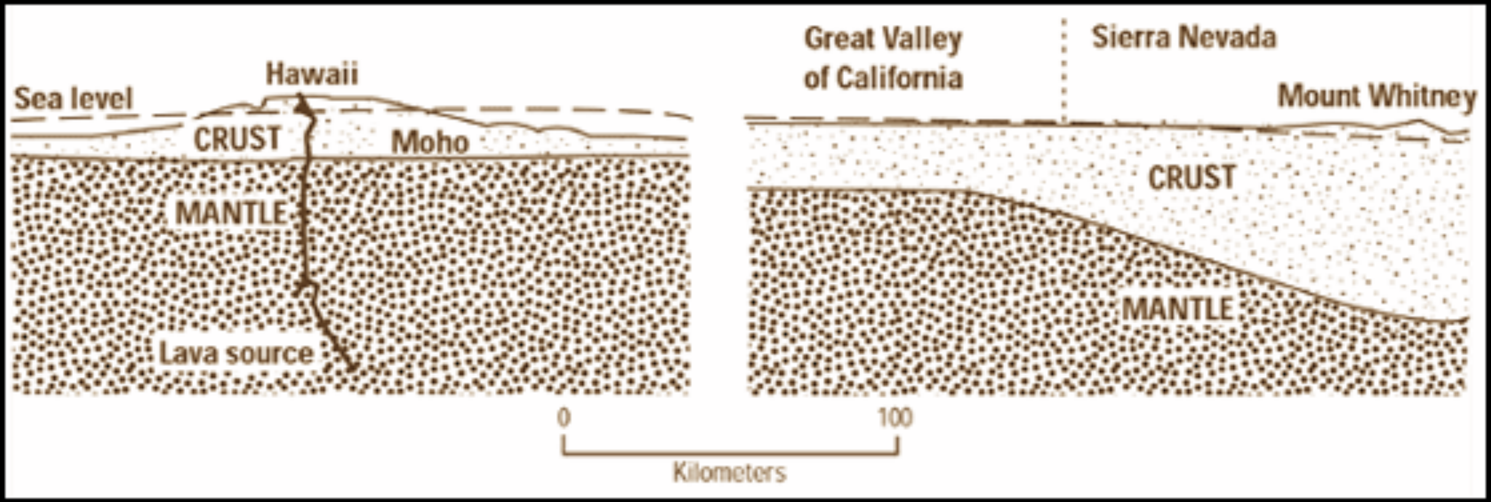
2. Venus, Mars

3. Moon, Mercury

Convections Cells



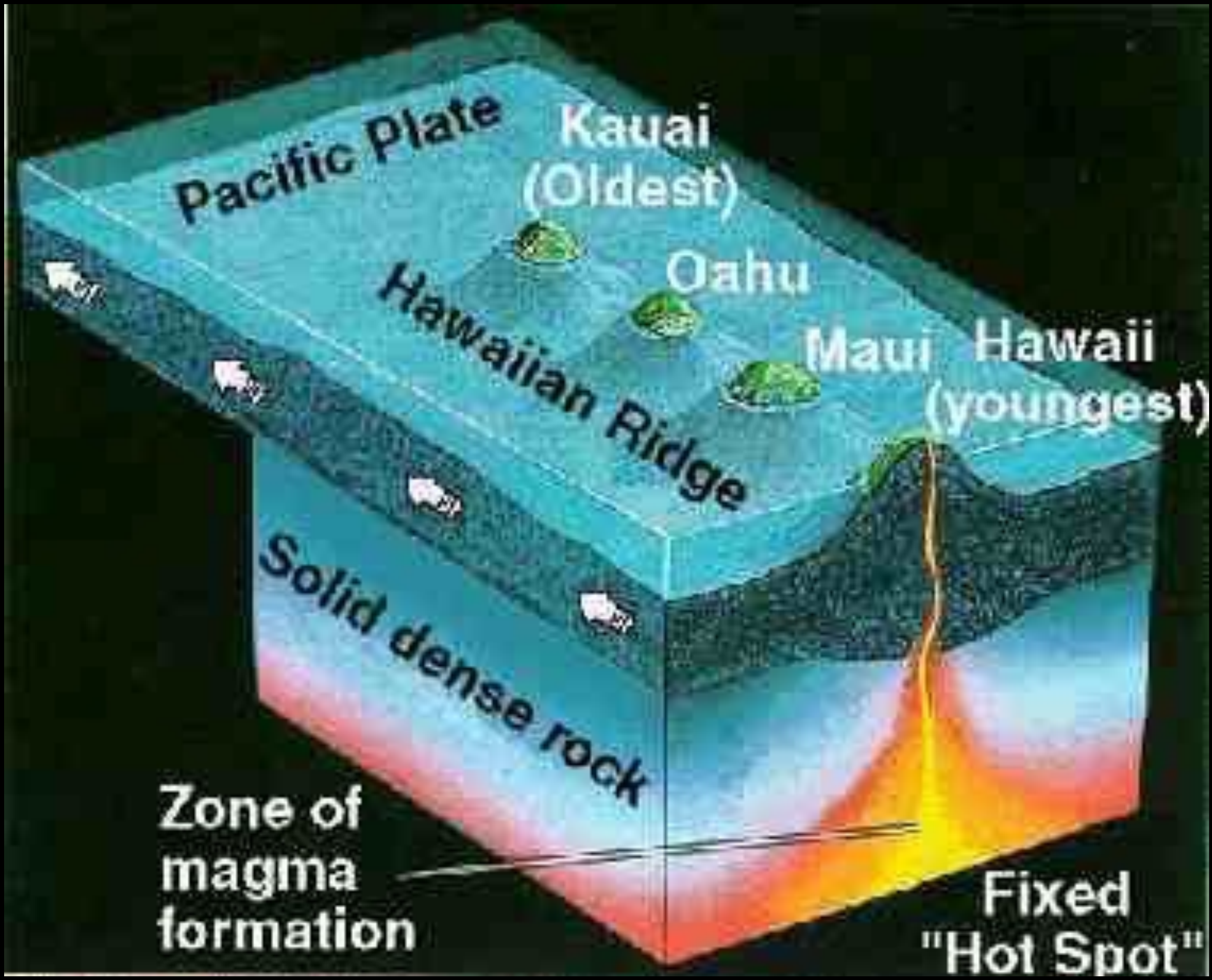
Mantle Hot Spots



Shield Volcano Hawaii forms over a mantle hot spot

Crust is thicker at plate boundaries

Mantle Hot Spots

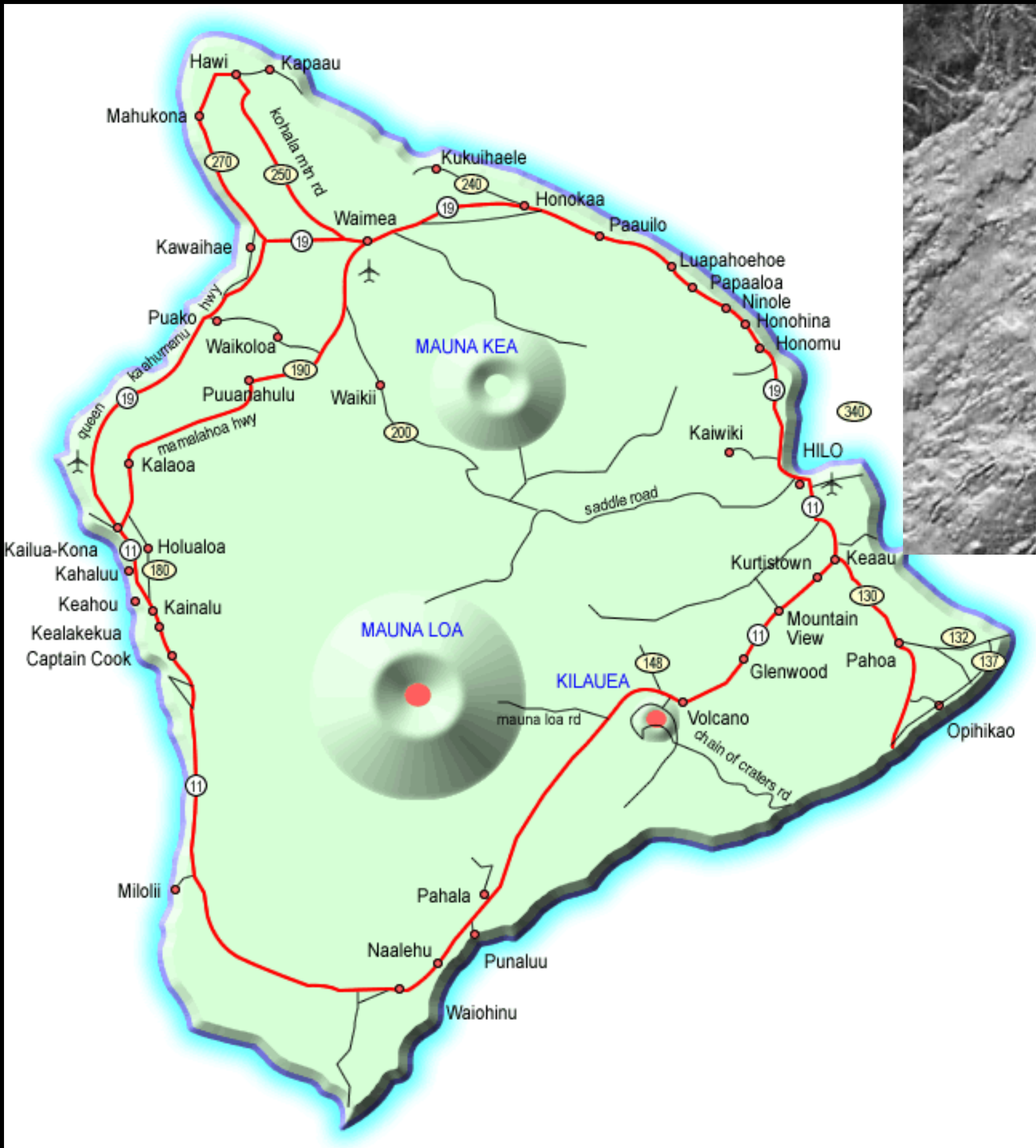


Why Does Magma Rise in a “Hot Spot” Mantle Plume?

1. Hot Material is buoyant. Hot air rises, Hot water rises. Hot magma rises.

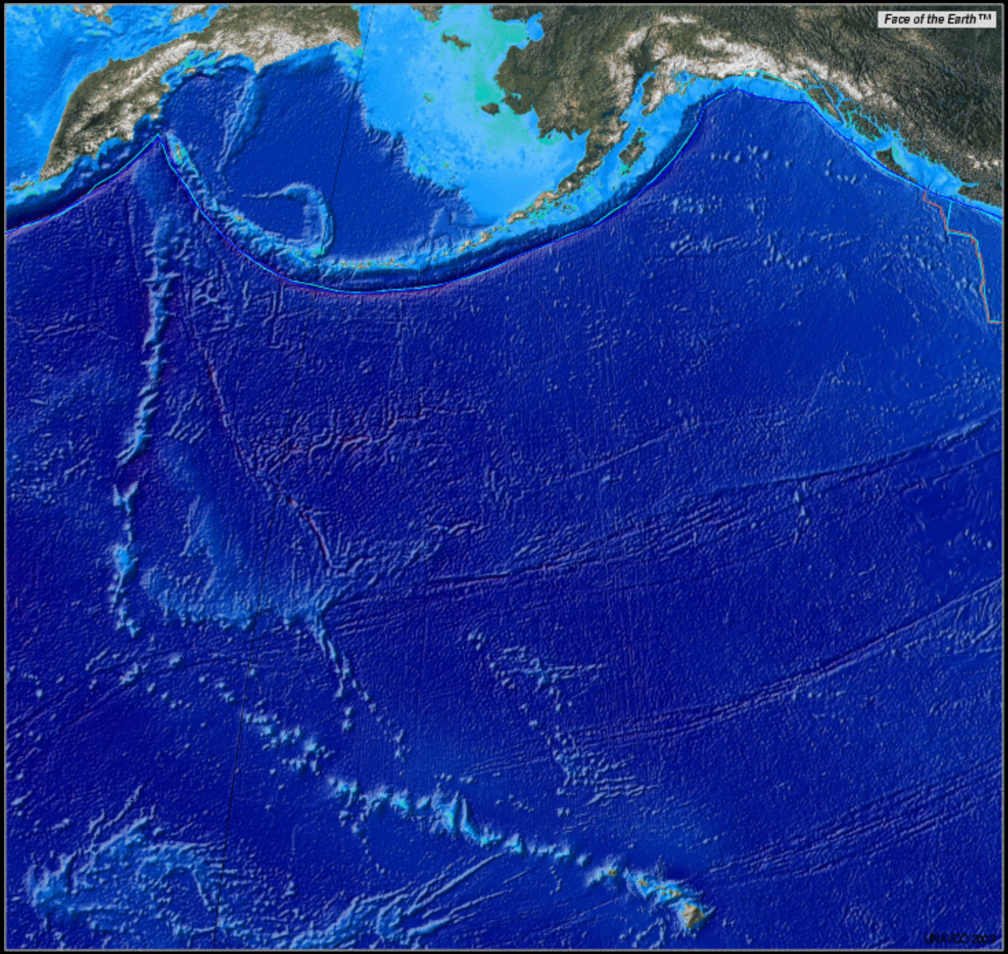
2. Decompression melting. As the magma rises, the pressure lessens, and some materials that are stable at depth, melt.

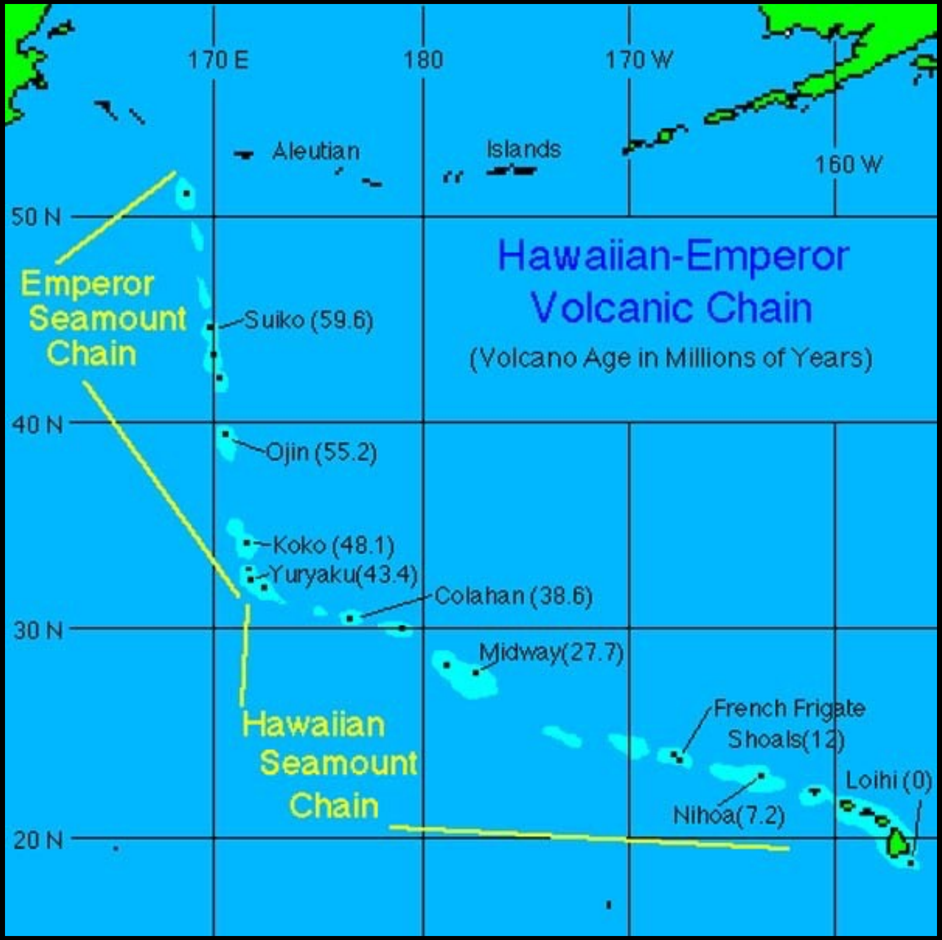
Hawaiian Volcanos



Kilauea Crater

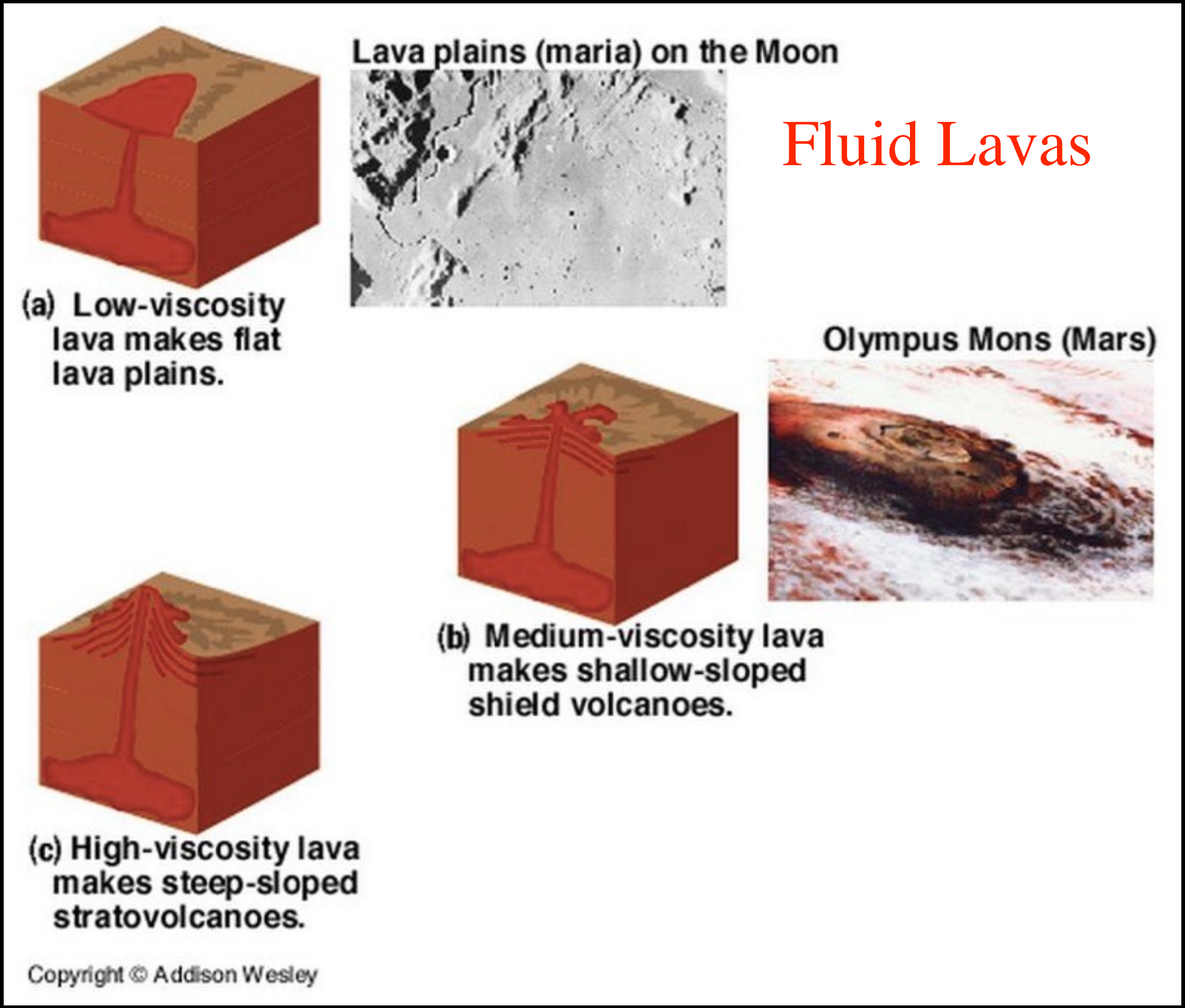
Mantle Hot Spots



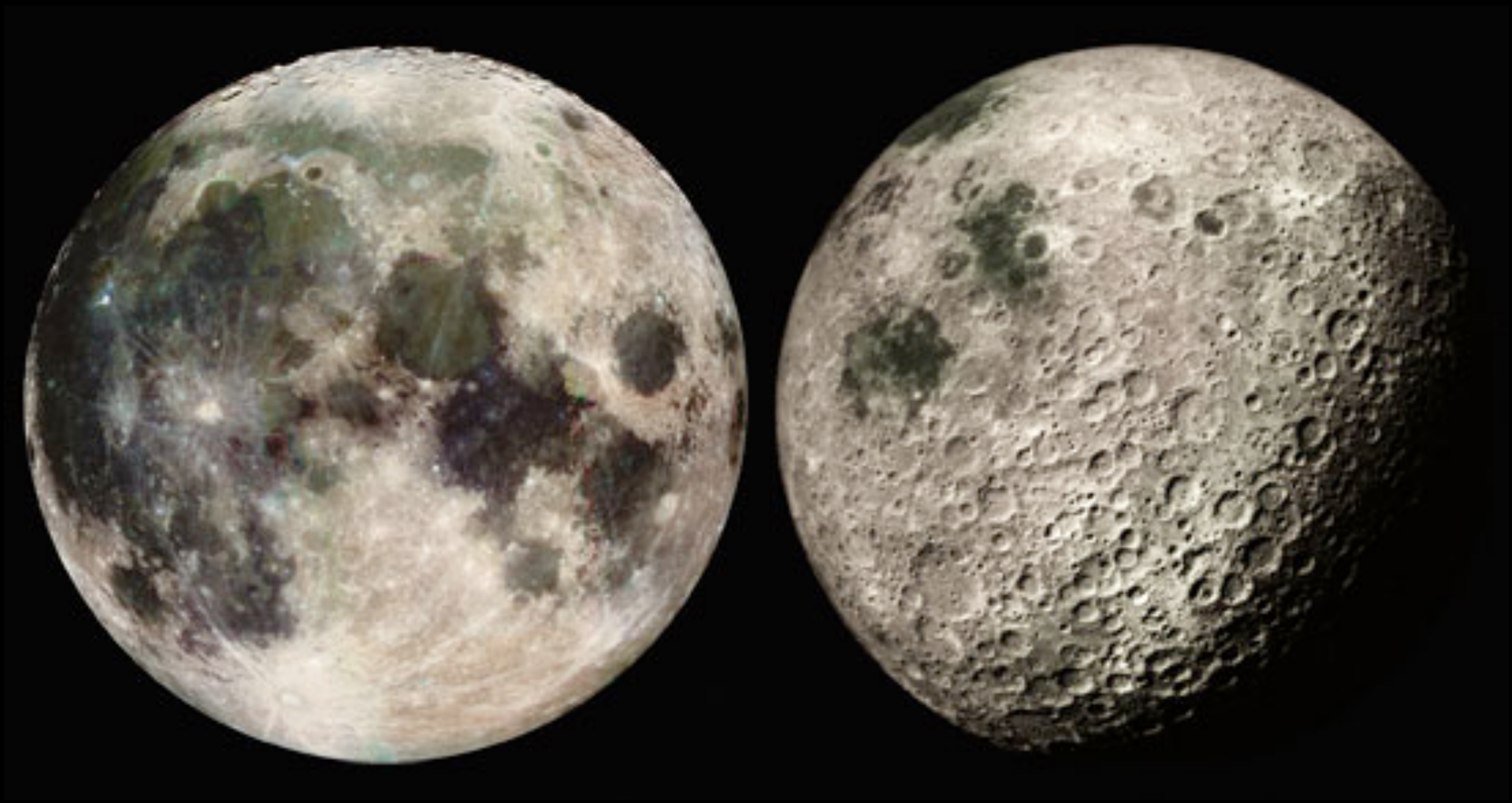


Interesting distribution of seamounts

Different Types of Lava



Thickness of the Moon’s Crust



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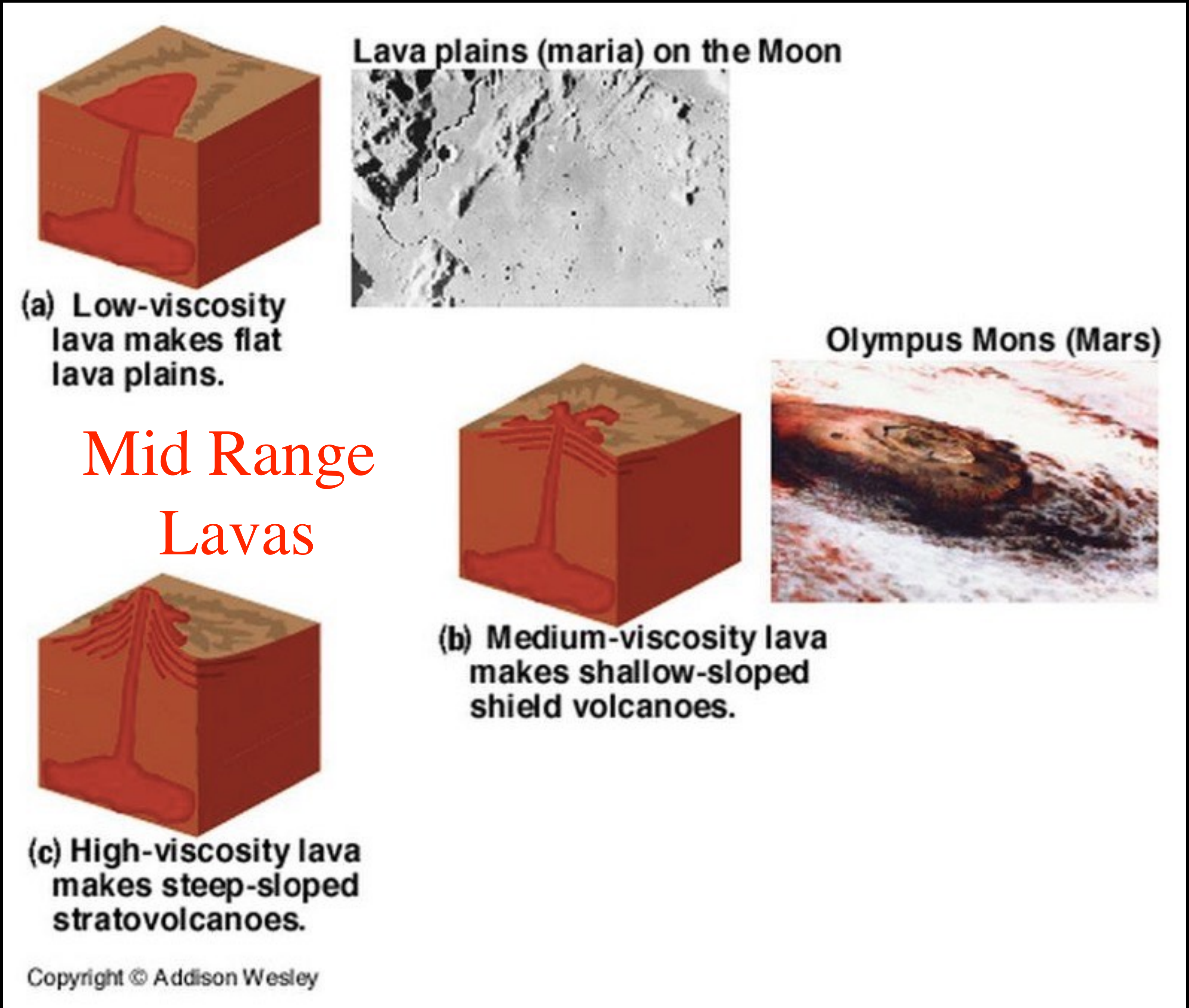
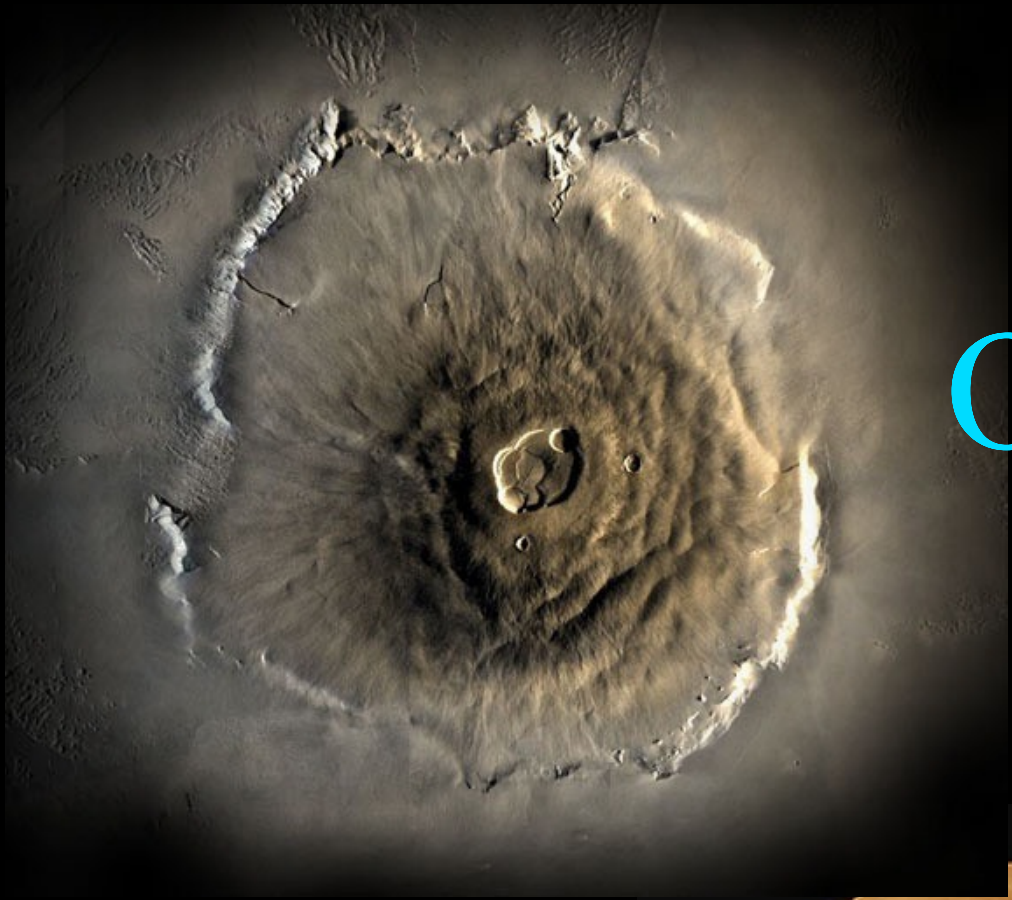
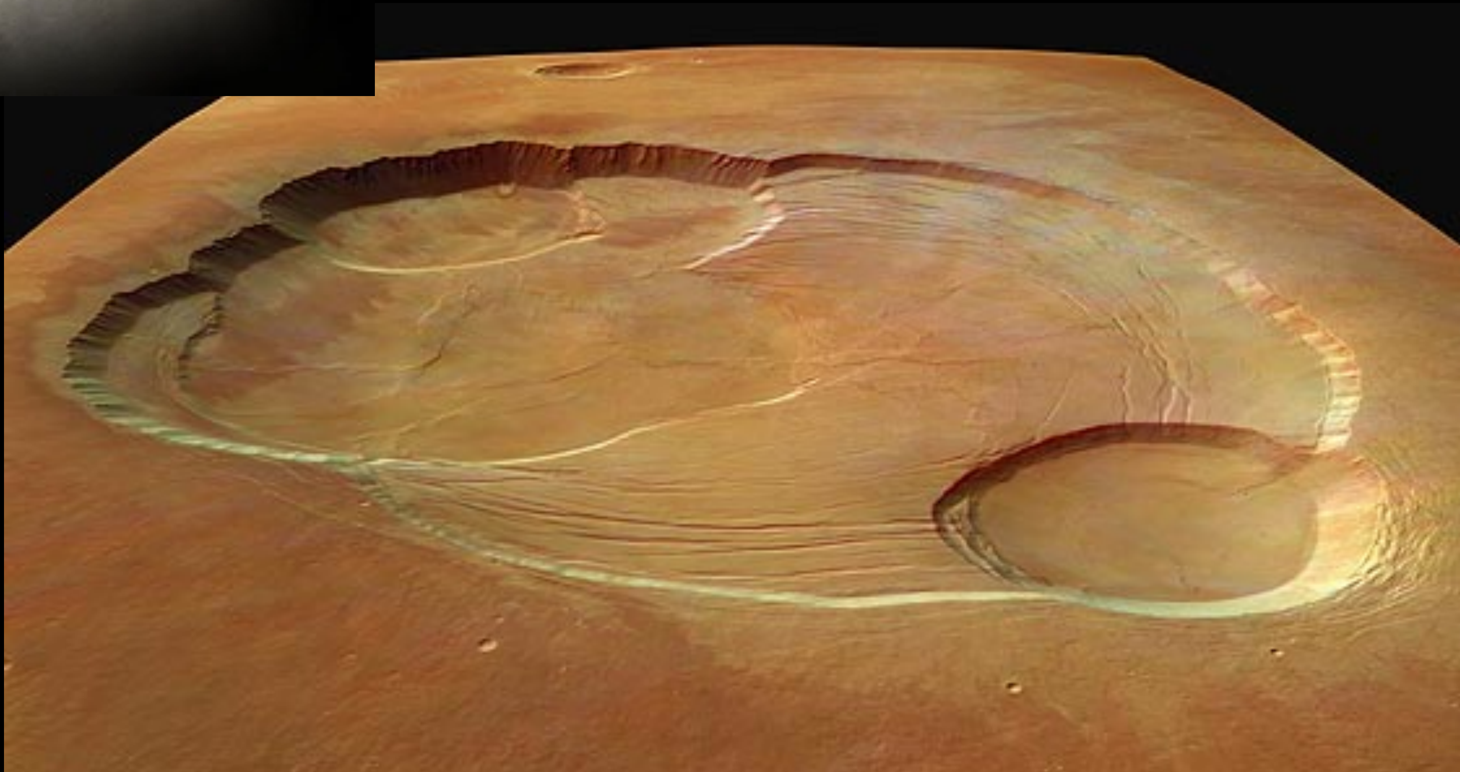
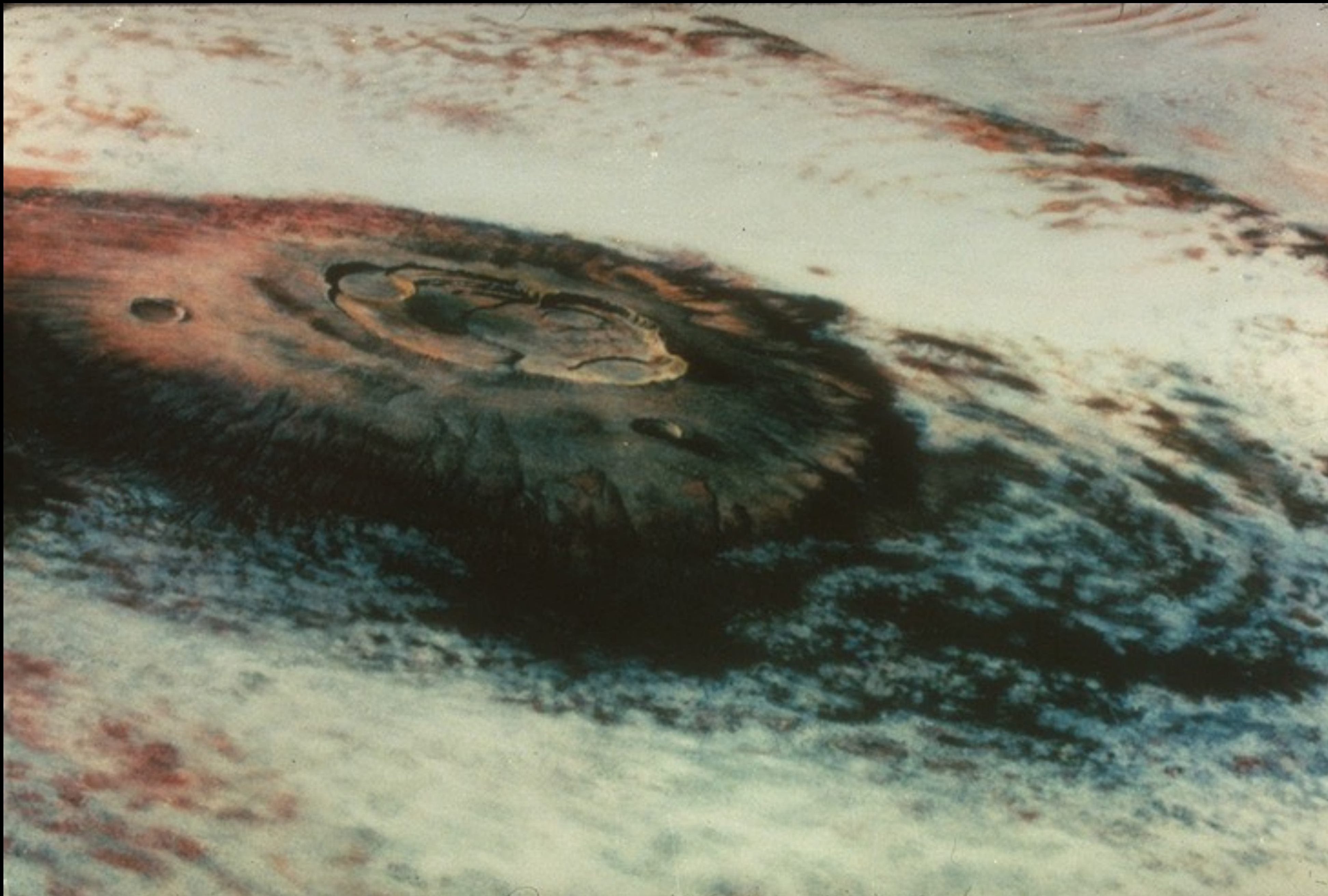




Mars: Olympus Mons



Olympus Mons



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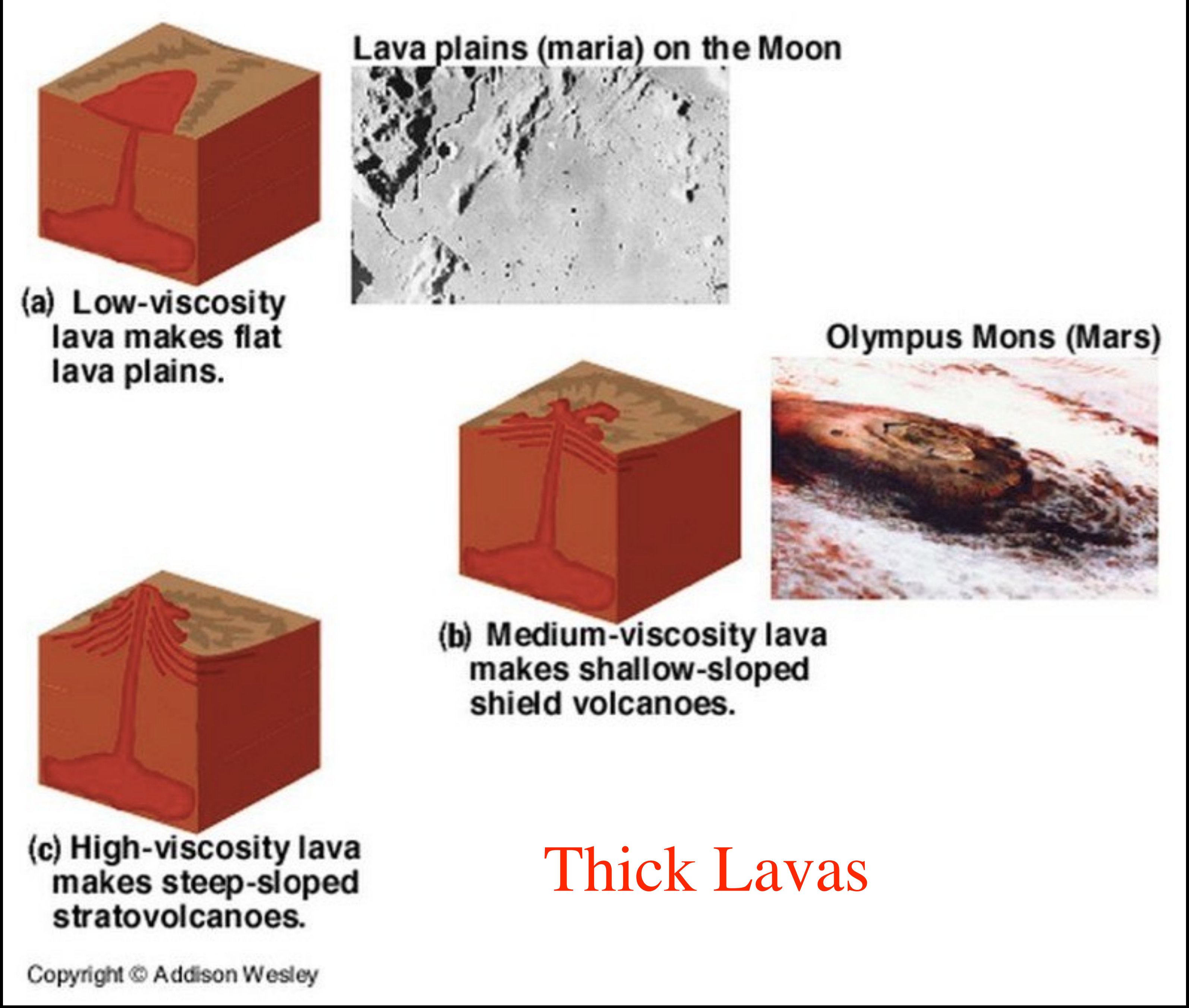


Thick Lavas

Mt. Fuji

Highest Mountains

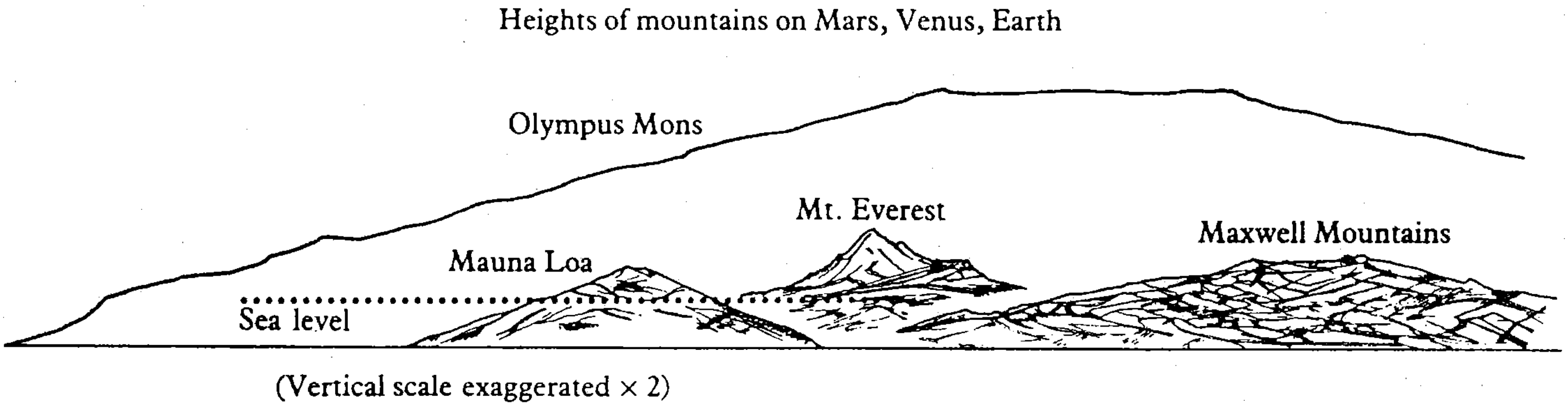
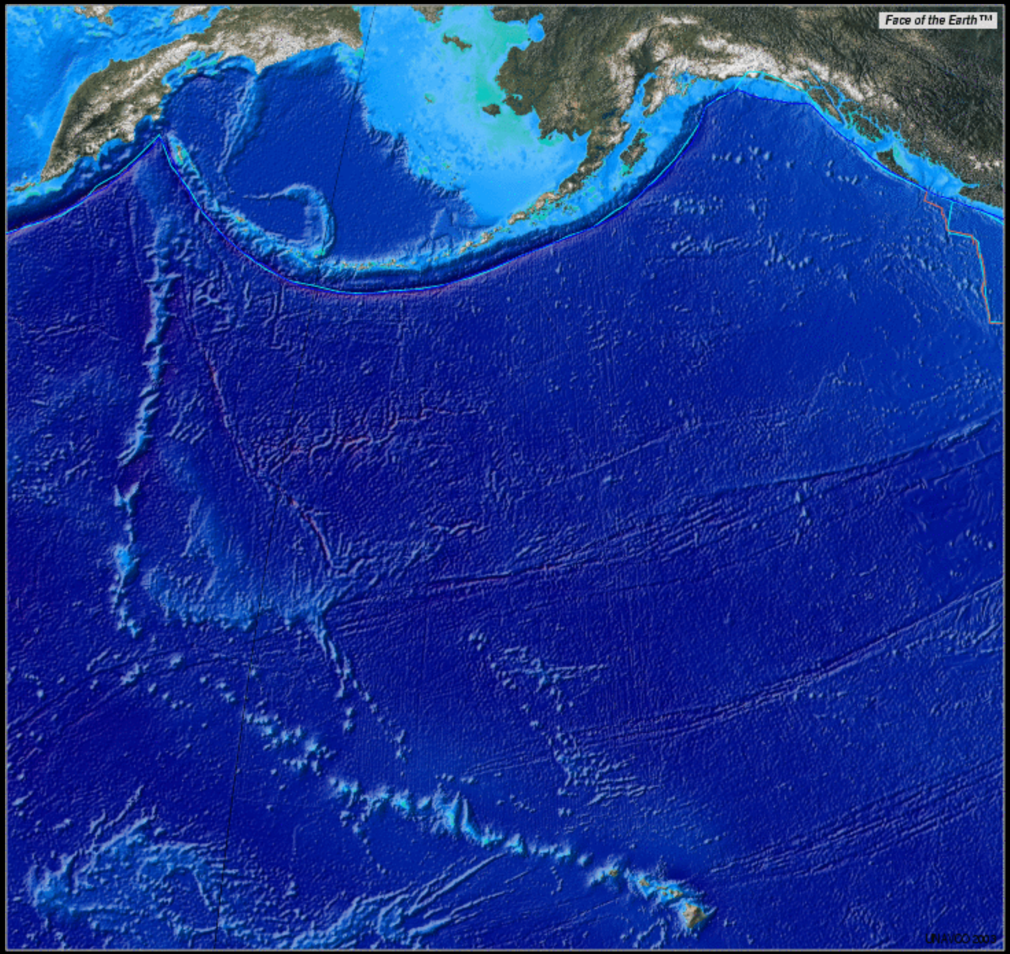
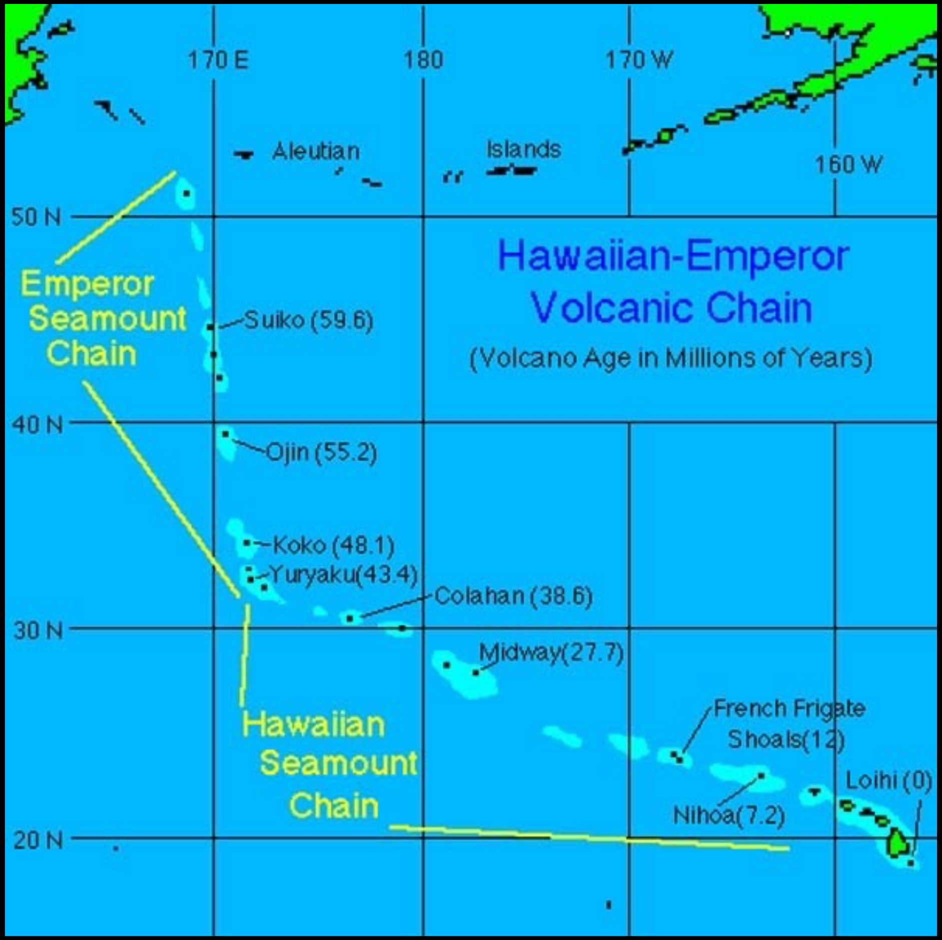


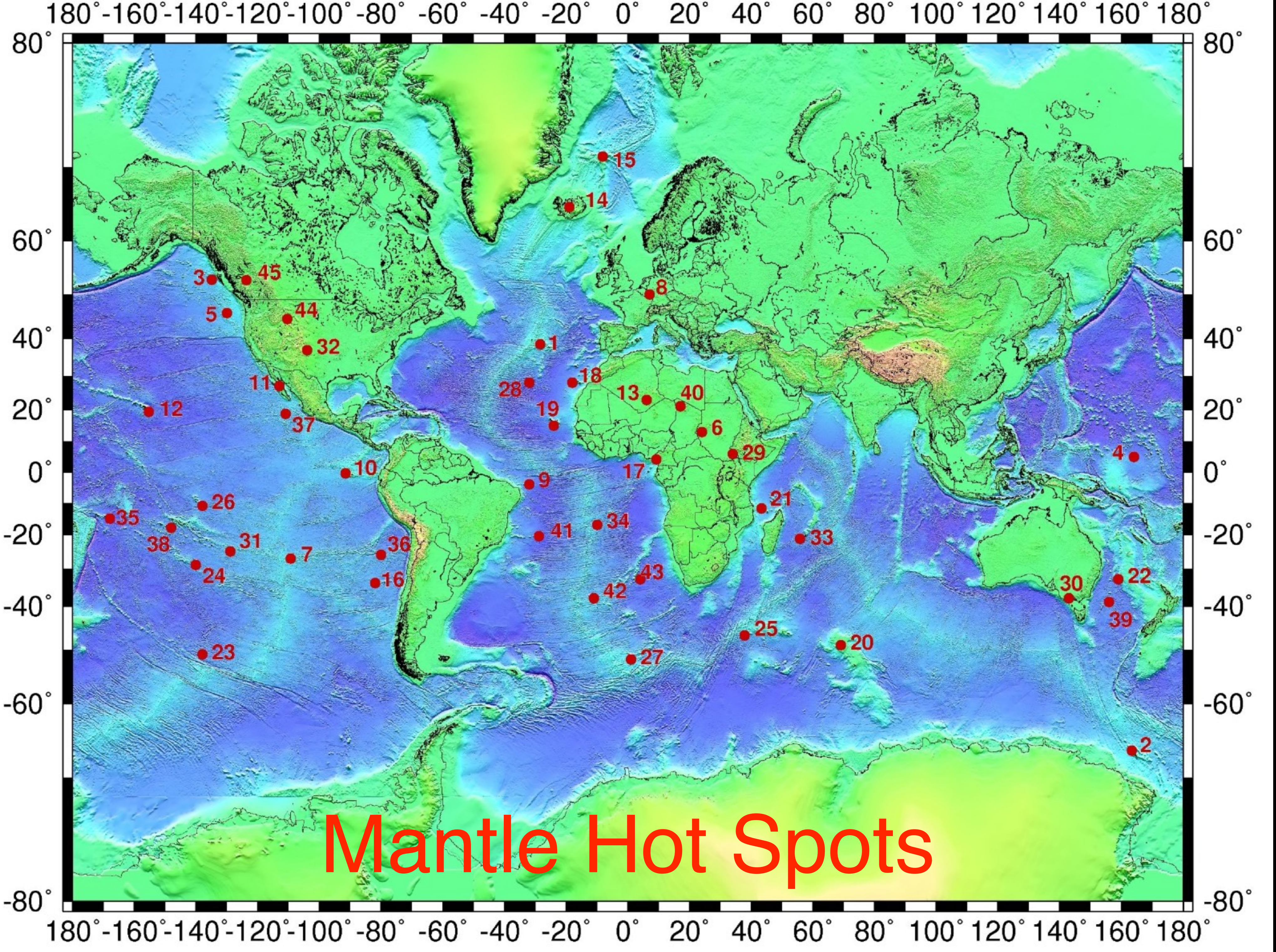
Figure 11.7 Comparison of highest elevations on Venus, Earth, and Mars. Martian mountains can grow higher because Mars has weaker gravity. Vertical scale is exaggerated by a factor of three.

Mantle Hot Spots



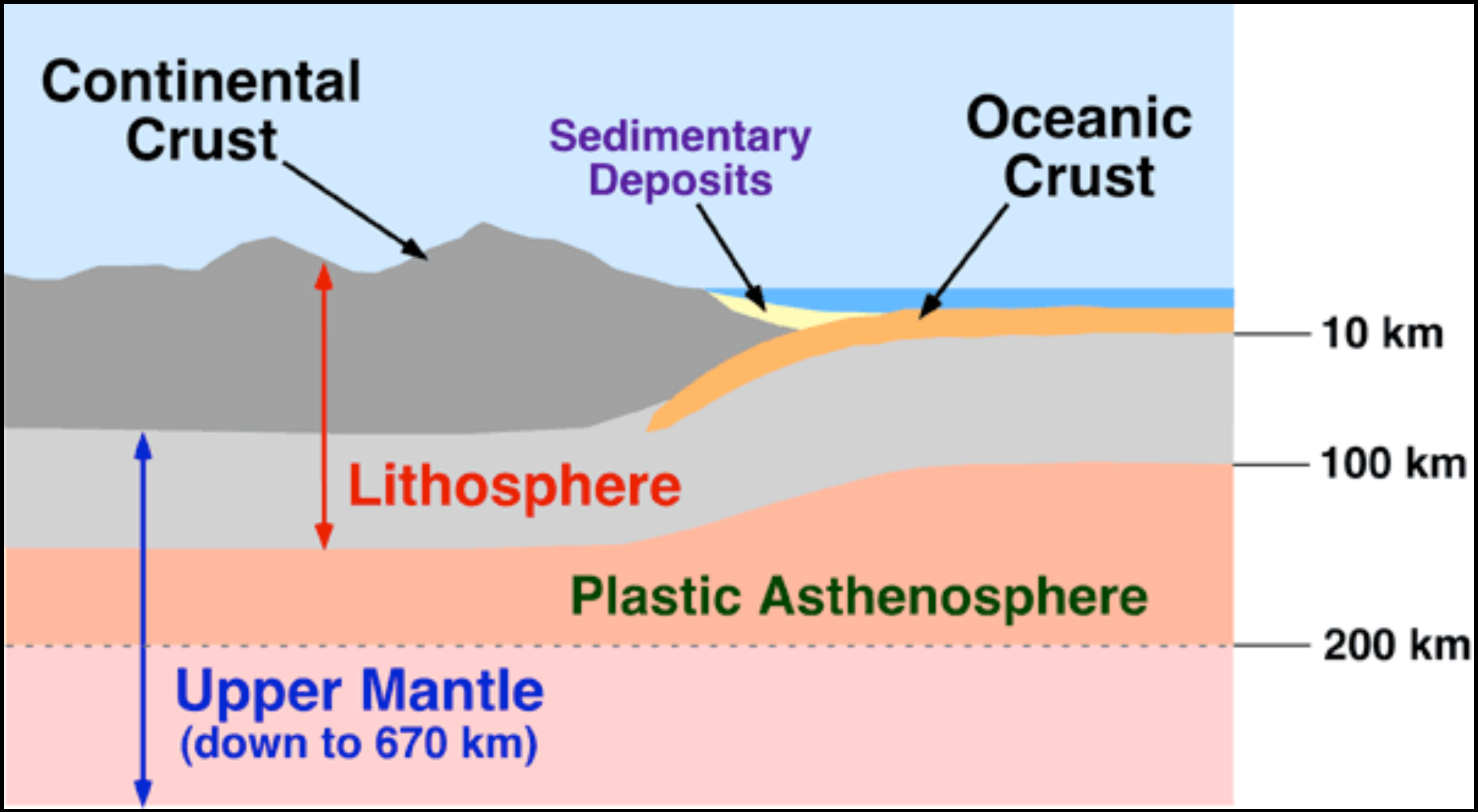


Interesting distribution of seamounts



Mantle Hot Spots
180° -160° -140° -120° -100° -80° -60° -40° -20° 0° 20° 40° 60° 80° 100° 120° 140° 160° 180°
80° 60° 40° 20° 0° -20° -40° -60° -80°
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45

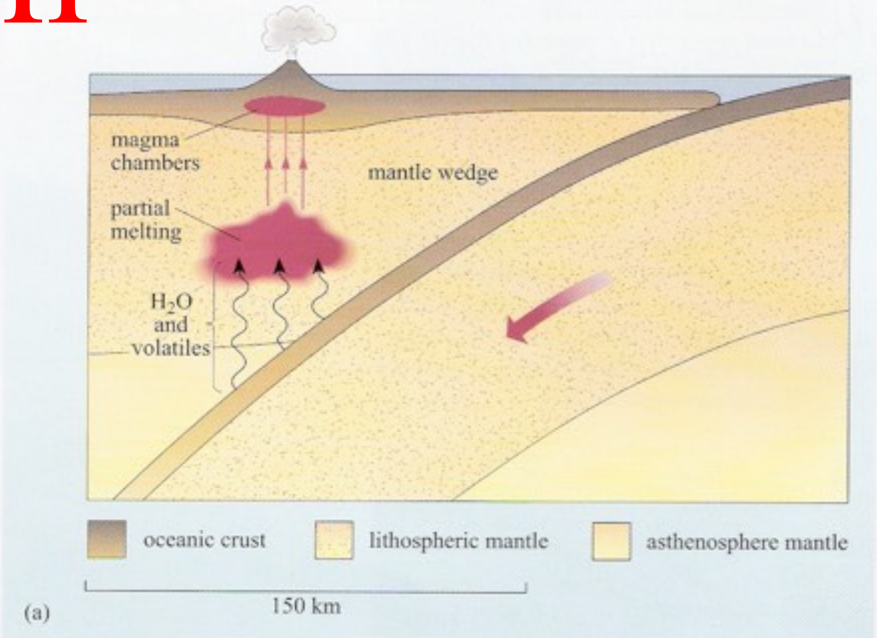
Layers of the Earth



Melting by Hydration

words, mantle altered in this manner begins to melt at lower temperatures and pressures than unaffected, or anhydrous, mantle. This is the process of hydration-induced melting.

Hydration of mantle peridotite occurs as a consequence of plate tectonic recycling (Sections 2.4.5 and 2.5.1). It takes place at depth within subduction zones where old, water-rich oceanic crust is reabsorbed into the mantle (Figure 3.9a). The resulting generation and surfaceward migration of magma produces arcuate belts of volcanoes, known as **volcanic arcs** (Figure 3.9b).



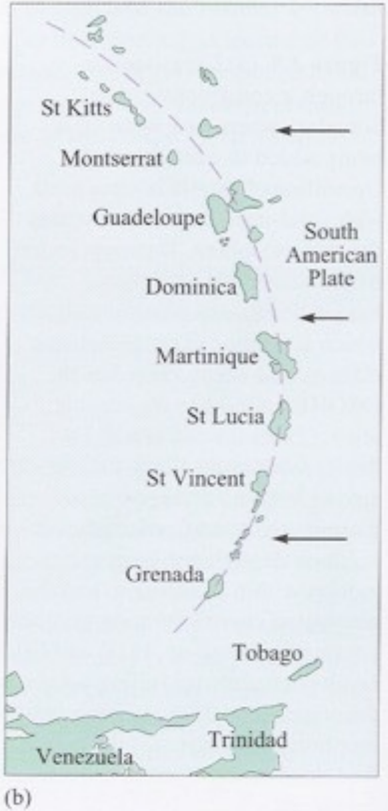


Figure 3.9 (a) Cross-section through a destructive plate boundary where old oceanic-crust material is being recycled back into the mantle during subduction. Heating of subducted material during its descent releases hydrous or gas-rich fluids which then rise and are added to the mantle wedge of the over-riding plate. These released fluids cause hydration reactions that reduce the melting point of the mantle-wedge mineral assemblage, so producing magmas. The volcanoes associated with this magmatism are typically arranged in arcuate belts (volcanic arcs) such as those of the Andes, Central America, and the Lesser Antilles of the Caribbean. (b) Sketch map of the volcanically generated islands of the Lesser Antilles that together form the volcanic arc of the eastern Caribbean. (Arrows show the relative movement of the South American Plate, which is presently being subducted beneath the Caribbean Plate.)

Partial Melting

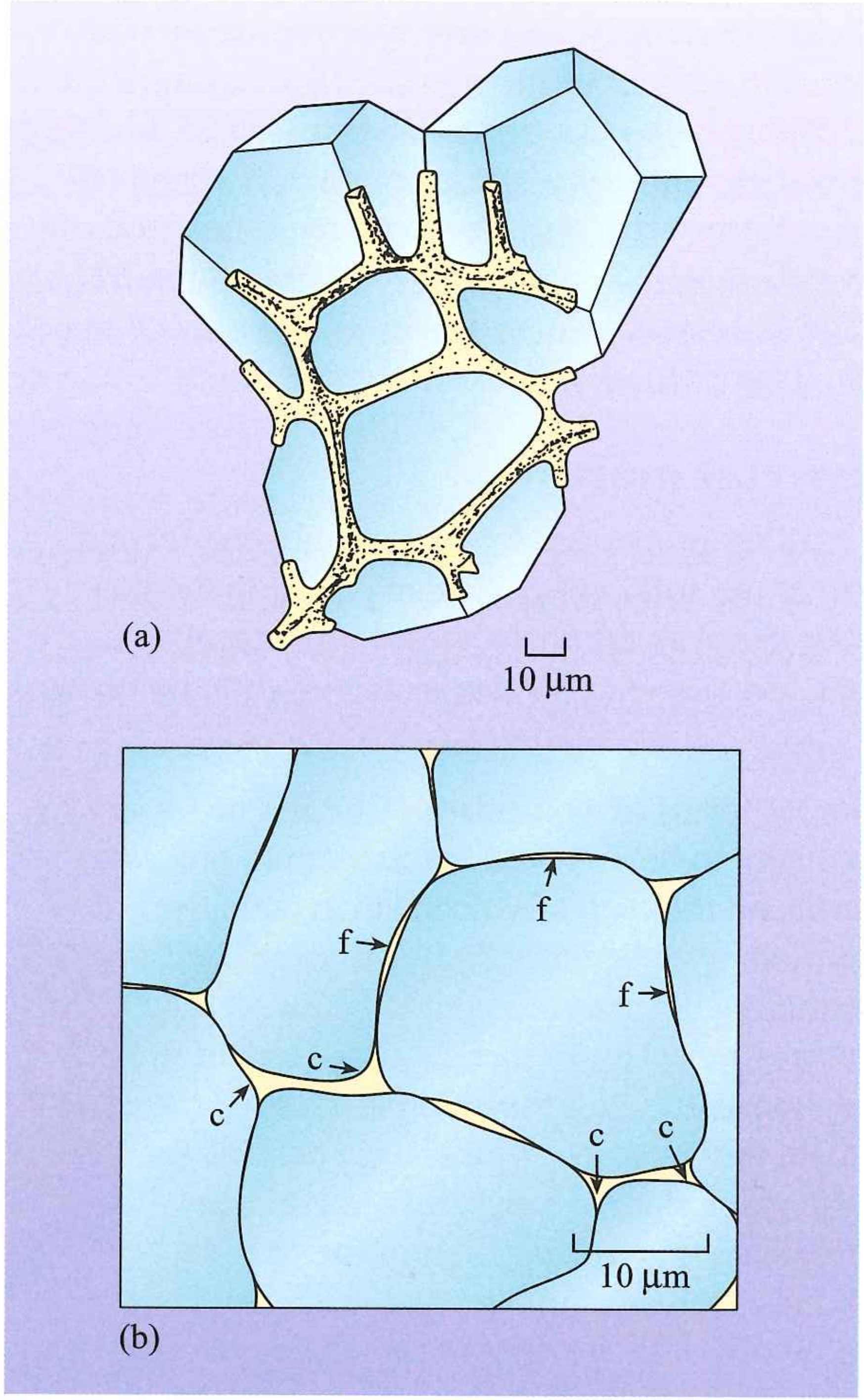
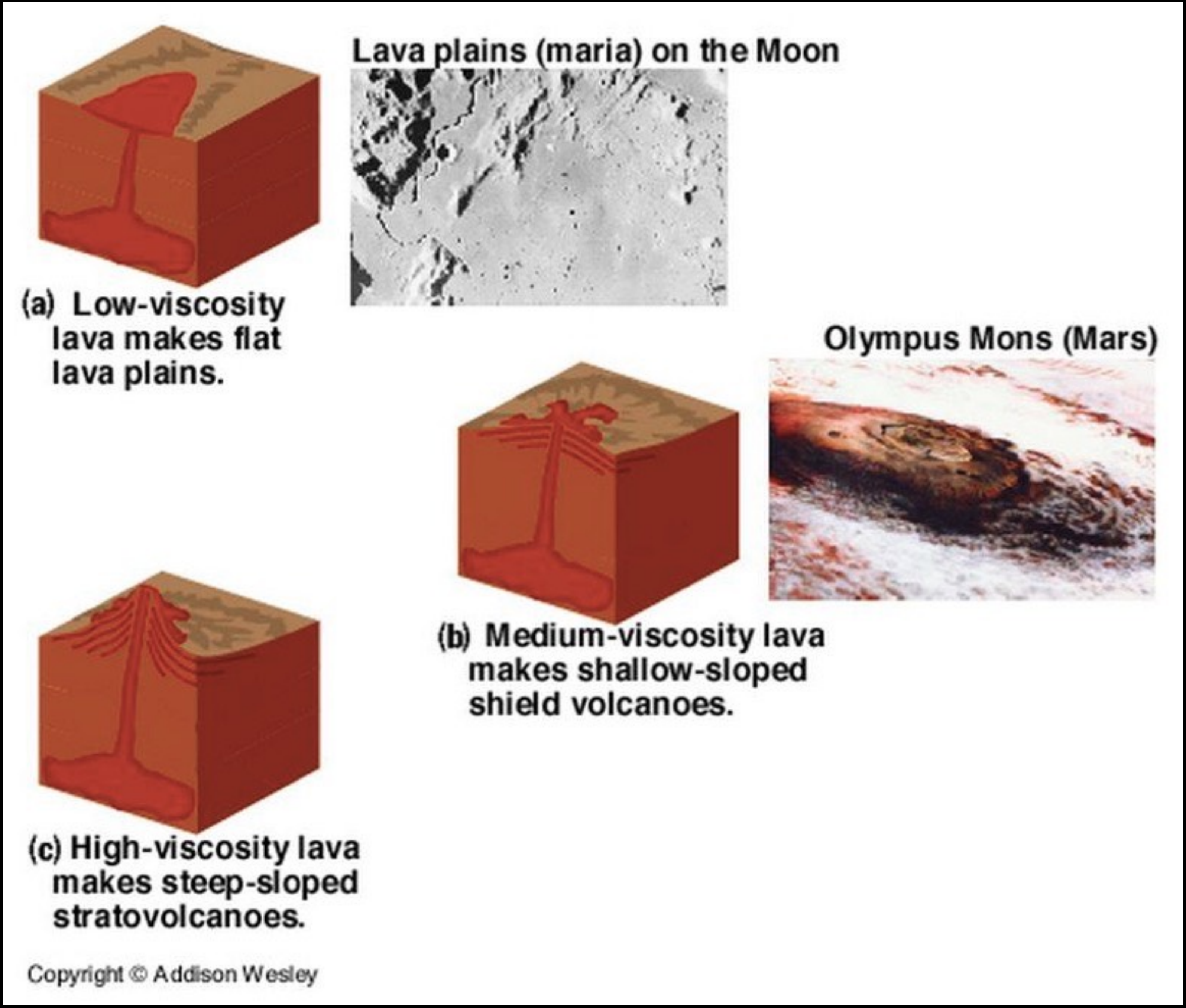


Figure 3.10 (a) Sketch showing a three-dimensional view of adjacent crystals in a rock in which partial melting has begun. The melt initially forms in the pockets (interstices) where three crystals meet and, with further melting, the pockets then become connected by channels of melt running along the grain boundaries. Once interconnected, the melt can then begin to migrate and coalesce into a larger body of magma. (b) Magnified image of a rock beginning to melt (melt: yellow, crystals: blue). Features labelled 'c' are interconnecting melt channels at crystal interstices and boundaries; features labelled 'f' are thinner films of melt coating grain boundaries that may not yet be sufficiently developed to form connections.

Different Types of Lava



Basaltic (low Silicon) lavas: effusive eruptions

Silicon-rich lavas: explosive eruptions

Midterm Exam: Thursday in Class

Three Questions (Two Quantitative, One Qualitative)

- Everything Covered in Class
- Chapter 5 Atmospheres
- Chapter 6 Surfaces/Interiors

1 page of notes front/back

Effusive Eruptions

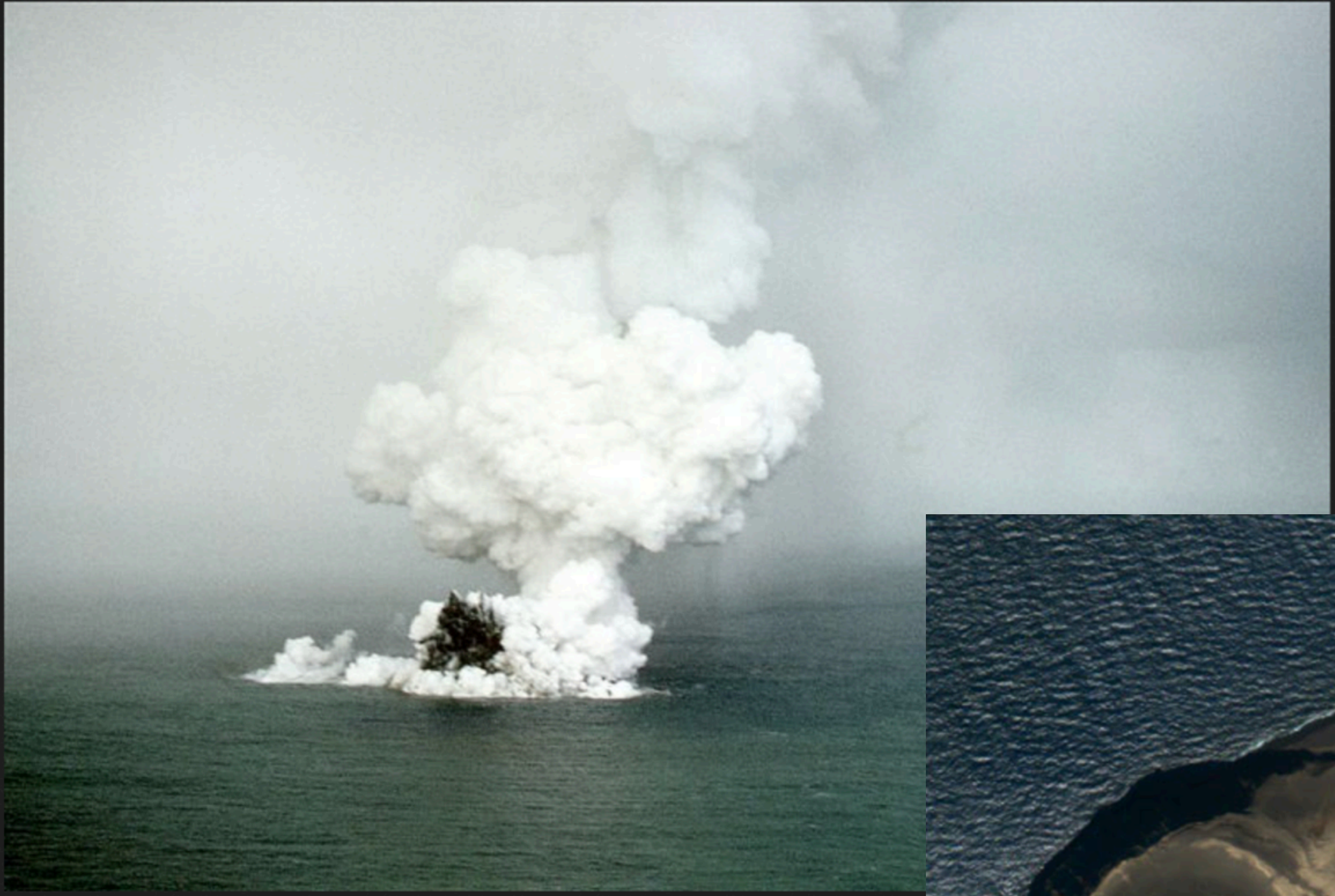
Explosive Eruptions

Mauna Loa

Mt. Fuji

Surtsey, Iceland

Surtsey Iceland



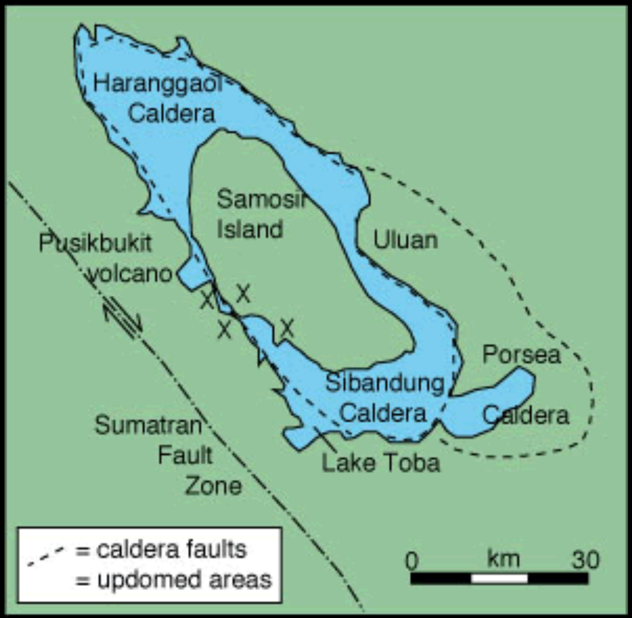
Volcanic Craters

1. Erupted 7,700 years ago creating 50 km^3 new volcanic material
2. 10km diameter, No rivers in or out
3. Deepest lake in U.S. at 1943 feet

Crater Lake Caldera, Oregon

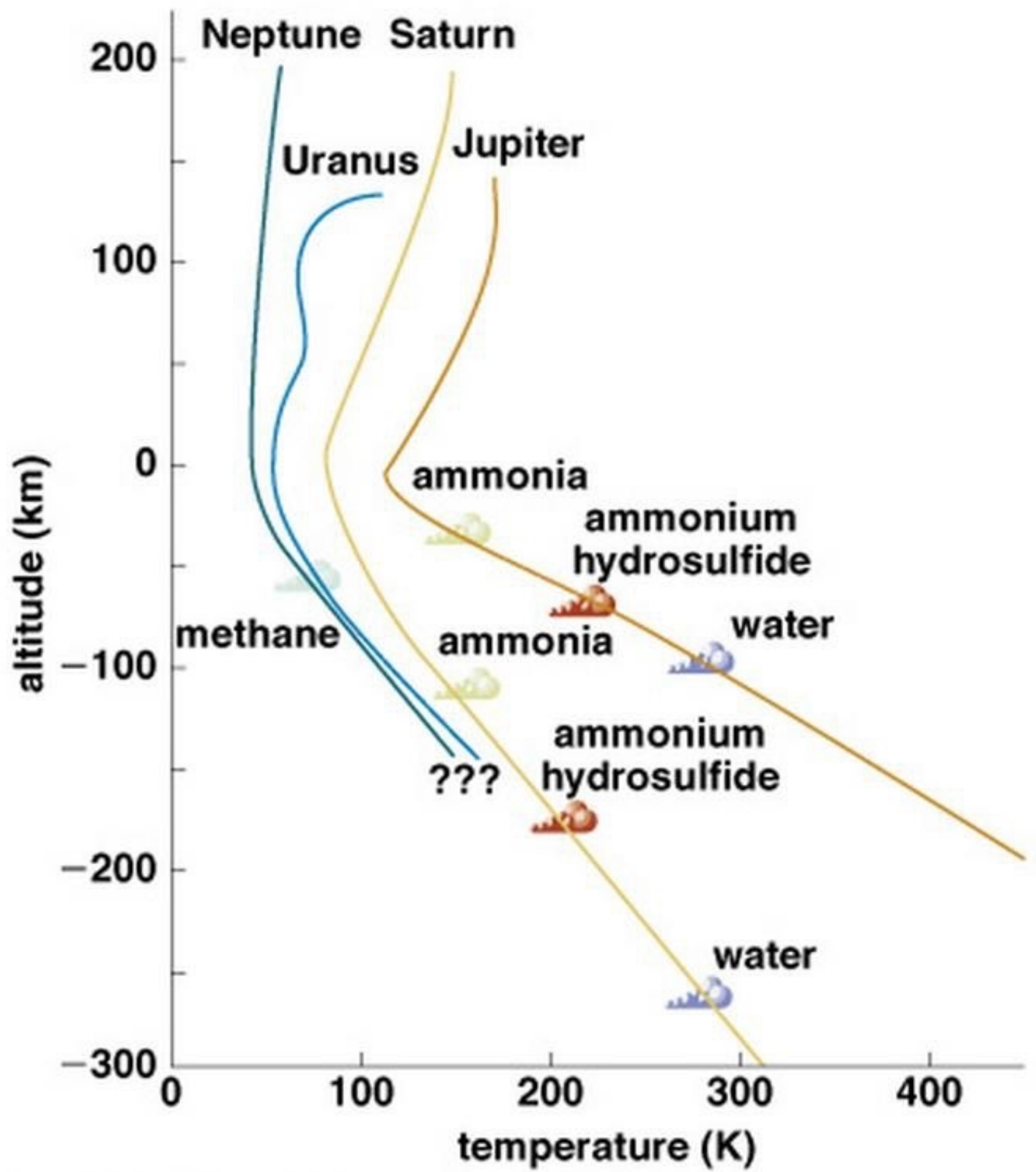
Volcanic Craters

Supervolcano Caldera,
Toba, Sumatra



1. Erupted 75,000 year ago creating 2800 km^3 new volcanic rock, 800 km^3 volcanic ash, cooler temperatures
2. 6 years of Volcanic Winter, Temps down by 10-15 deg.
3. Ash found in India, Lake Malawi in Africa
4. Prolonged deforestation in South Asia
5. Genetic Bottleneck: Evidence shows human population decreased to 3,000-10,000 individuals 50-100kyr ago
6. Similar evidence for chimps, orangutans, cheetahs, tigers

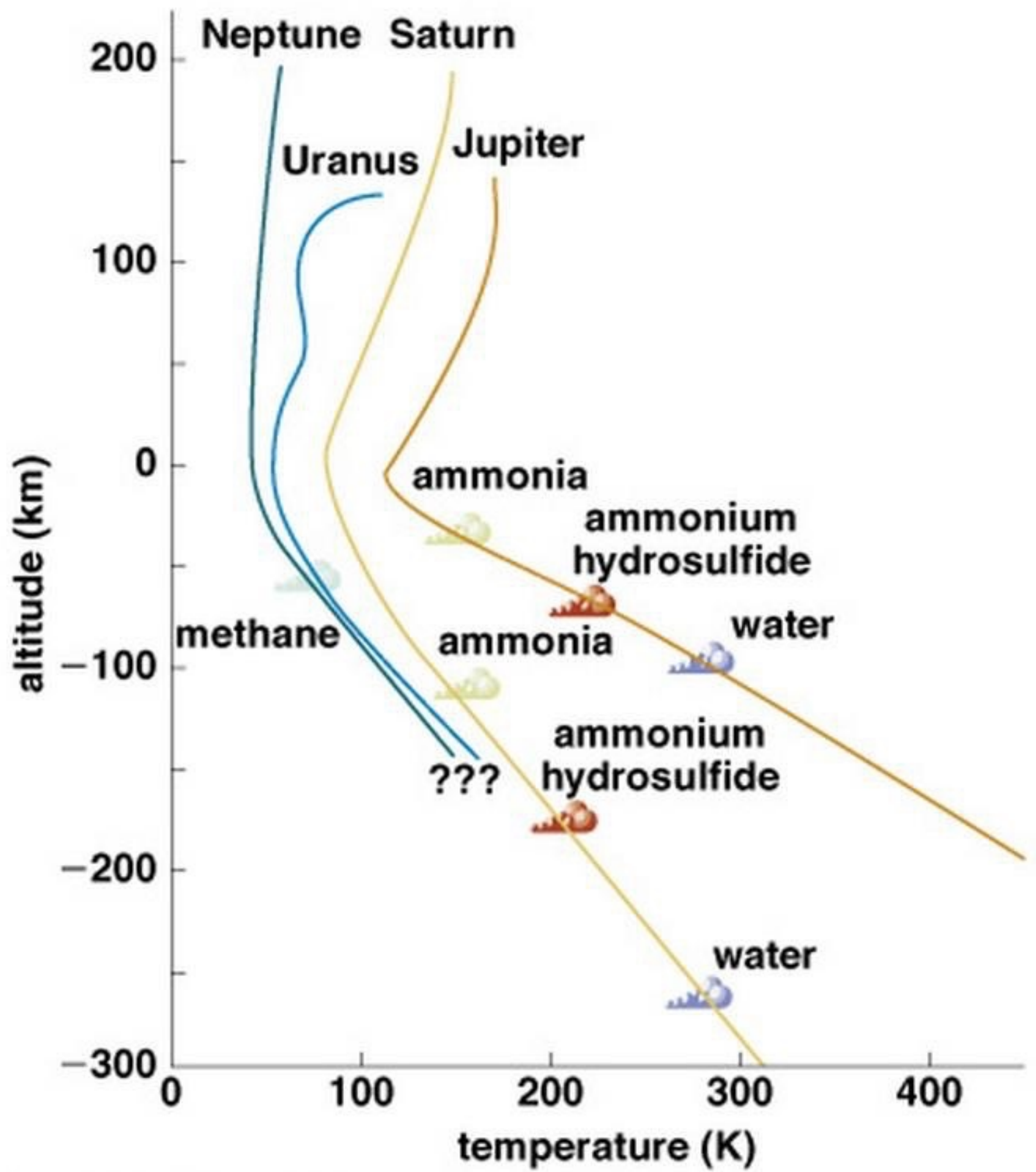
Cloud Decks



Neptune
Saturn
Uranus
Jupiter
200
100
0
−100
−200
−300
altitude (km)
ammonia
ammonium
hydrosulfide
water
methane
ammonia
???
ammonium
hydrosulfide
water
0
100
200
300
400
temperature (K)

Cloud Decks

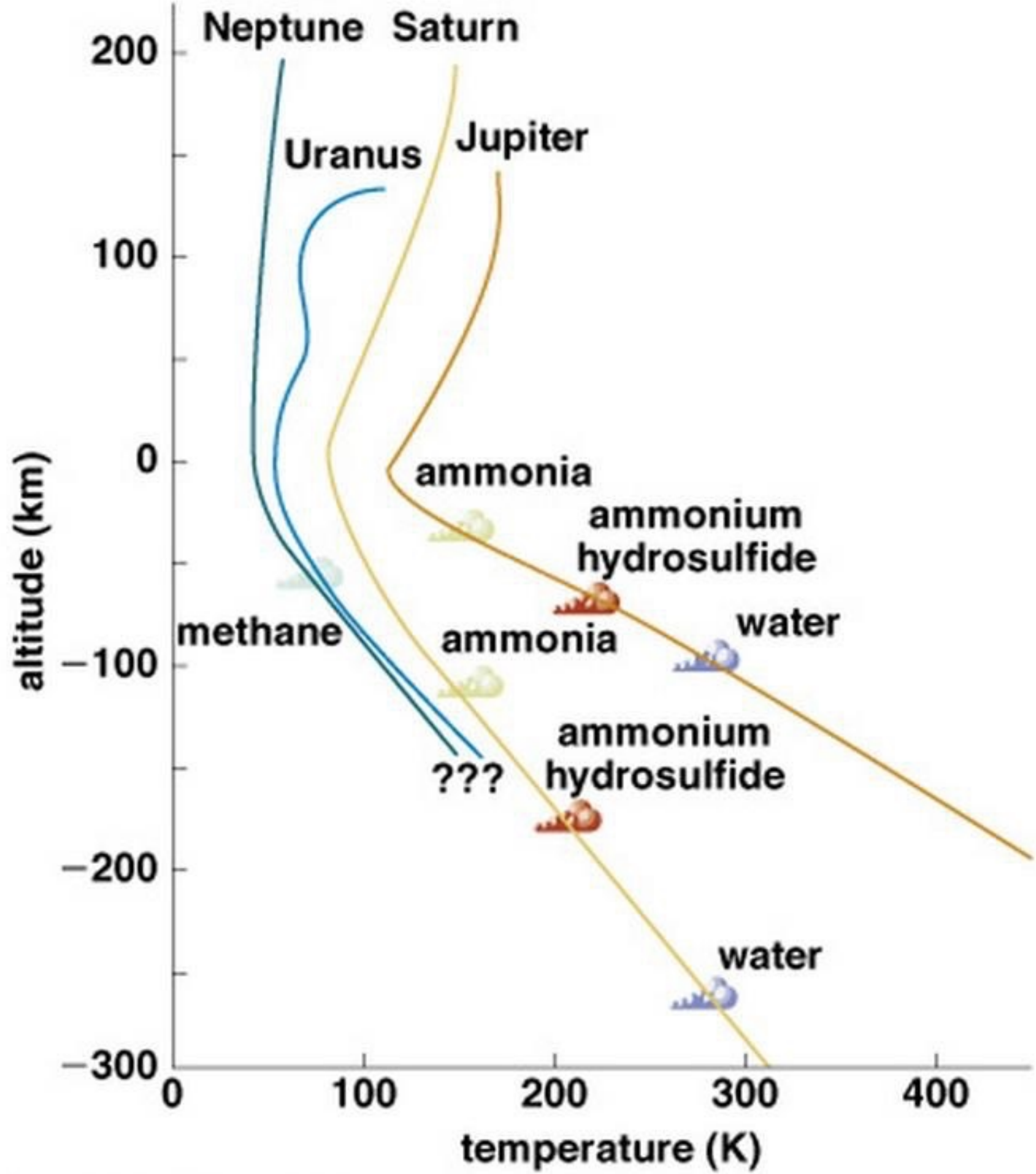
Why no Methane clouds on Jupiter & Saturn?



Cloud Decks

Why no Methane clouds on Jupiter & Saturn? Too Hot!

Why are cloud decks separated more on Saturn than Jupiter?

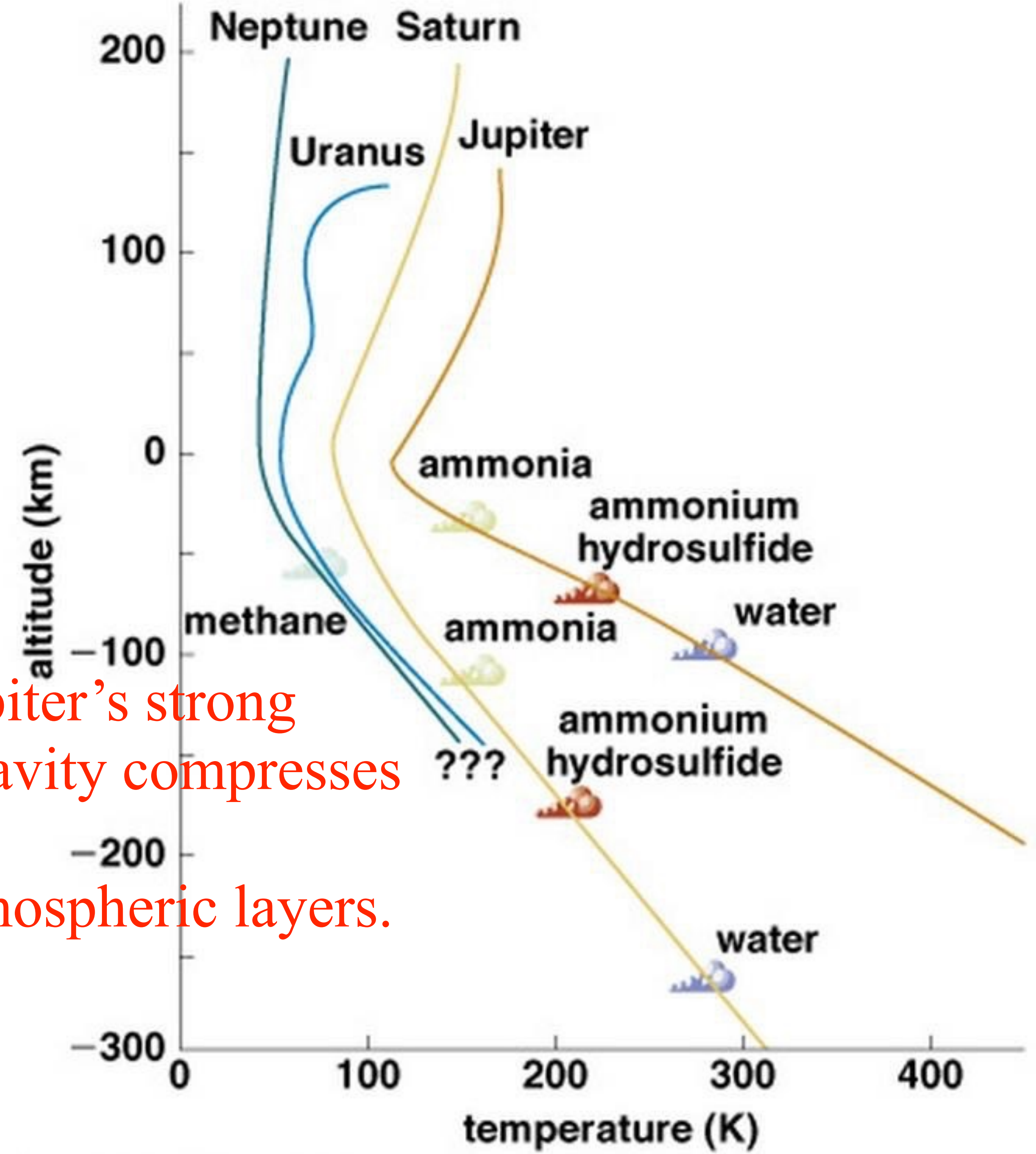


Cloud Decks

Why no Methane clouds on Jupiter & Saturn? Too Hot!

Why are cloud decks separated more on Saturn than Jupiter? Jupiter's strong Gravity compresses the atmospheric layers.

What happens below the water clouds?

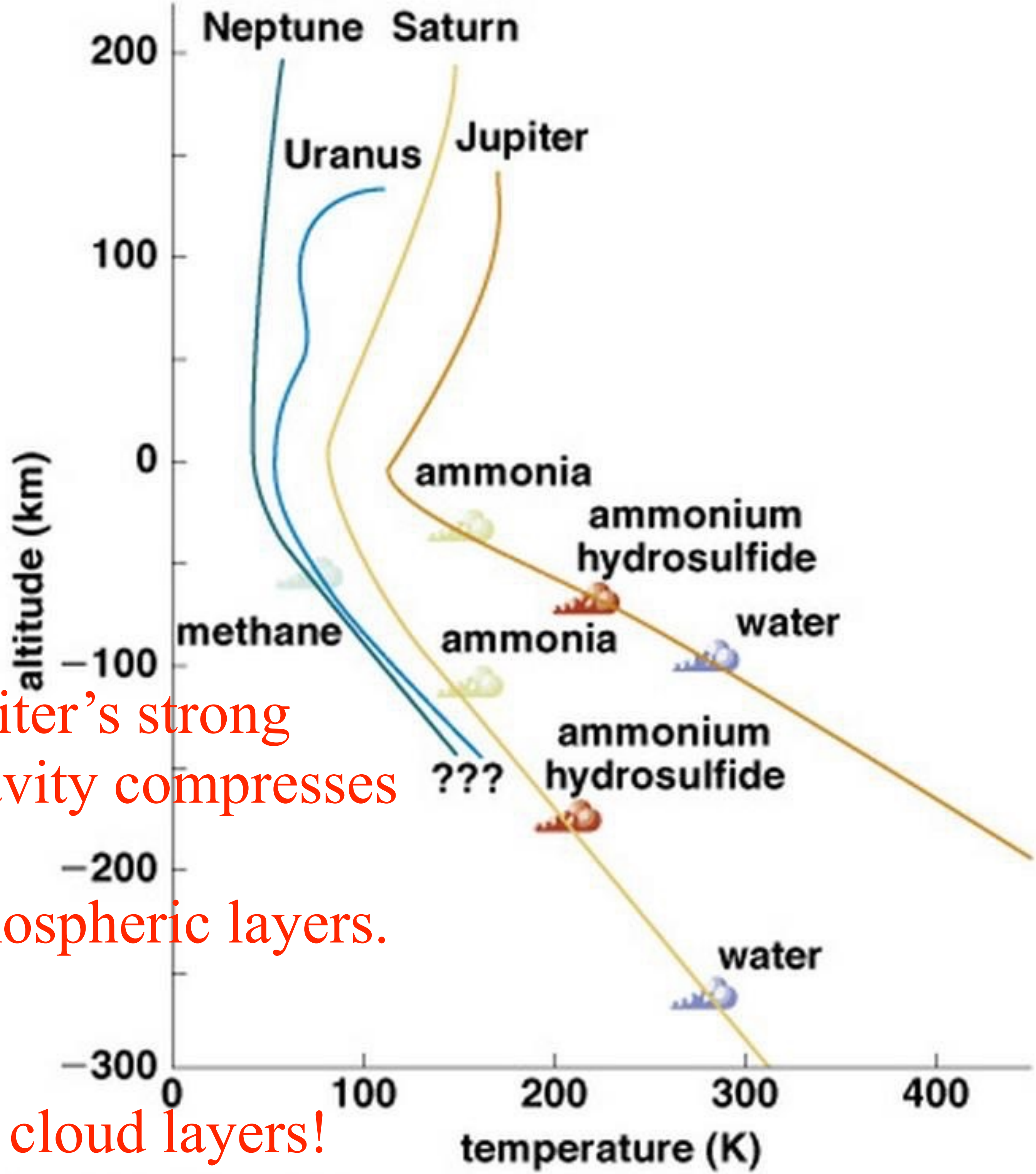


Cloud Decks

Why no Methane clouds on Jupiter & Saturn? Too Hot!

Why are cloud decks separated more on Saturn than Jupiter? Jupiter's strong Gravity compresses the atmospheric layers.

What happens below the water clouds? More cloud layers!

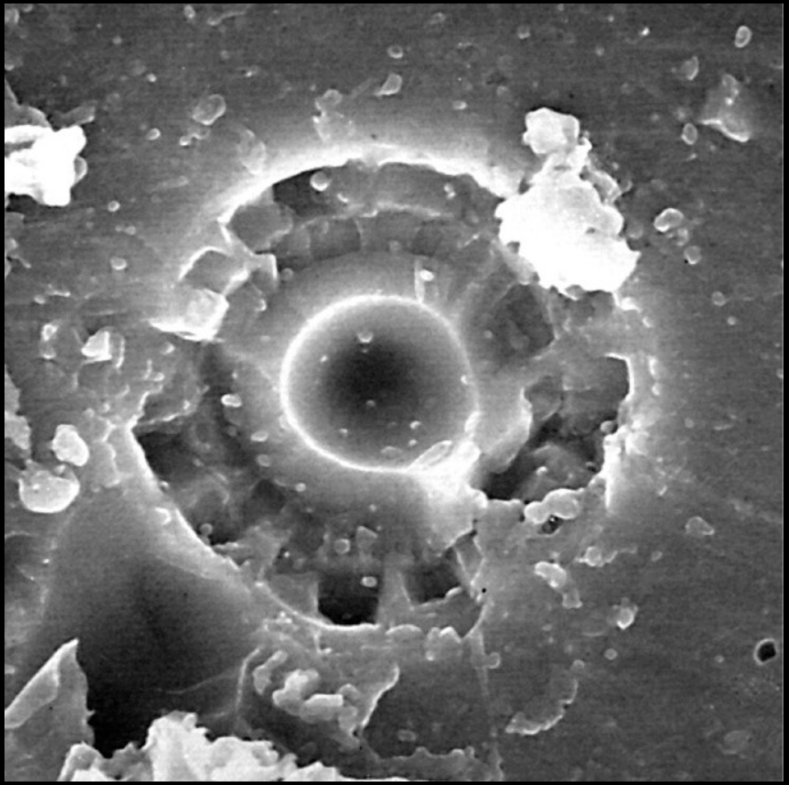


Impact Craters

Big Ones

4000 km-sized (10^7 m) impact structure on Ganymede

Small Ones



10 micron (10^{-5} m) crater in lunar glass

Impacts on the Moon

Front side of the Moon

Back side of the Moon

Craters give Relative Surface Ages

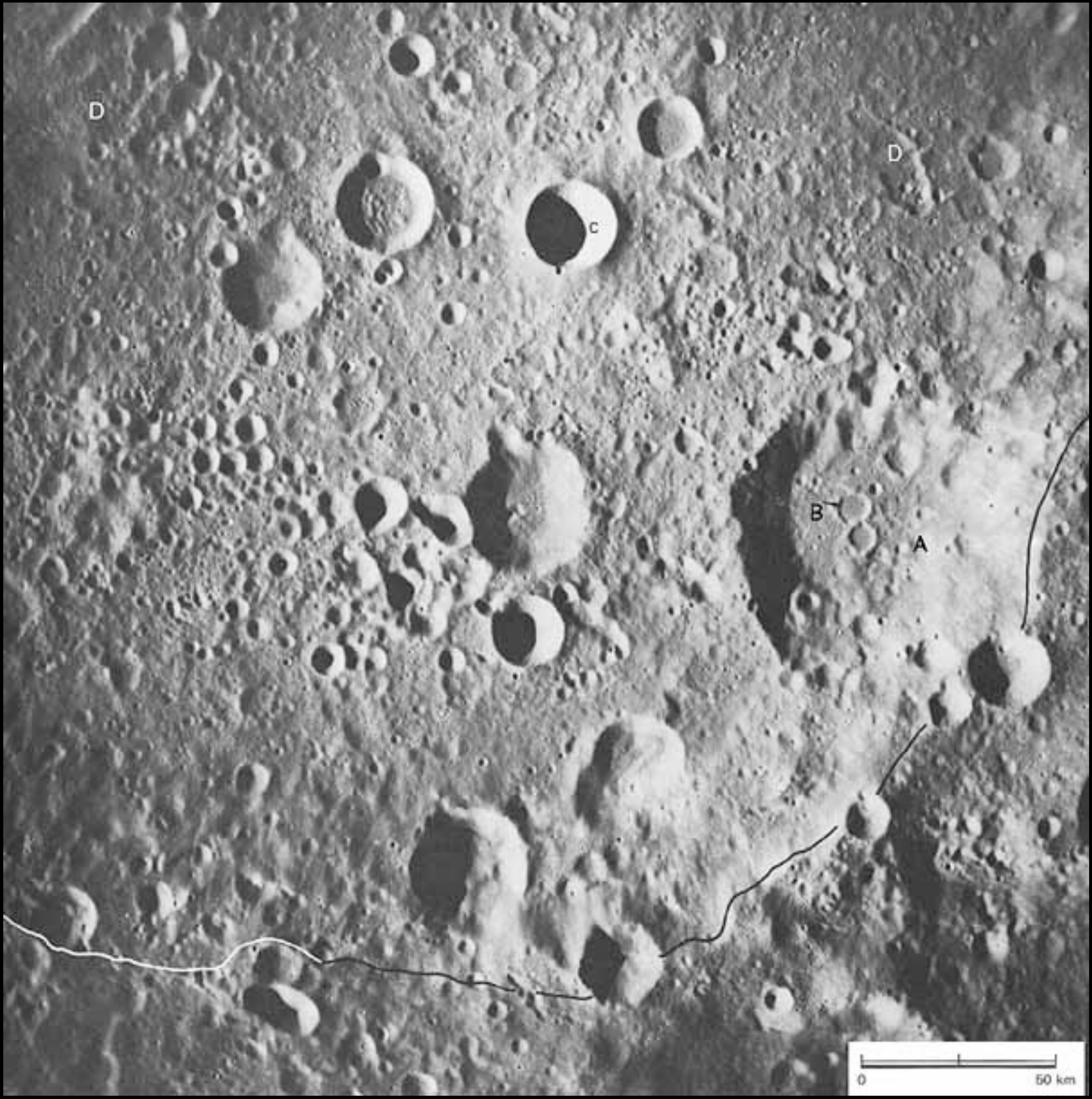
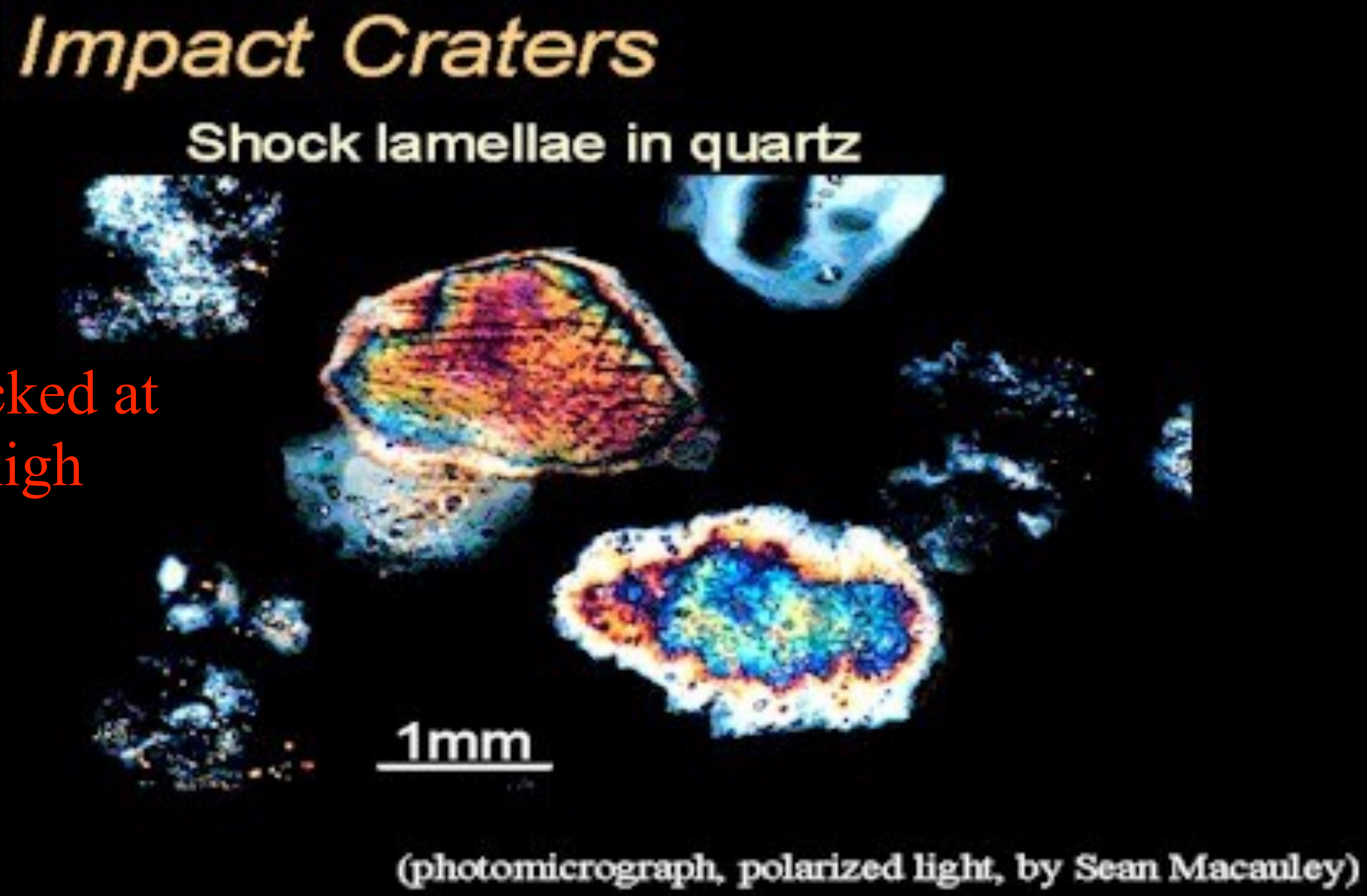


Image of the Moon

Impacts affect Mineralology

Quartz shocked at extremely high pressures

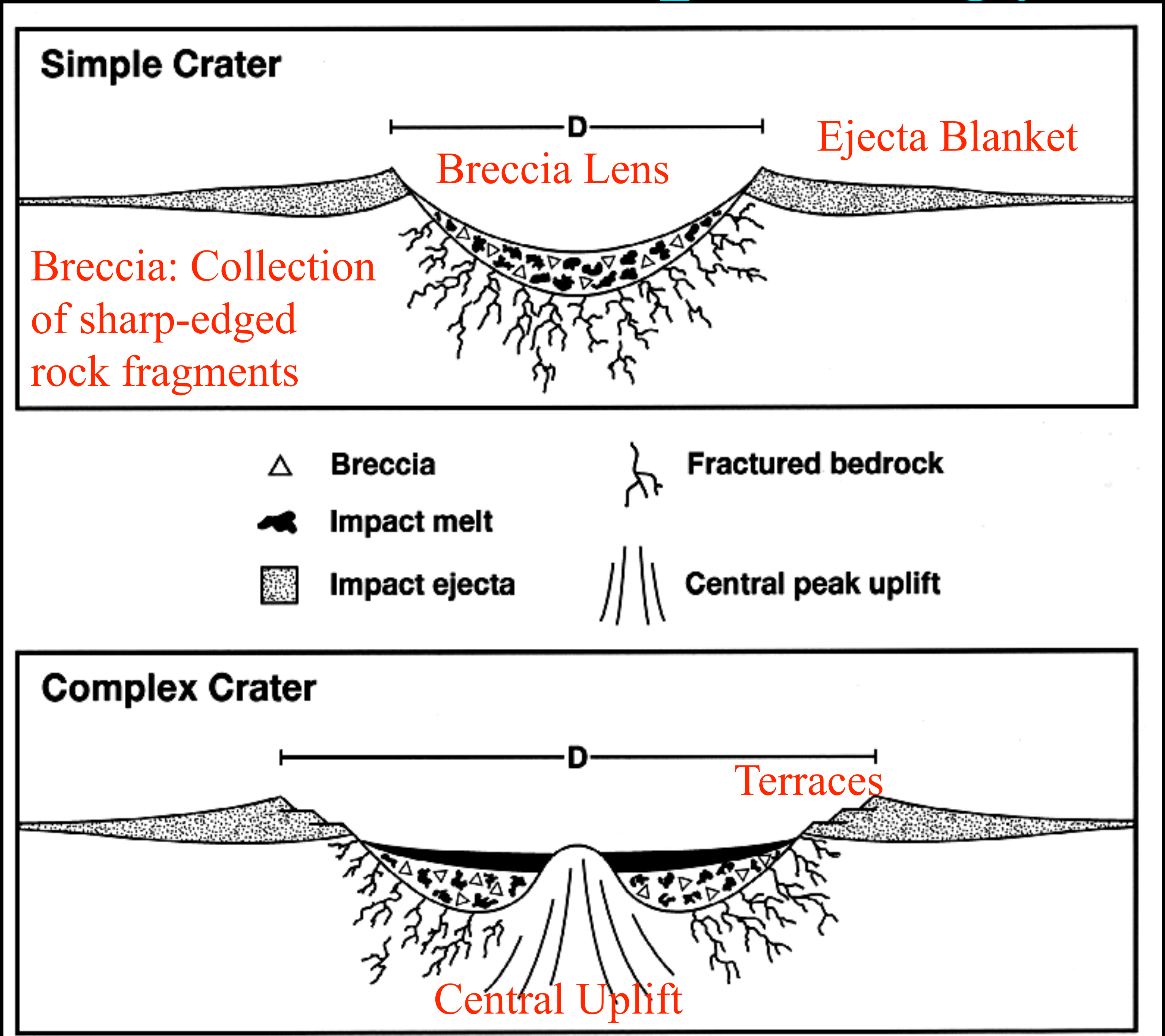


A Piece of Earth's Mantle

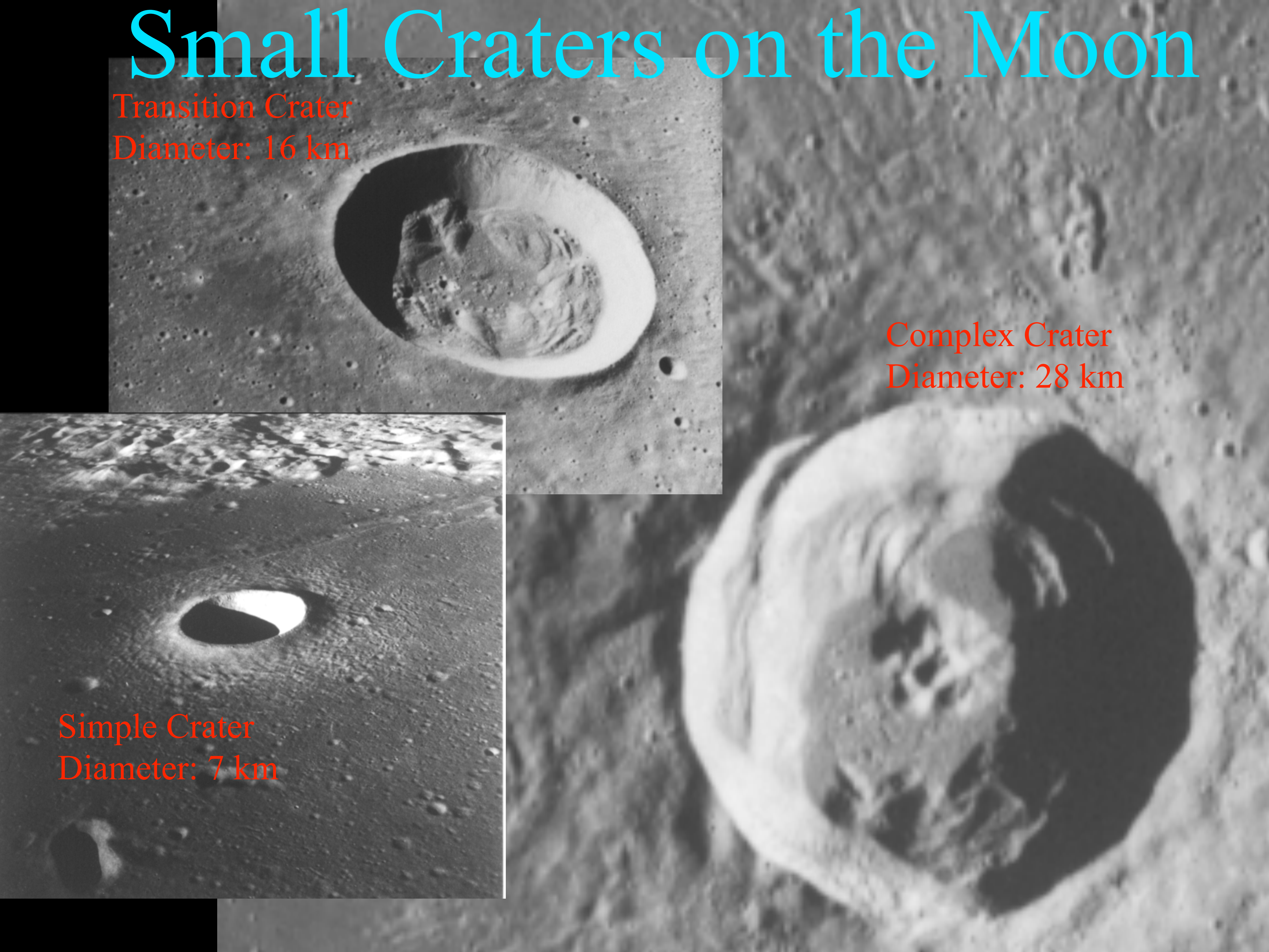
Eclogite - formed at the high pressures found ~100 km deep

These are much lower than the largest impact induced pressures.

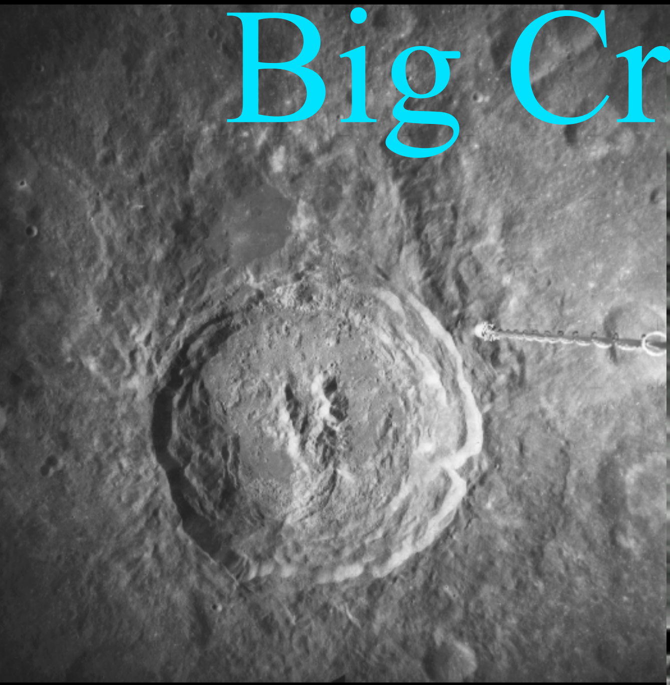
Crater Morphology



Small Craters on the Moon



Big Craters on the Moon



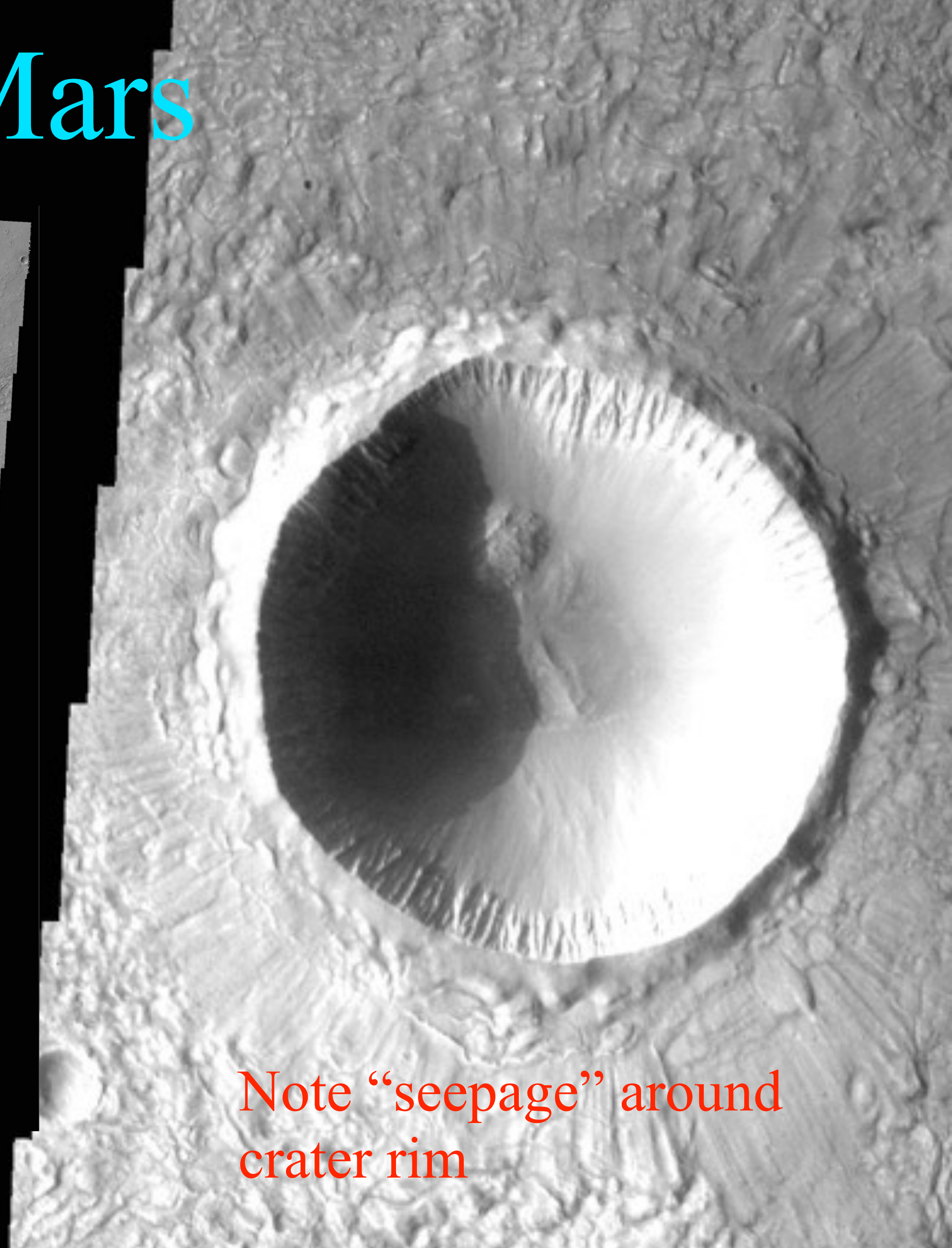
King Crater
Diameter: 77 km

Copernicus Crater
Diameter: 93 km

Schrodinger Crater: Diameter: 320 km

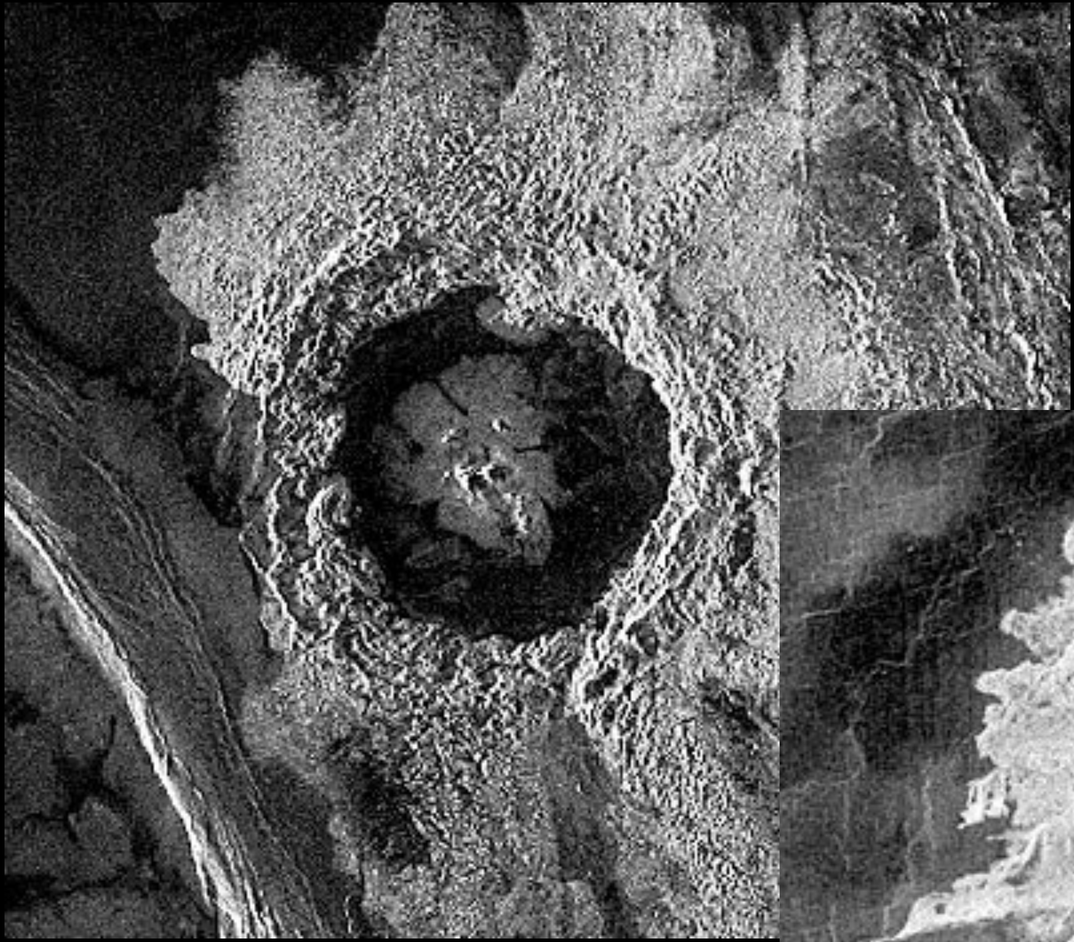
Craters on Mars

Note “fluidized” ejecta blanket



Note “seepage” around crater rim

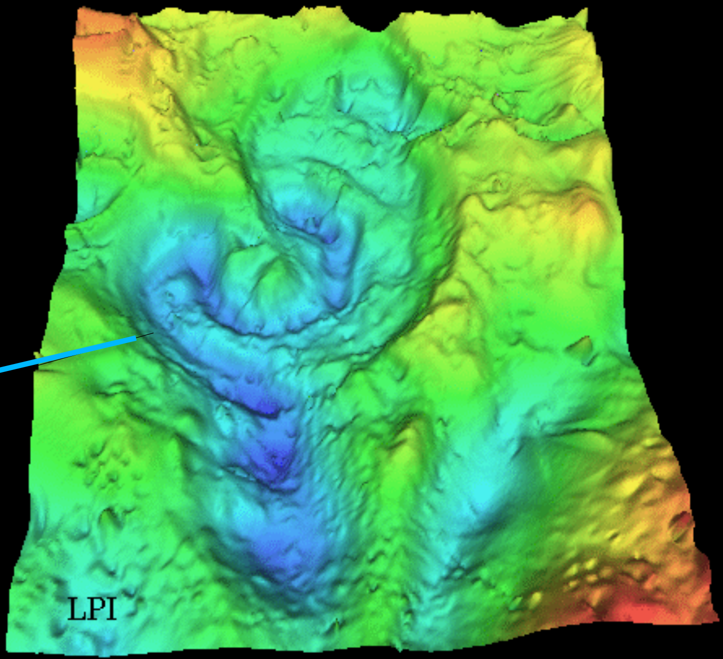
Craters on Venus



Note asymmetric ejecta blankets

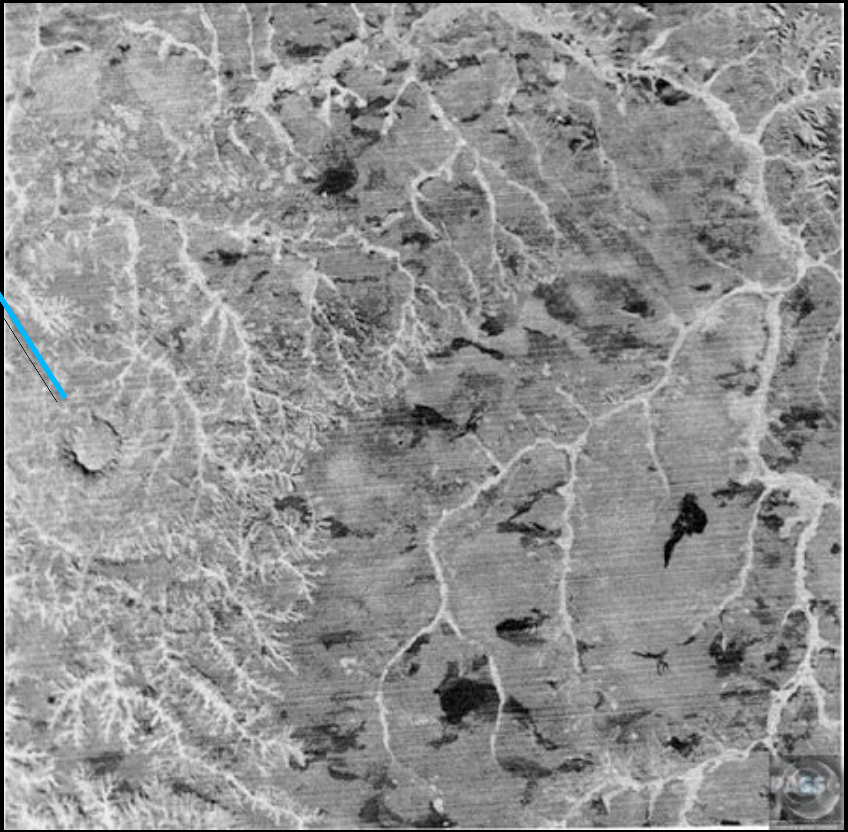
Craters on Earth

Chicxulub, Mexico
200 km diameter
Gravity Data



Craters on Earth

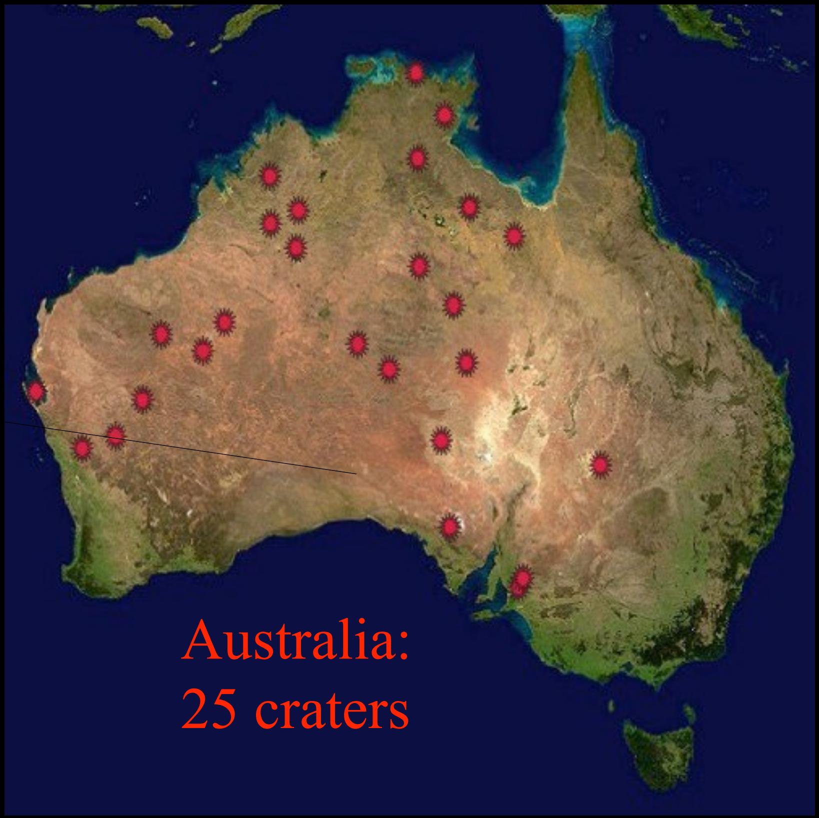
Serra de Cangalha
12 km diameter
Landsat Image



Craters on Earth

Meteor Crater, Arizona
1 km diameter

Craters on Earth



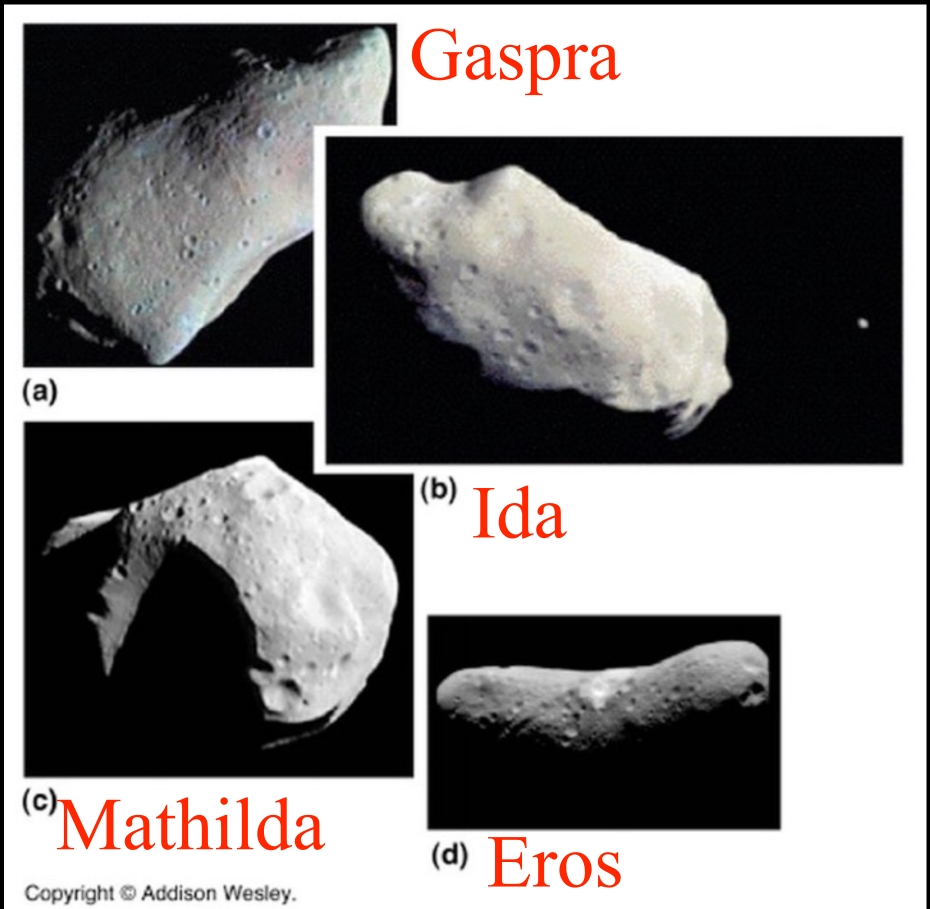
Why so many more in Australia?

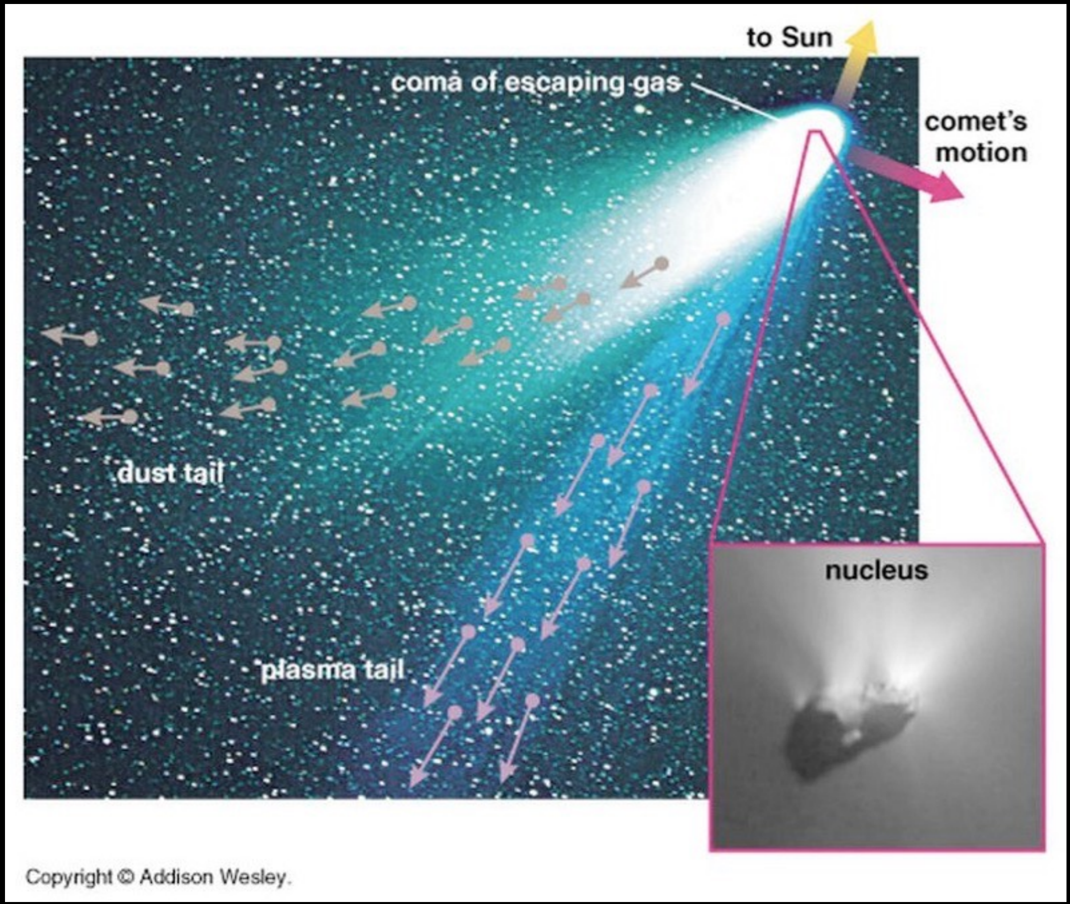
Impact Craters

Wolf Impact Crater, Australia:
Diameter 0.9 km, Age: 0.3Myr

Current Impactor Population

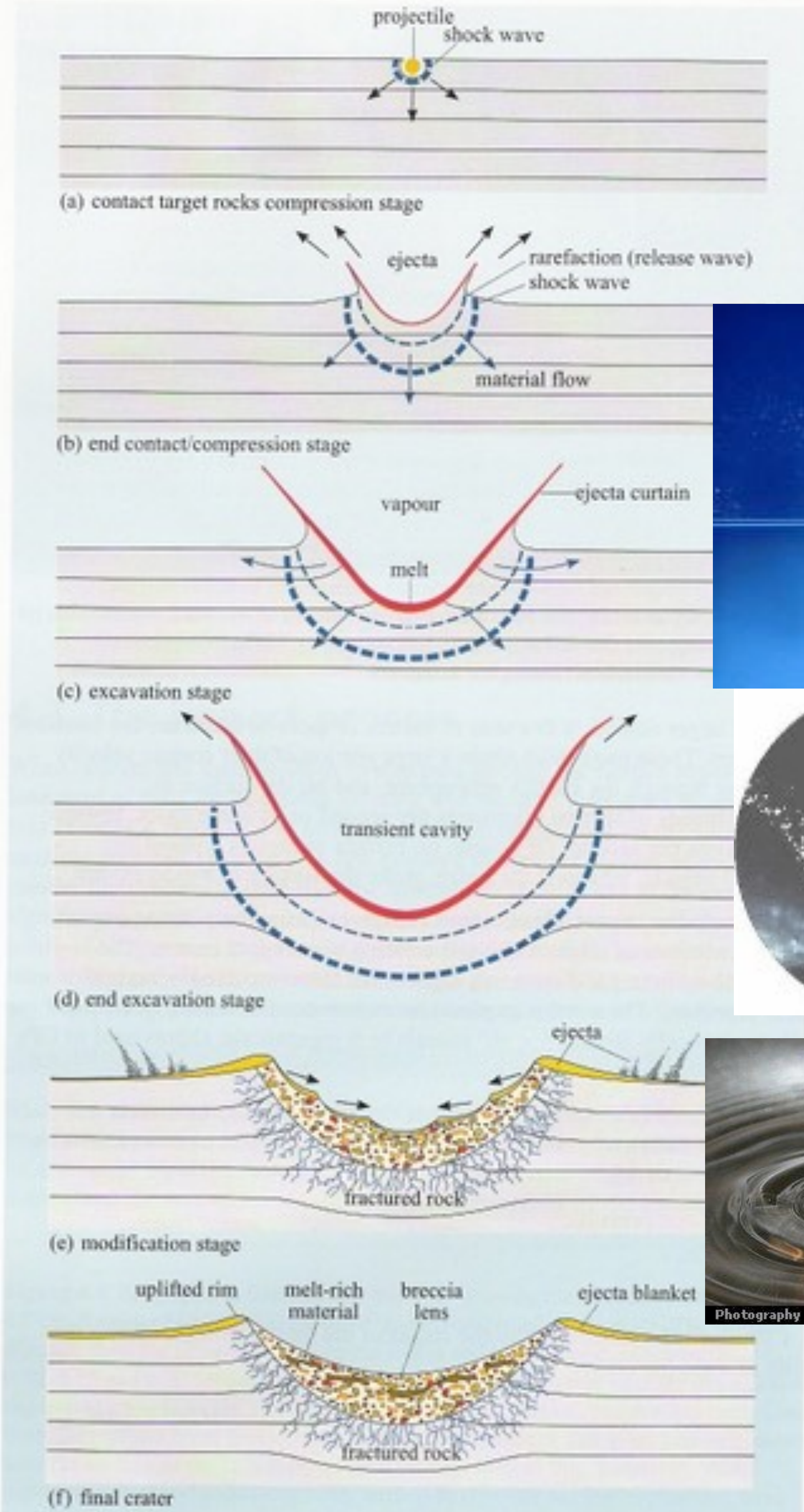
Some Asteroids visited by spacecraft





Comets - icy objects begin to melt in the inner Solar System

The Cratering Process



Three Stages:

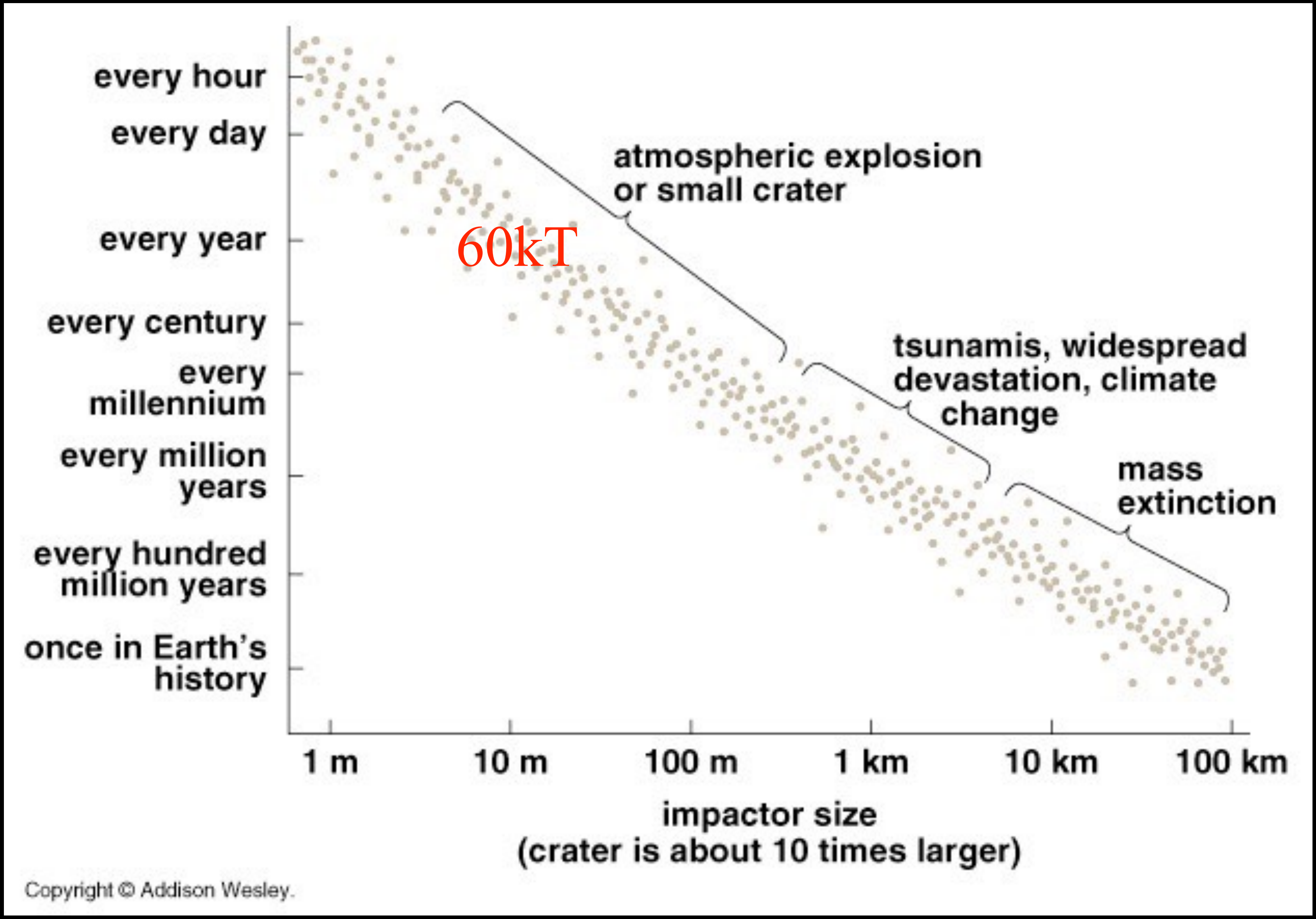
1. Contact & Compression

2. Excavation

3. Modification

NO MIDTERM 1 MATERIAL BEYOND THIS POINT

Impact Frequency



Small impact happen much more often than large ones

Impactor Populations

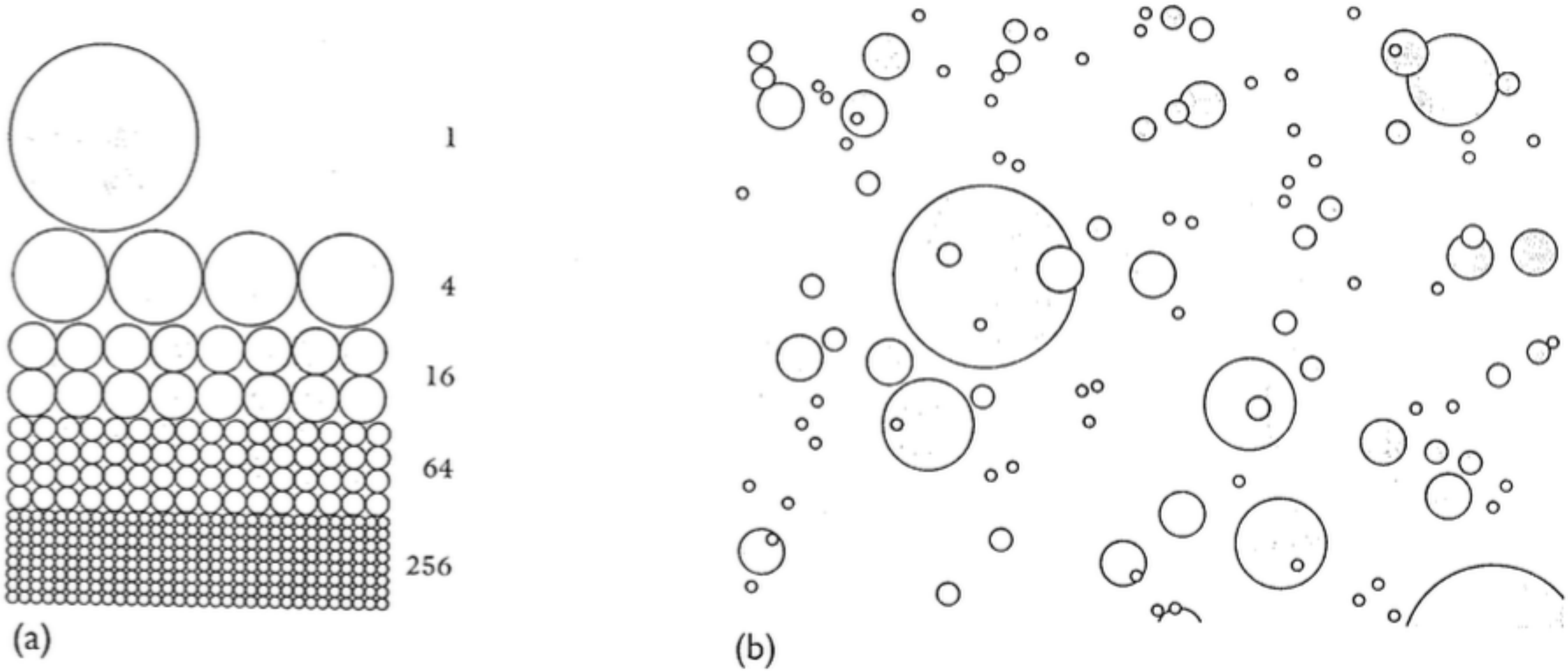


Figure 7.17 **(a)** The relative number of objects that could strike the Moon, according to a law in which the number of objects increases in inverse proportion to the square of the object's radius. **(b)** A random distribution of craters made by the population of objects shown in (a).

Estimate the Power of the Ground to stop a Meteoroid!

How much material must the meteoroid interact with to slow by 50%?

From Physics:
Momentum = (mass) (velocity) is conserved.
So velocity will be halved when mass is doubled.

Now assume that all ground in front of the impactor is plastered onto its surface.

So the impactor will penetrate into the ground by a few diameters. Observed: A few diameters.

Estimate the Power of Air to stop a Meteoroid!

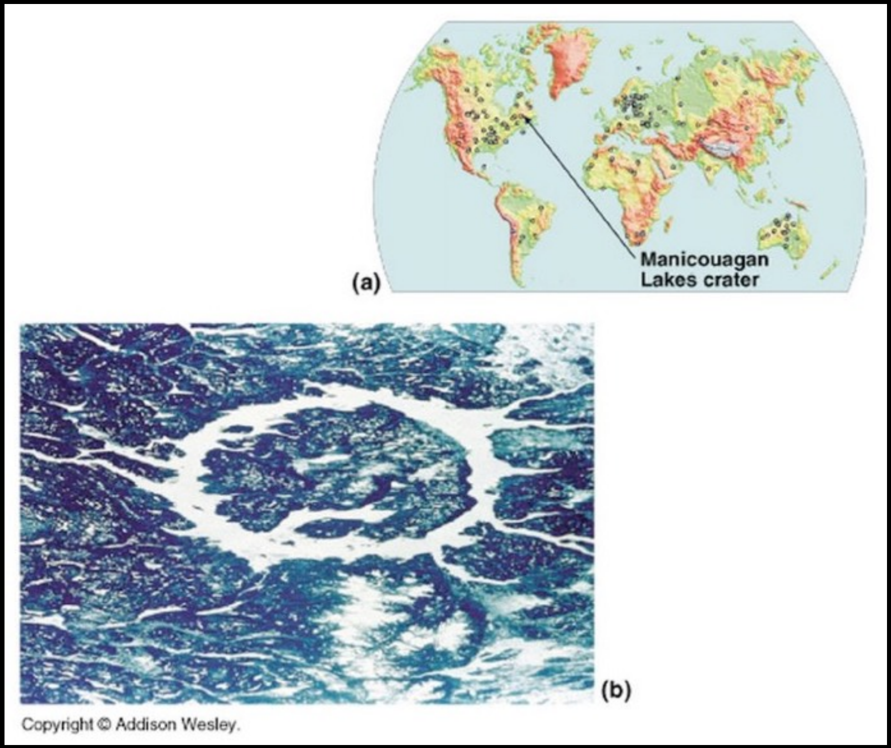
Assume that all air in front of the impactor is plastered onto its surface!

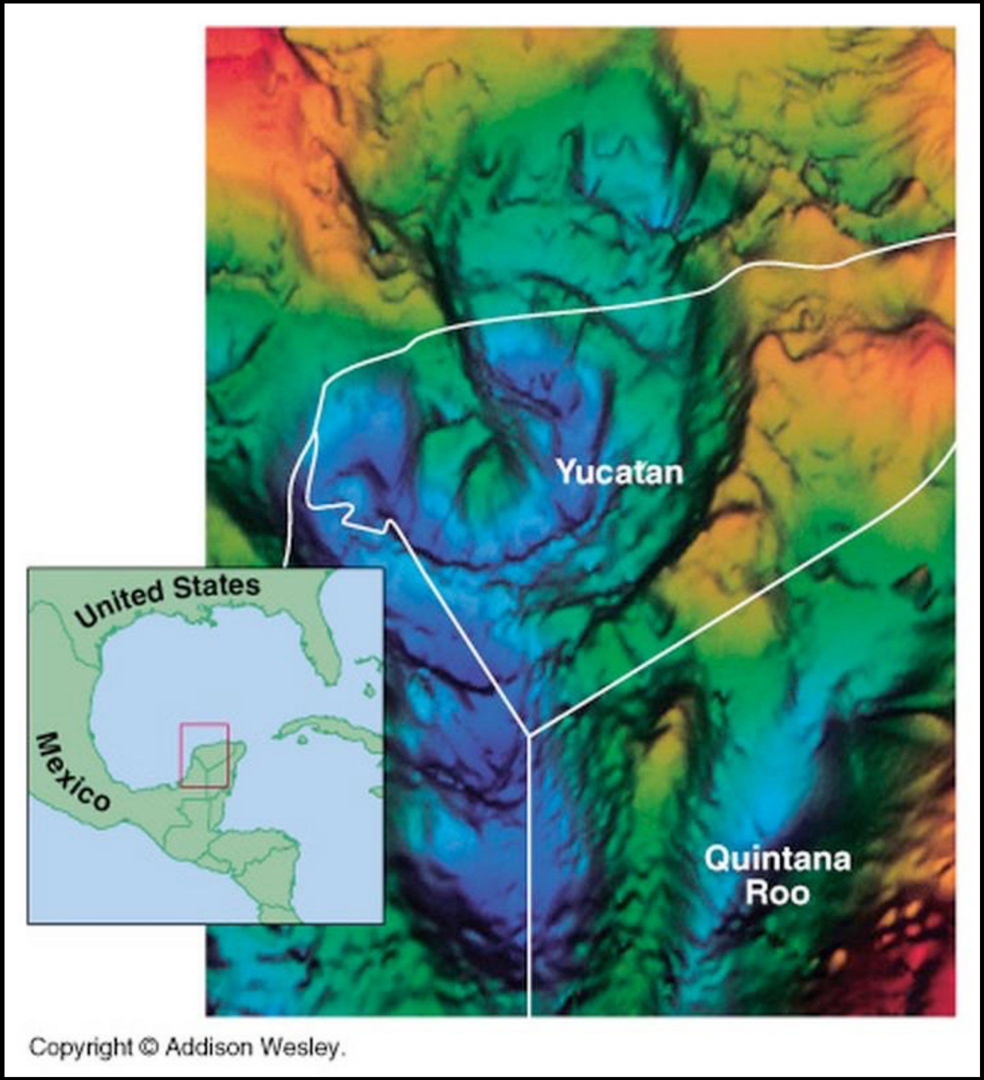
Air is 1/1000 as dense as water and is ~10km thick

So the impactor will penetrate into the atmosphere by a thousand diameters. So 10km/1000 = 10m will make it through the atmosphere.

Observed: Must be ~50-100 m to make it through

Big Impact Craters on Earth





Very Small Craters on Earth

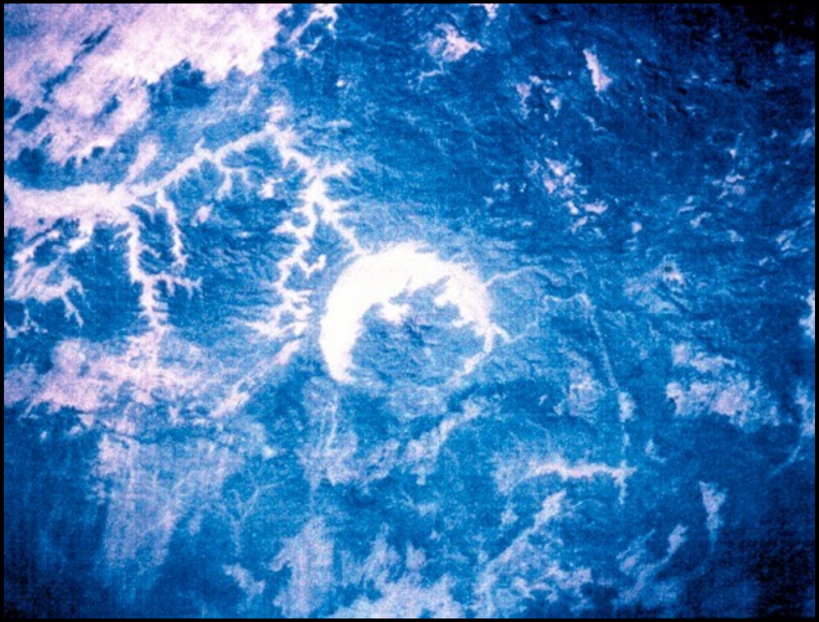
Is your insurance up to date?

At what speed was this impact?

Craters on Earth

Manicouagan, Canada: 100km, 214Myr

Gosses Bluff, Australia: 22km, 142.5Myr

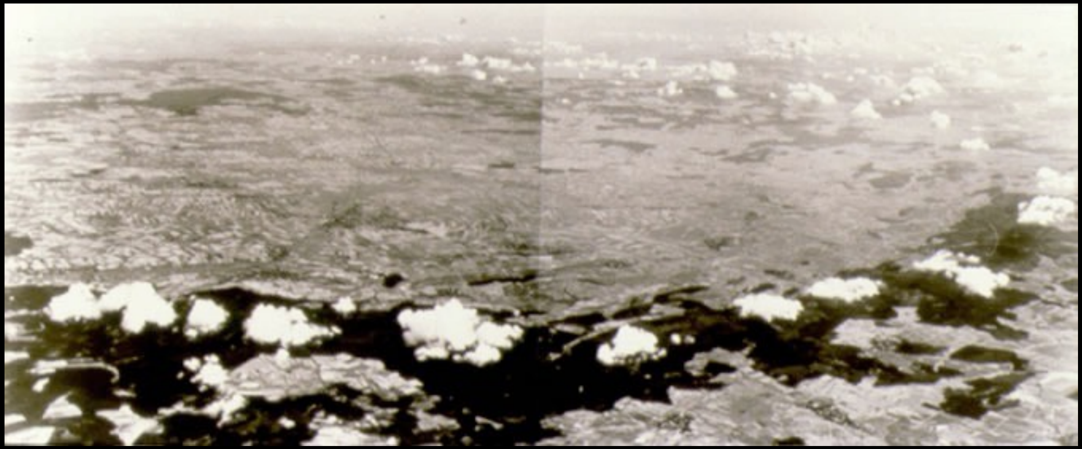


Gwen Fada, Chad: 14km, <350Myr

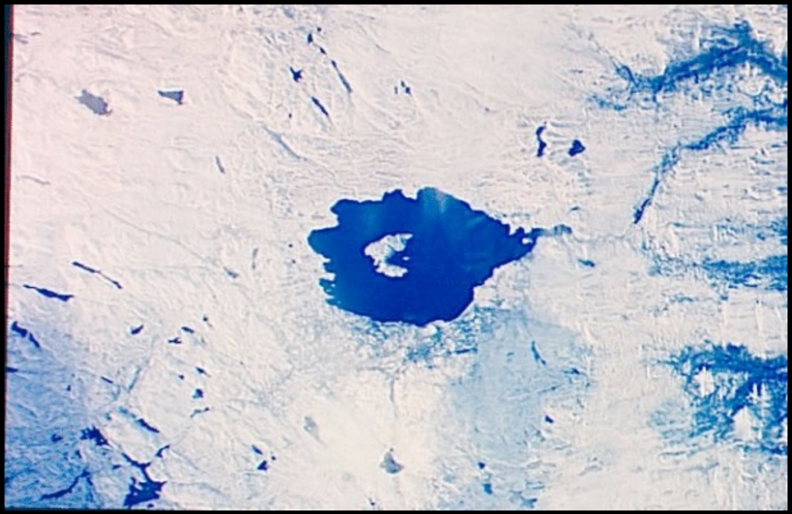
Aorounga, Chad: 10km, <350Myr

Space Shuttle!

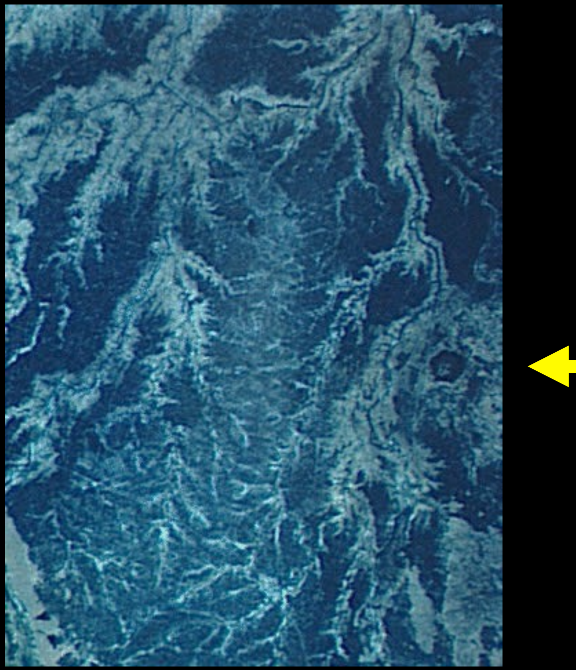
Clearwater Lakes, Canada
26km, 290Myr



Ries, Germany
24km, 15Myr



Mistastin Lake, Canada:
28km, 38Myr



Ramgarh, India: 5.5km, unknown

Deep Bay, Canada
5km, 100 +/- 50 Myr

Ouarkziz, Algeria: 4km, <70Myr

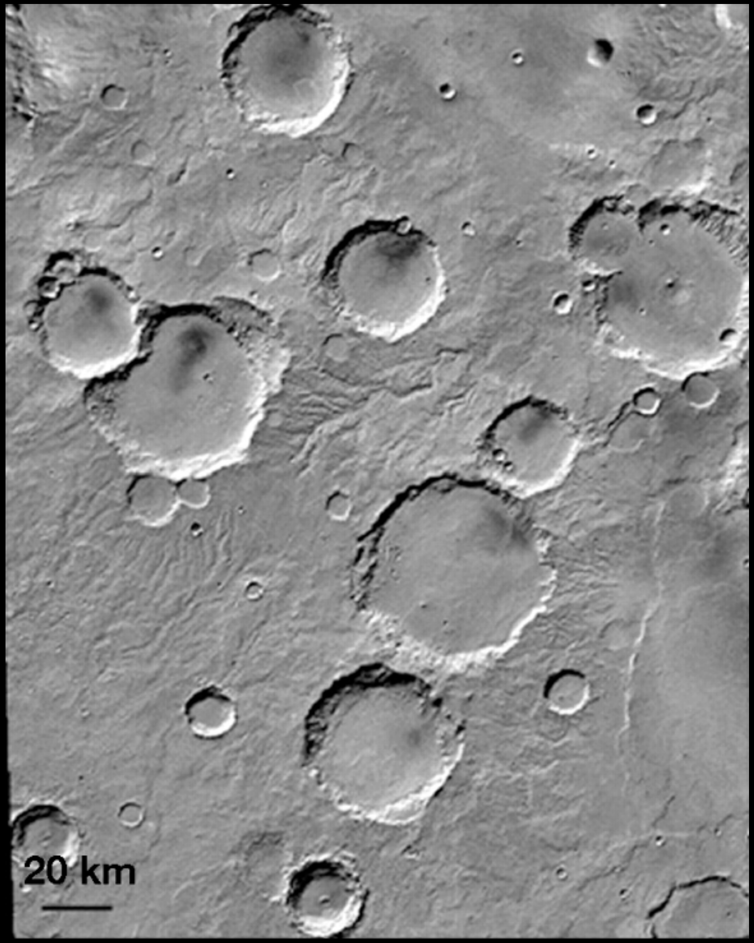
Roter Kamm, Namibia:
2.5km, 3.7Myr

Meteor Crater, Arizona: 1.2km, 49,000 yr

Wolf Creek, Australia: 850m, 0.3Myr

Goat Paddock, Australia: 5km, <55Myr

Craters on Mars

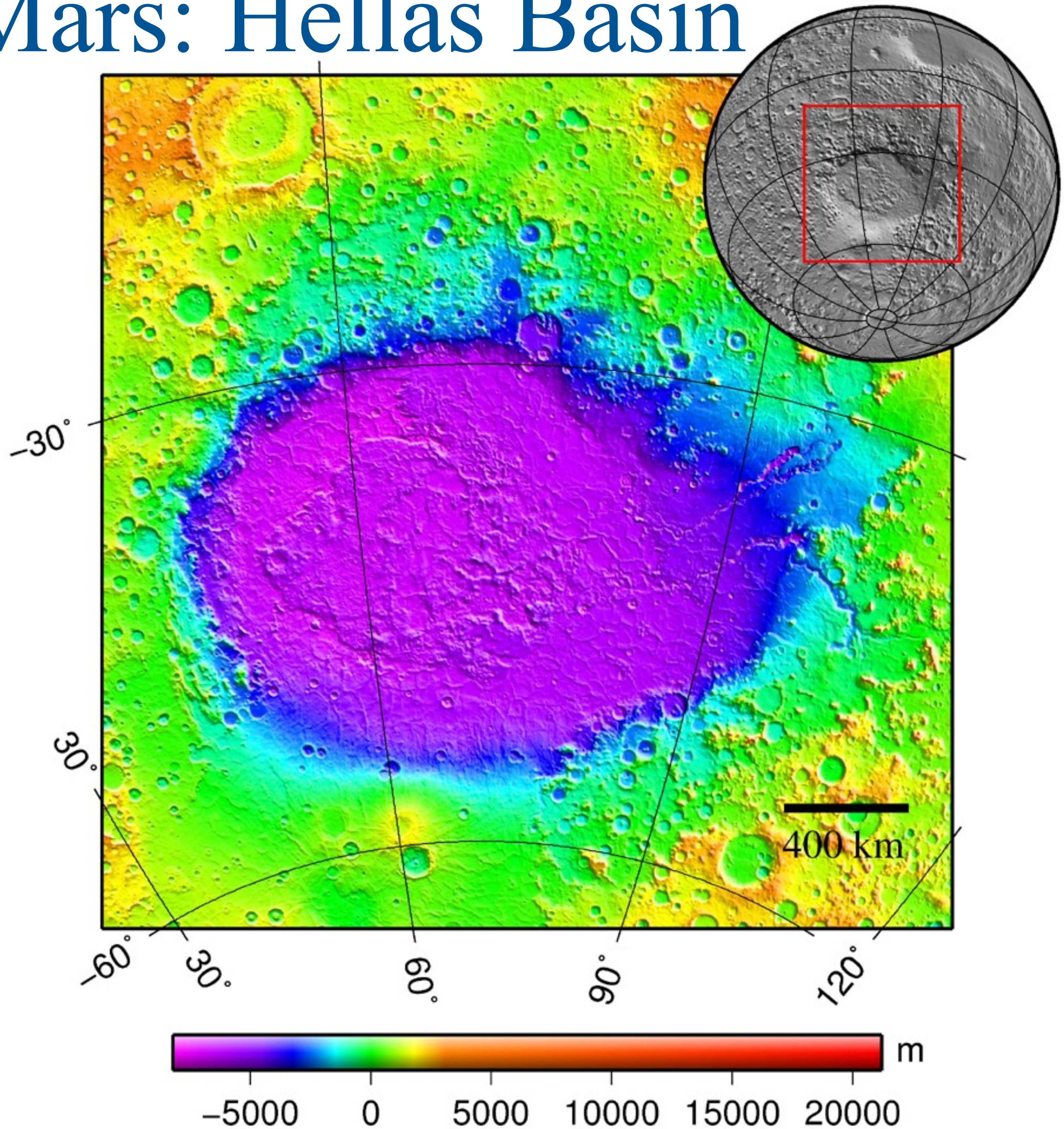


Viking Image, Mars
southern hemisphere

Victoria Crater, Mars: 750m

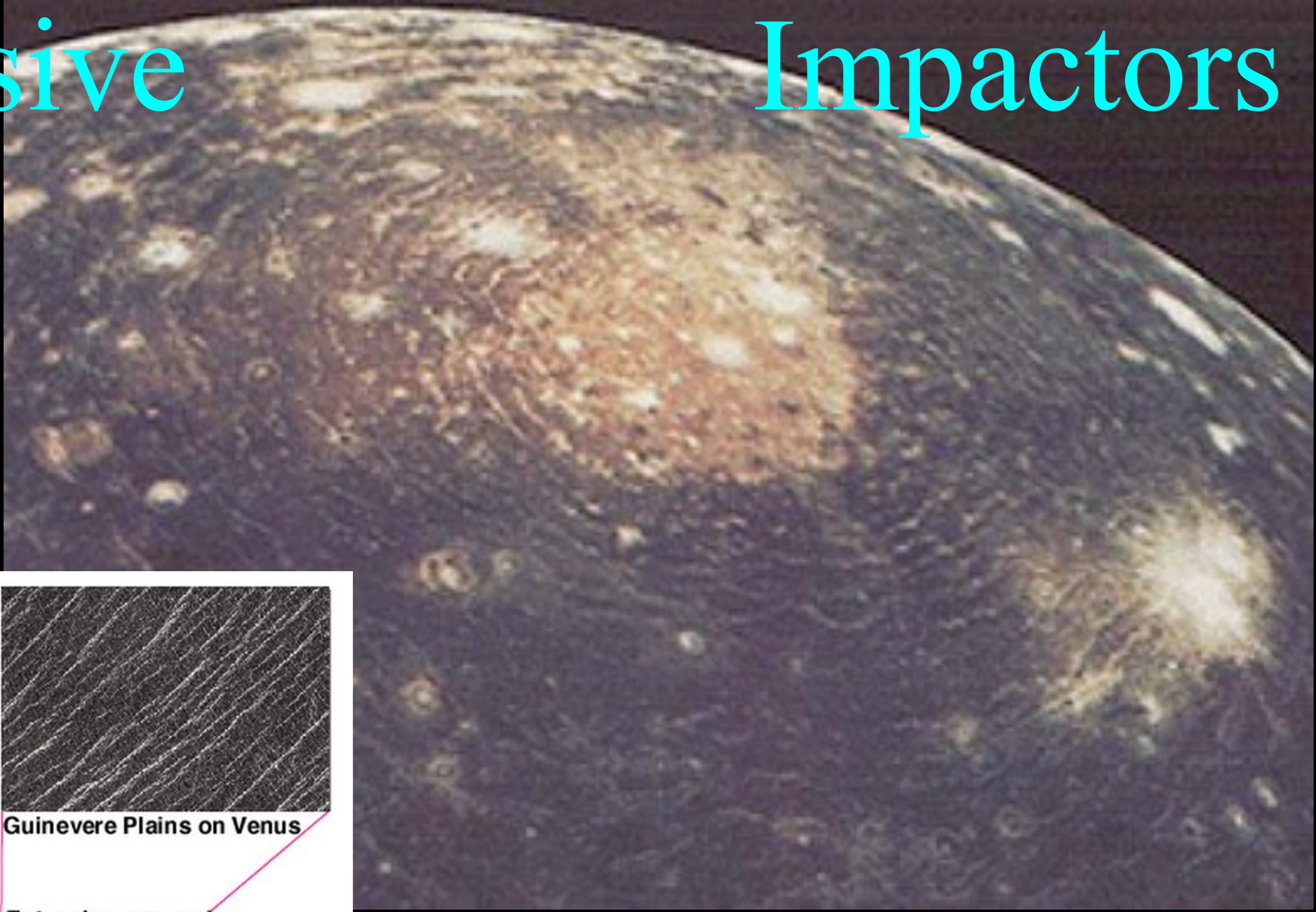
Mars, multiple strikes: 78km x 25km

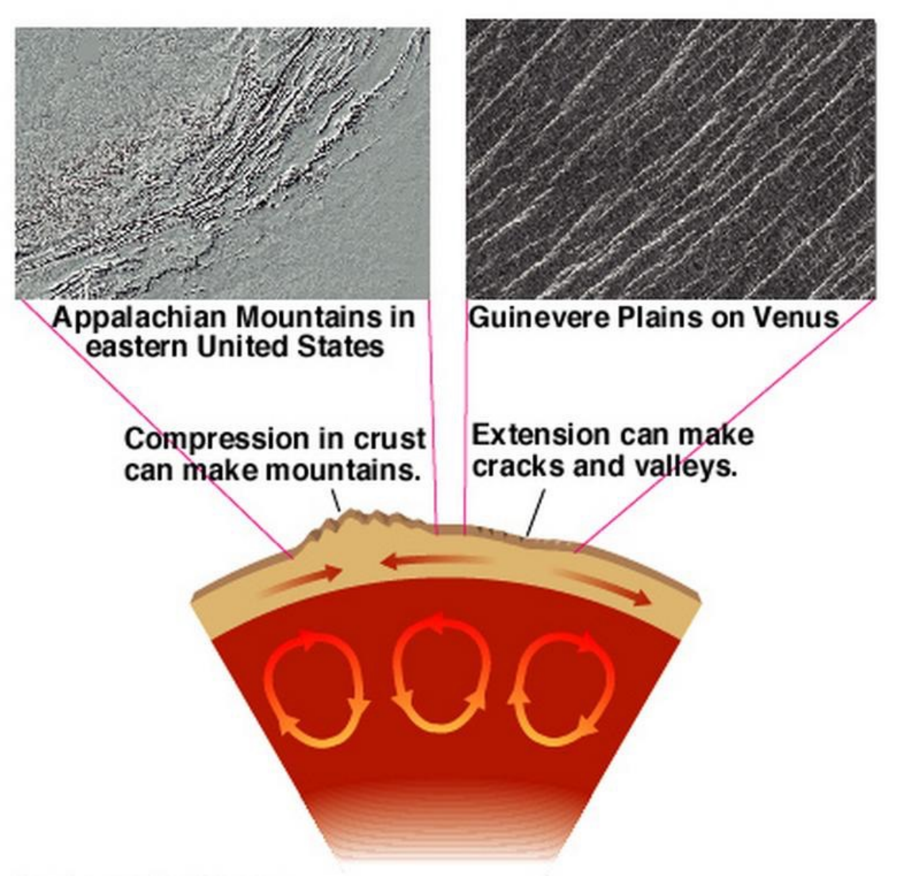
Mars: Hellas Basin



Massive Impactors

Ganymede





Circular features in huge multi-ringed basins are caused by an impactor that penetrates the lithosphere and sets up currents in the mantle.

Last Slide