Astronomy 101
The Solar System
Tuesday, Thursday
2:30-3:45 pm
Hasbrouck 20

Tom Burbine
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Course

- **Course Website:**
  - http://blogs.umass.edu/astron101-tburbine/
- **Textbook:**
  - **Pathways to Astronomy (2nd Edition)** by Stephen Schneider and Thomas Arny.
  - **You also will need a calculator.**

Office Hours

- Mine
- Tuesday, Thursday - 1:15-2:15pm
- Lederle Graduate Research Tower C 632

- Neil
- Tuesday, Thursday - 11 am-noon
- Lederle Graduate Research Tower B 619-O

Homework

- We will use Spark
- https://spark.oit.umass.edu/webct/logonDisplay.dowebct
- Homework will be due approximately twice a week

Astronomy Information

- Astronomy Help Desk
- Mon-Thurs 7-9pm
- Hasbrouck 205

- The Observatory should be open on clear Thursdays
- Students should check the observatory website at: http://www.astro.umass.edu/~orchardhill for updated information
- There's a map to the observatory on the website.

Final

- Monday - 12/14
- 4:00 pm
- Hasbrouck 20

HW #11

- Due today

HW #12 and #13

- Due Thursday

If you come to class

- For people who took the both exams:
  - People who came to class last Thursday
  - Average for both exams was 82.5 (~B)

  - People who didn't come to class last Thursday
  - Average for both exams was 79 (~C+)

Kepler Mission

- NASA has just announced that the orbital Earth-like exoplanet hunter will not be able to detect a world like our own until *2011 at the earliest*.
- Amplifiers in the space telescope's electronics that are used to boost the signal from the CCDs are noisy
- Too noisy now to detect the small dip in brightness of a planet passing in front of a star

Magnetic Field

- Definition:
  - a physical field that arises from an electric charge in motion, producing a force on a moving electric charge

Rocks on the Surface

- If you can see rocks on the surface that comes from the interior, you can study them

- Rocks can deform and flow
- Easier for rock to deform and flow when it is warmer

Lithosphere

- Lithosphere is a planet's outer layer of cool and relatively rigid rock
- Asthenosphere is the region in the upper mantle characterized by low-density, semi-plastic (or partially molten) rock material chemically similar to the overlying lithosphere

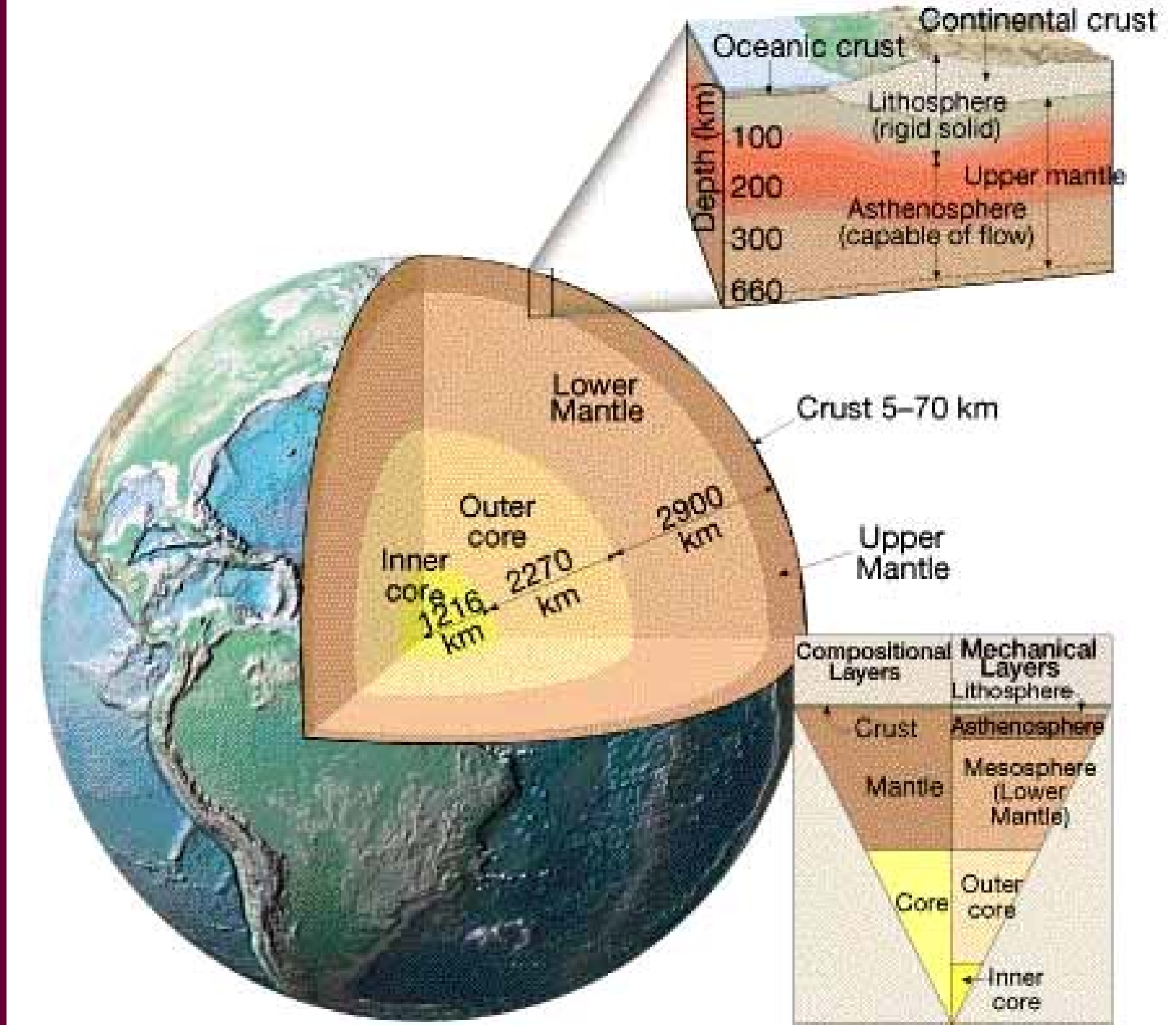
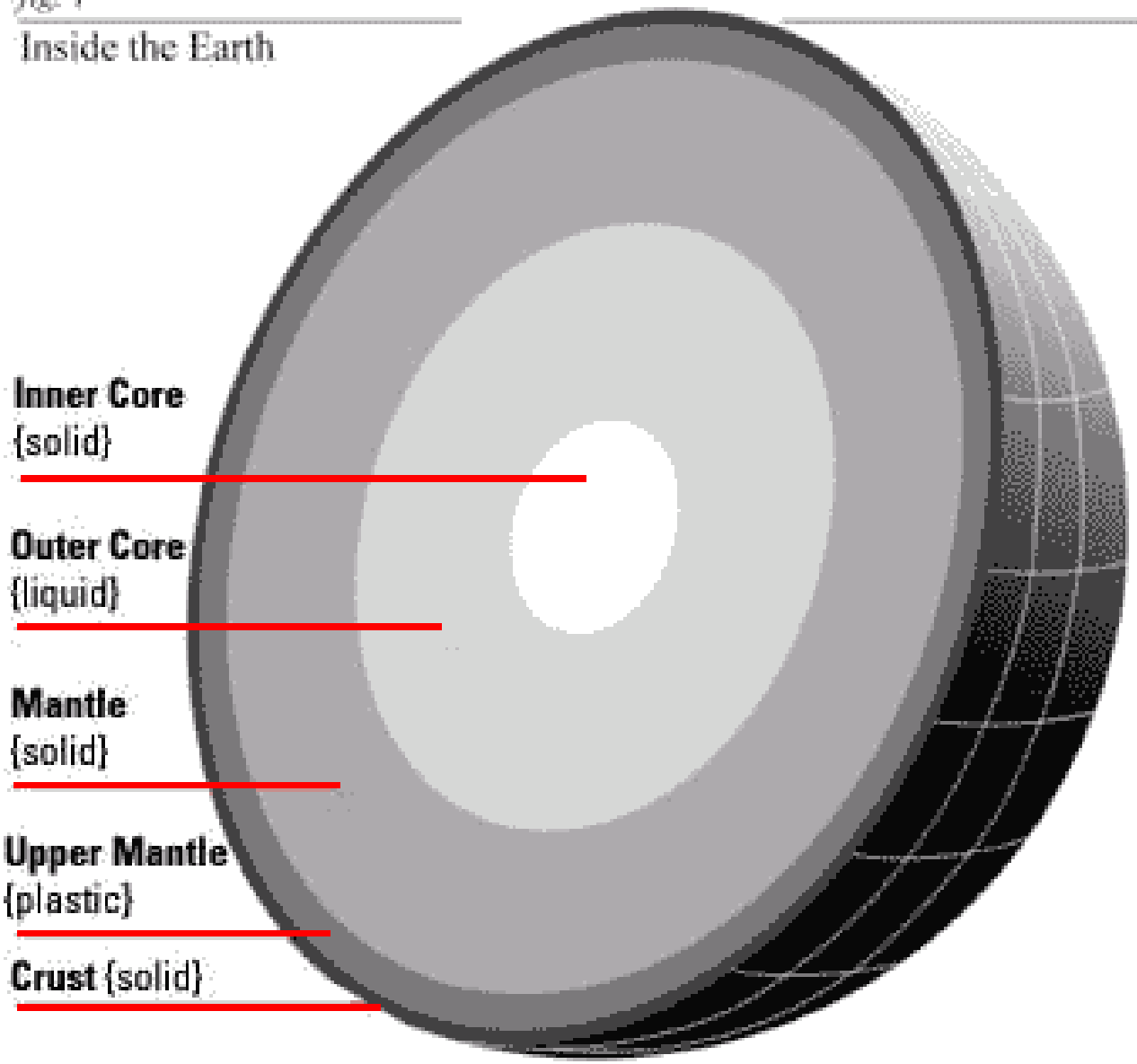
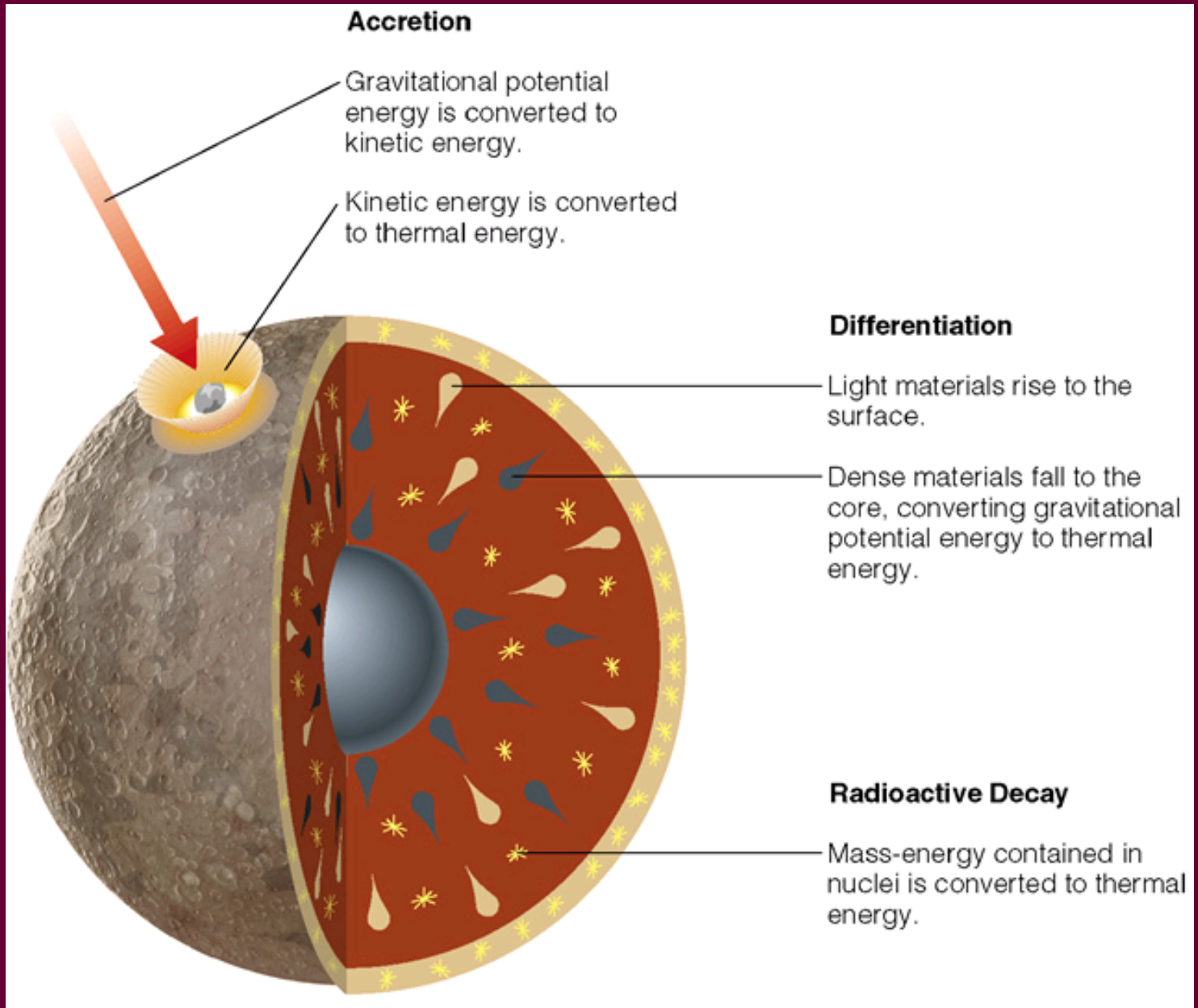

Continental crust
Oceanic crust
Depth (km)
100
200
300
660
Lithosphere
(rigid solid)
Upper mantle
Asthenosphere
(capable of flow)
Lower
Mantle
Crust 5–70 km
Outer
core
Inner
core
1216
km
2270
km
2900
km
Upper
Mantle
Compositional
Layers
Mechanical
Layers
Lithosphere
Crust
Asthenosphere
Mantle
Mesosphere
(Lower
Mantle)
Core
Outer
core
Inner
core

fig. 1

Inside the Earth



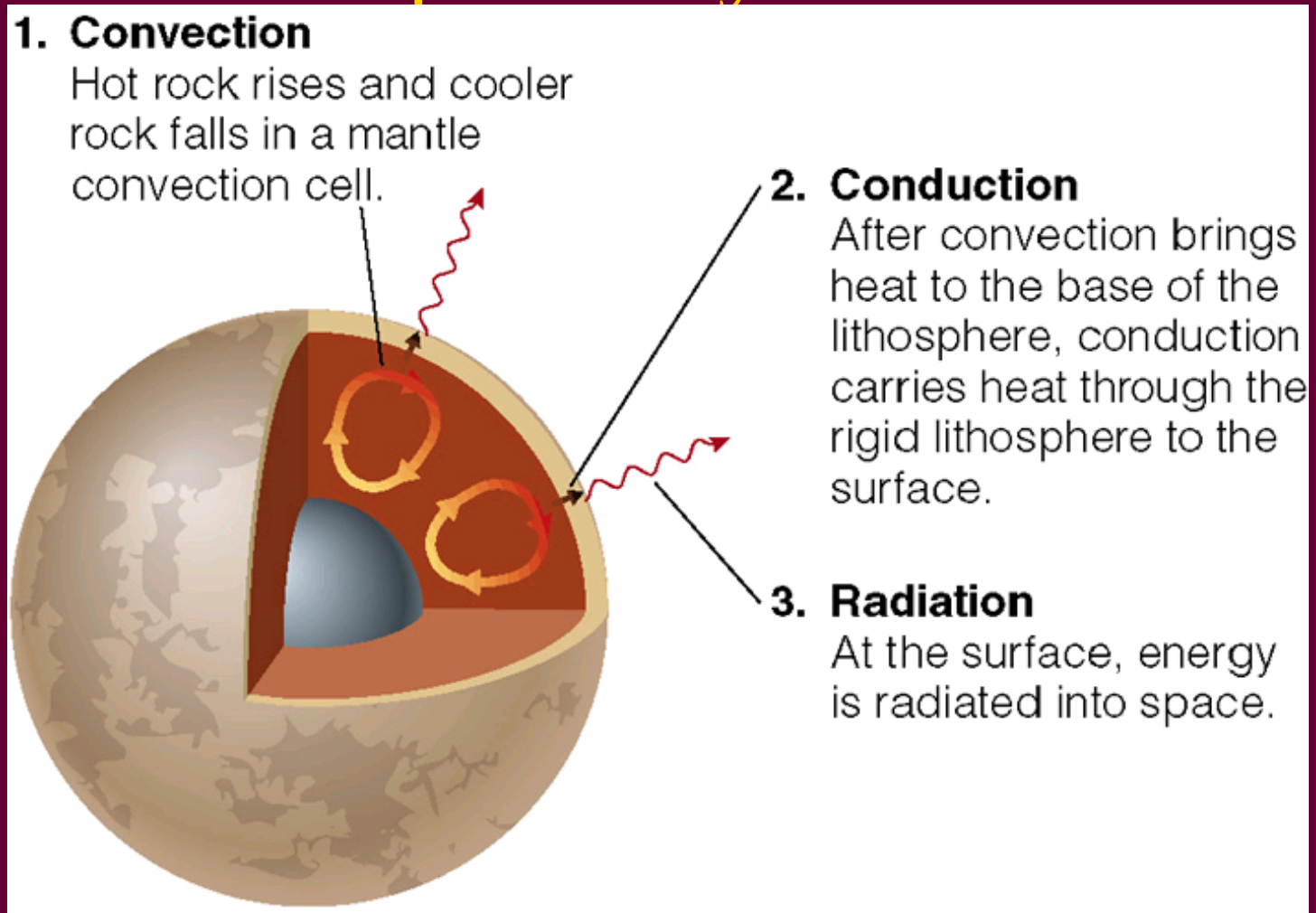
Heating of Planet

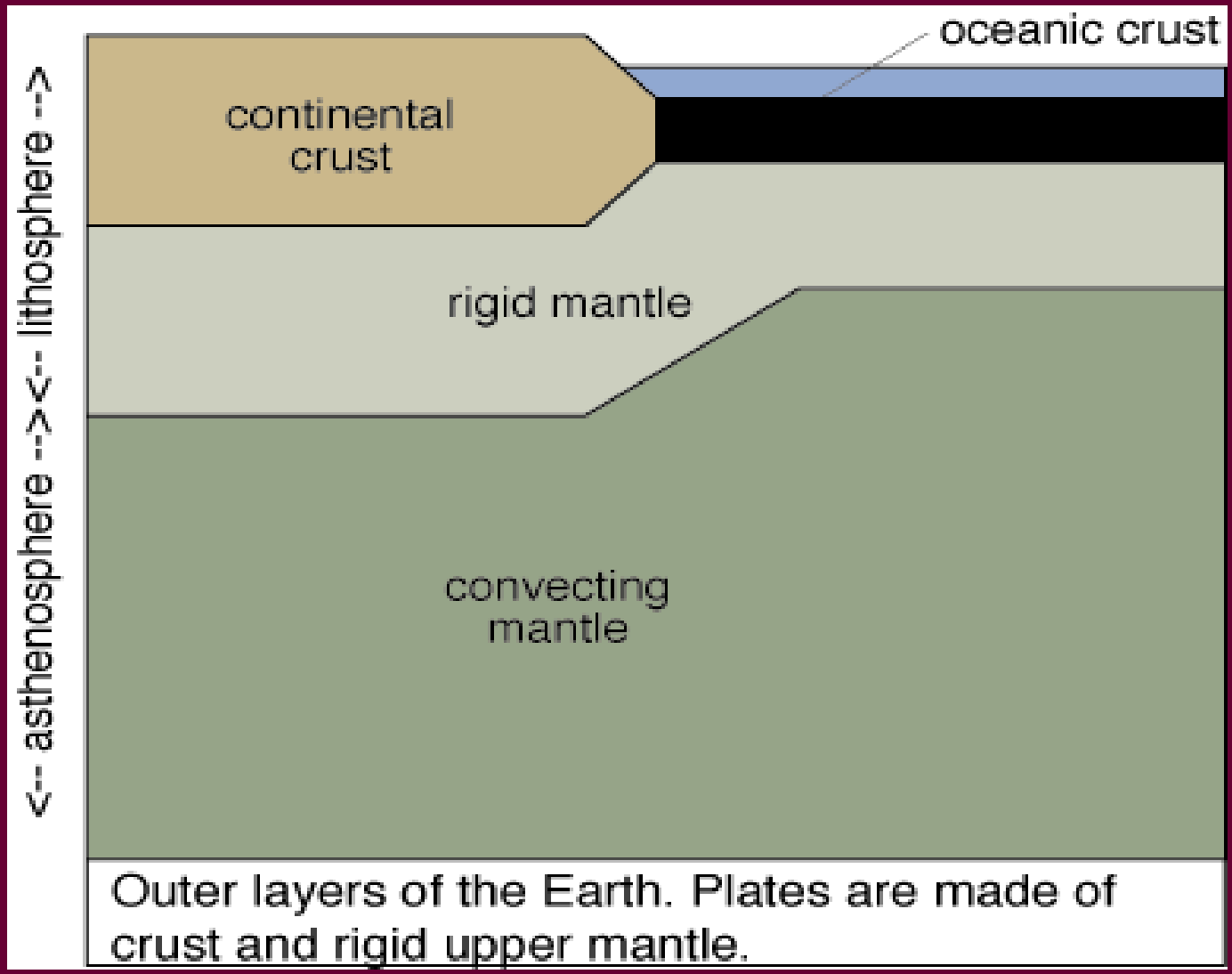


How does the planetary interior cool off?

- Heat is transported outward

How does the planetary interior cool off?





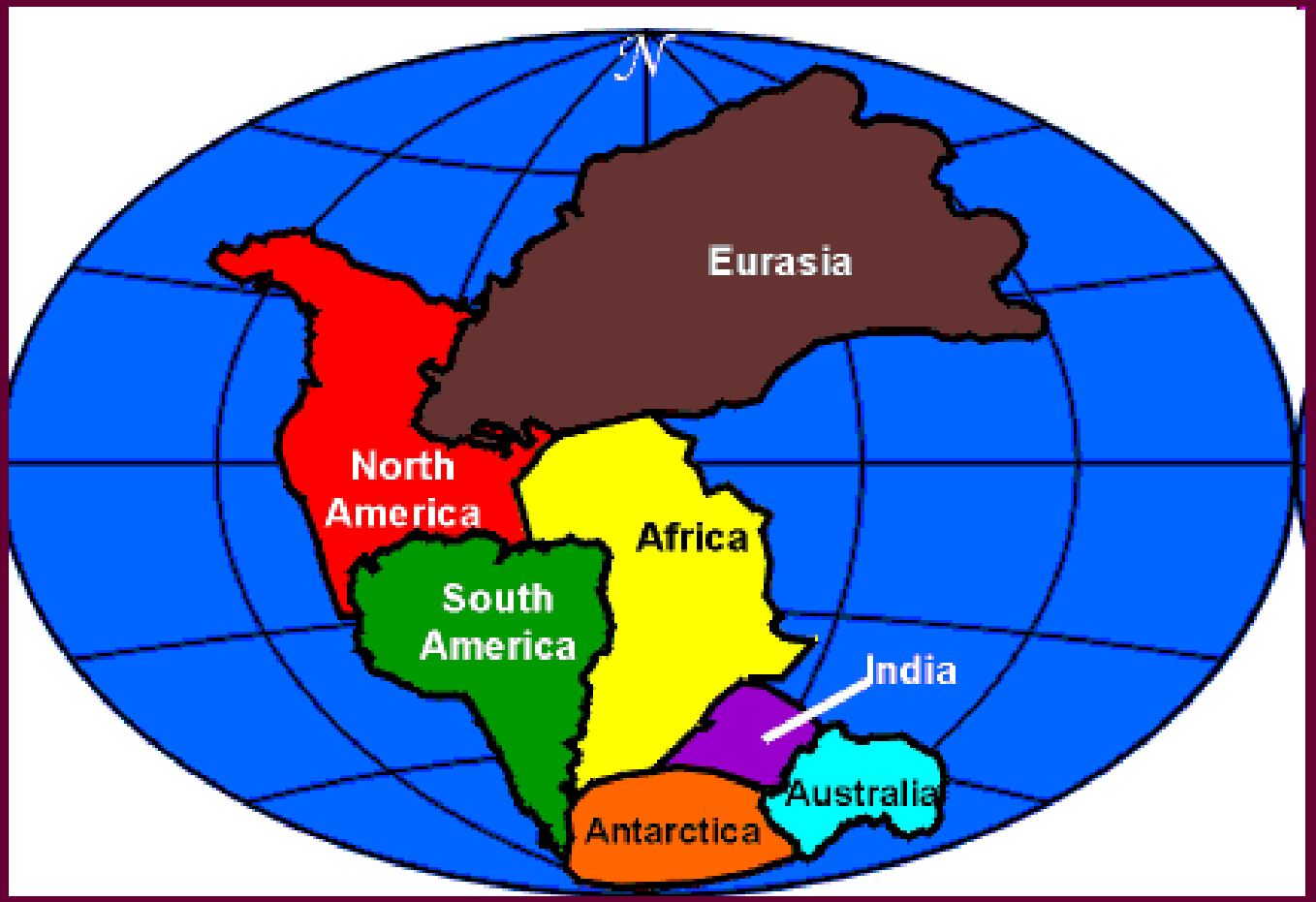
Outer layers of the Earth. Plates are made of crust and rigid upper mantle.

Plate Tectonics

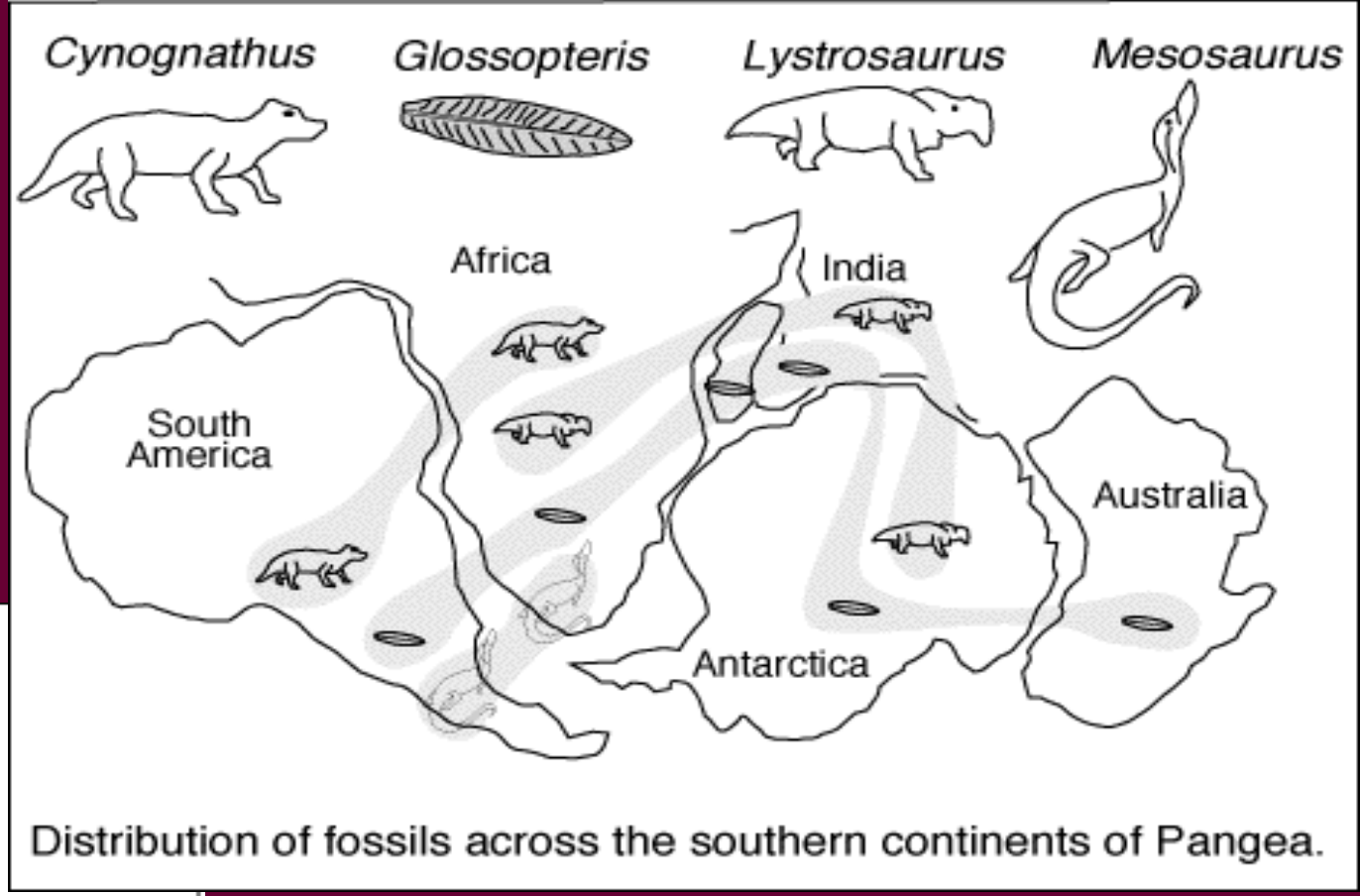
- Plate tectonics describes the large scale motions of Earth's lithosphere.
- Venus – does not appear to have plate tectonics
- Mars – maybe
- Satellites of Jupiter – maybe
- Titan (Satellite of Saturn) - maybe

Pangea

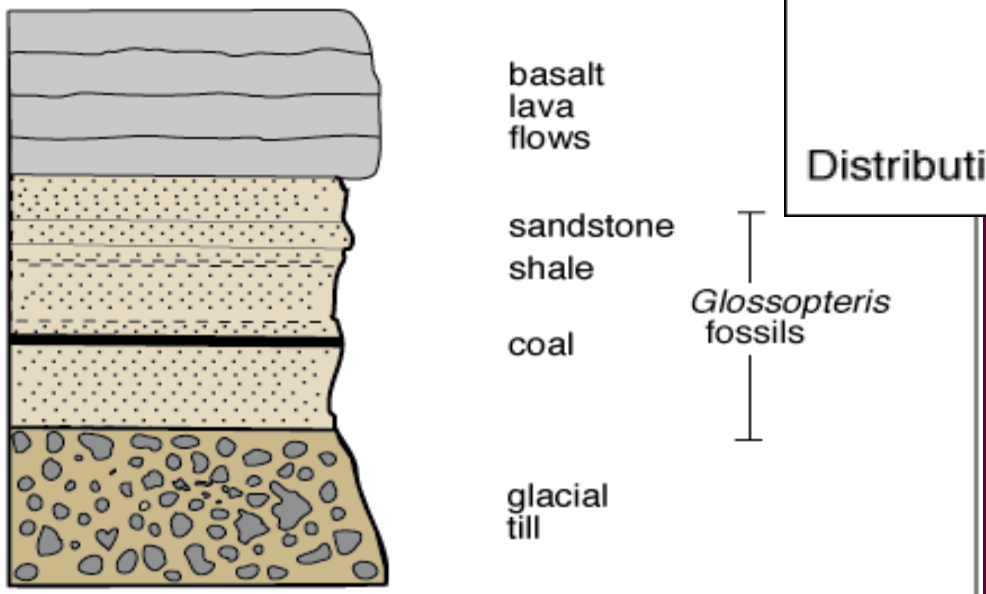
- Pangea - One large supercontinent
- http://upload.wikimedia.org/wikipedia/commons/8/8e/Pangea_animation_03.gif



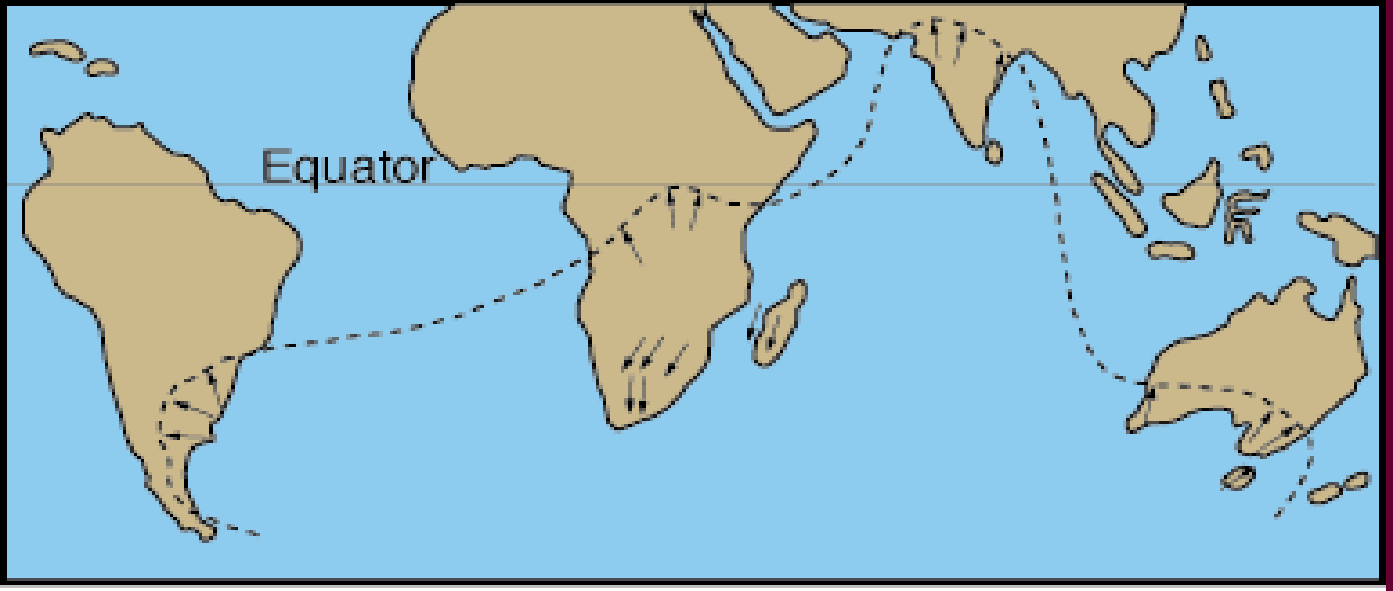
http://geology.csupomona.edu/drjessey/class/Gsc101/pangea.gif



Distribution of fossils across the southern continents of Pangea.

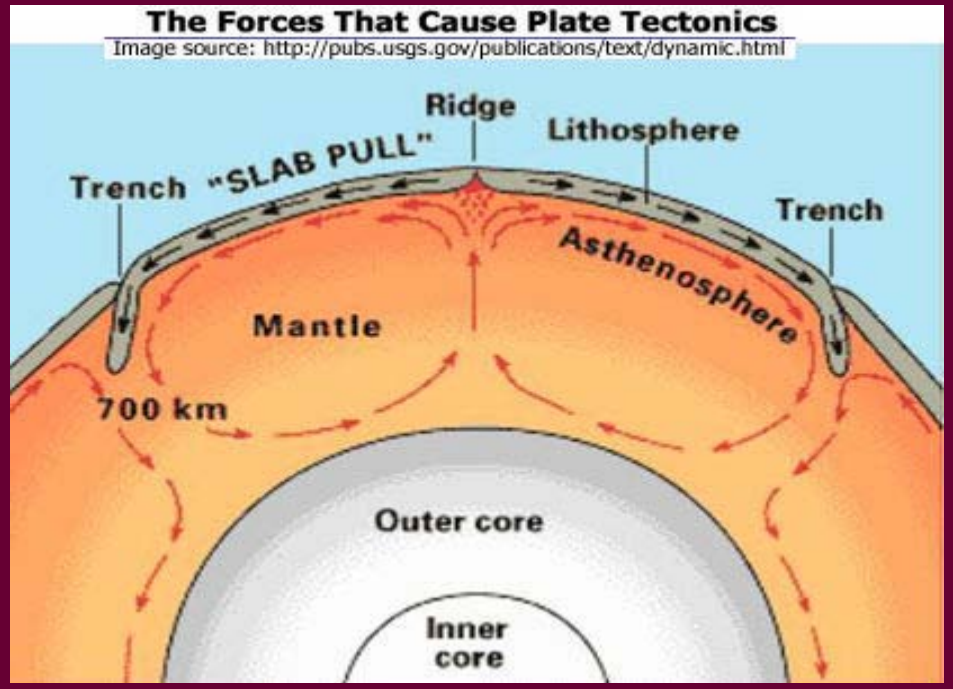


Similar layers of rock were formed in Antarctica, Australia, South America, Africa, and India before Pangea broke apart. Glossopteris fossils were found in the rocks on each continent.



Grooves carved by glaciers (shown by arrows) provided evidence for continental drift. This diagram assumes the continents were in their present-day locations.

The distribution of glacial features can be best explained if the continents were part of Pangaea



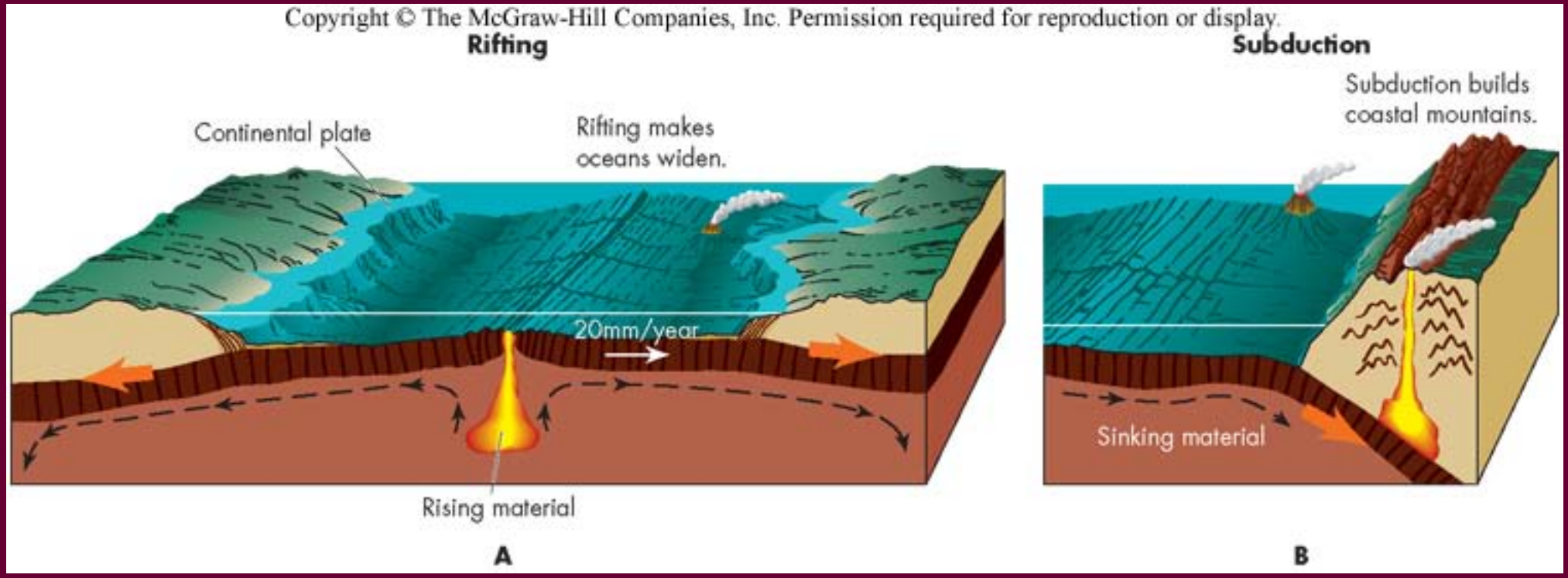
Principles of Plate Tectonics

1. The surface of the Earth is composed of lithospheric plates that are in constant motion.

2. The plates move in response to plastic flow in the athenosphere.

3. Motion in the asthenosphere is caused by convection driven by the Earth's internal heat.

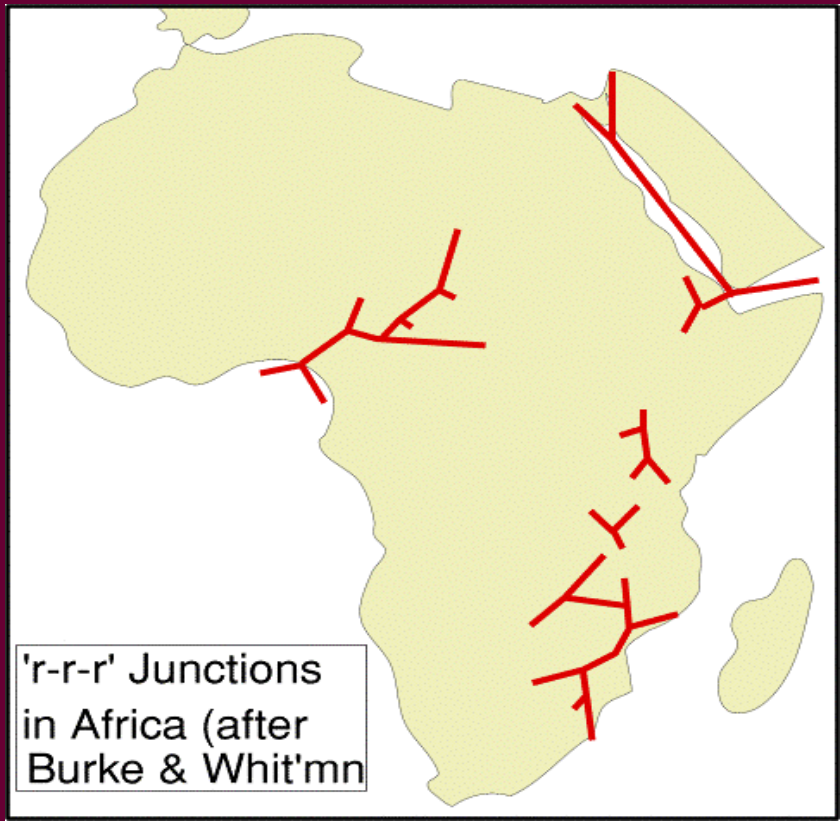
4. The internal heat comes from radioactive decay and the latent heat from the Earth's formation.



Three Types of Plate Tectonic Boundaries

- Divergent – plates move apart, space is filled with molten magma
- Convergent – plates collide
- Transform – plates slide horizontally past each other

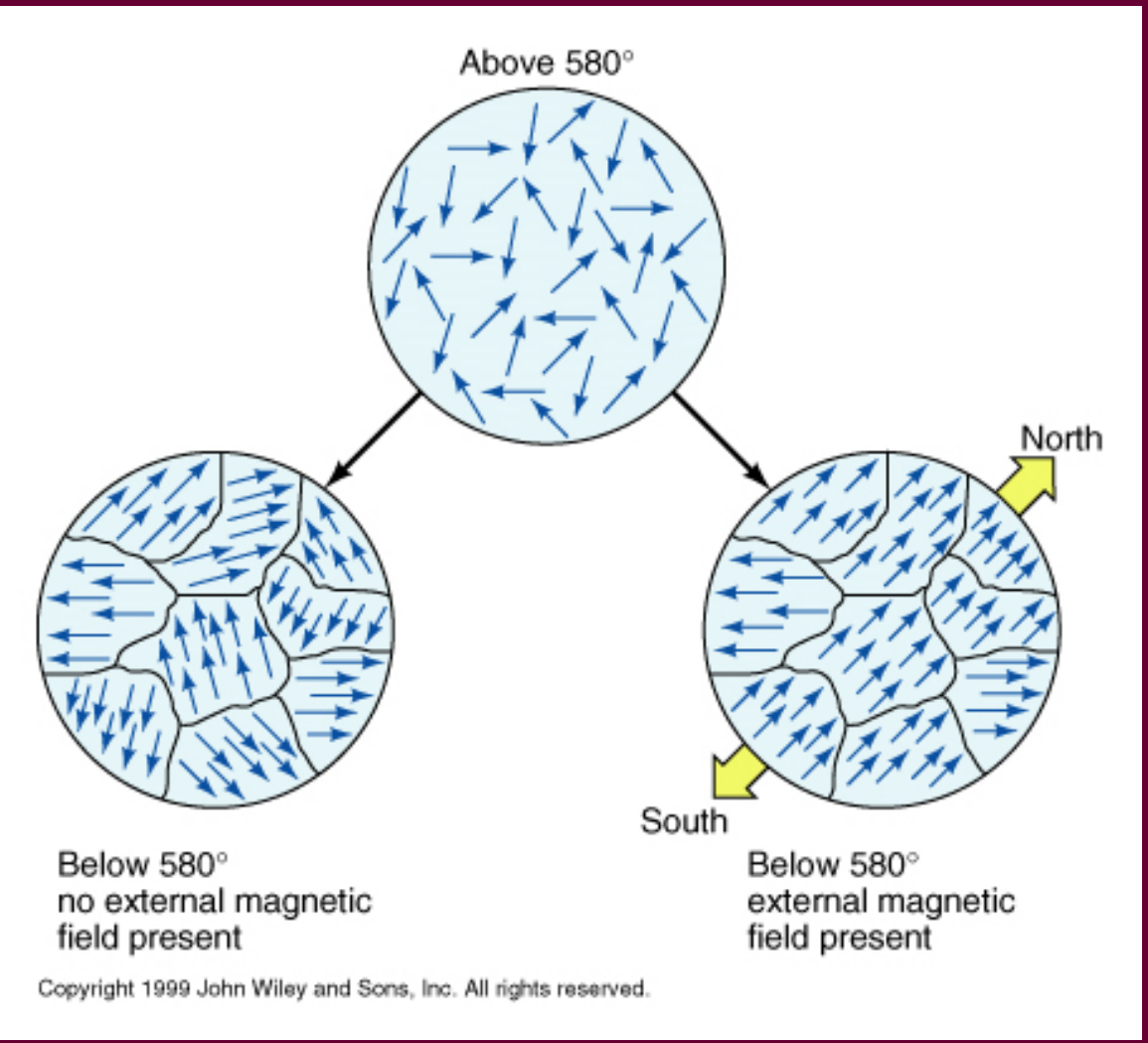
Divergent plate boundary



New rift opening up in Africa

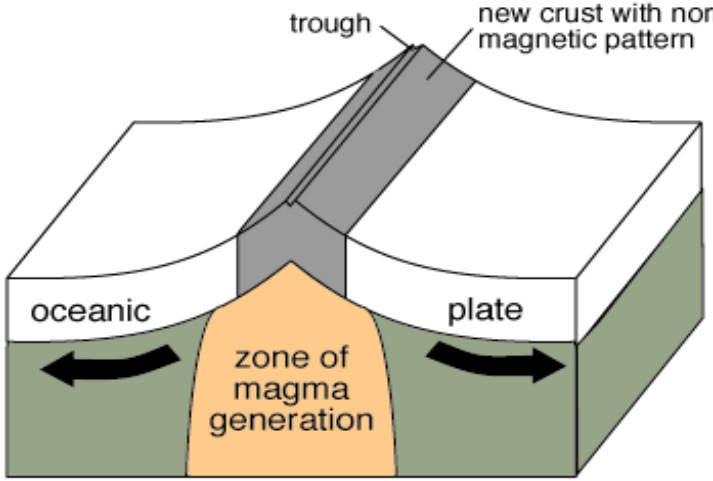
- http://www.treehugger.com/files/2009/11/rift-ethiopian-desert-confirmed-beginning-new-sea.php

When lava cools

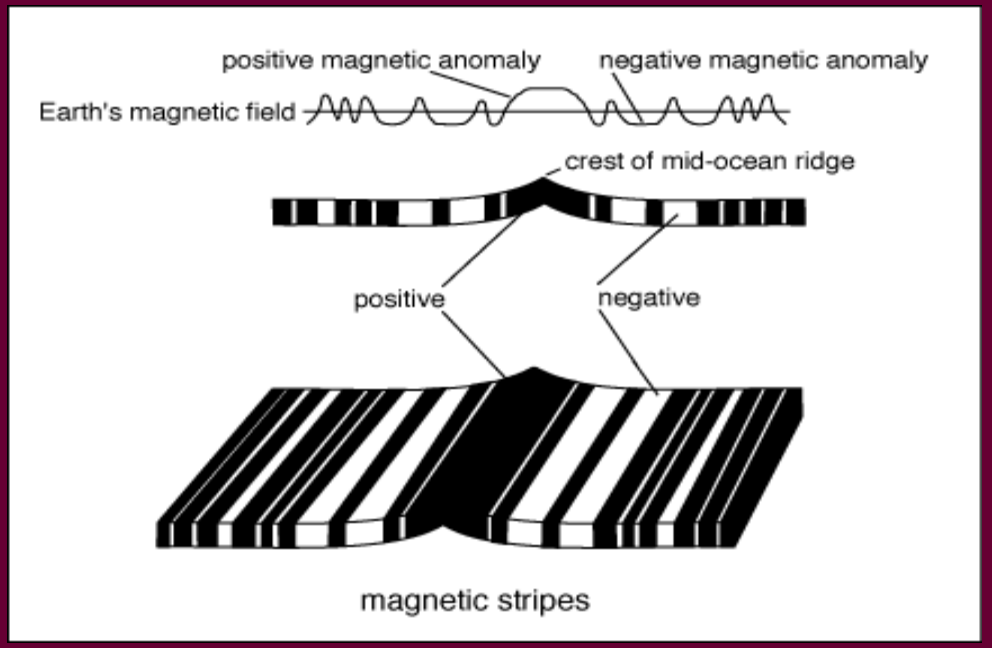


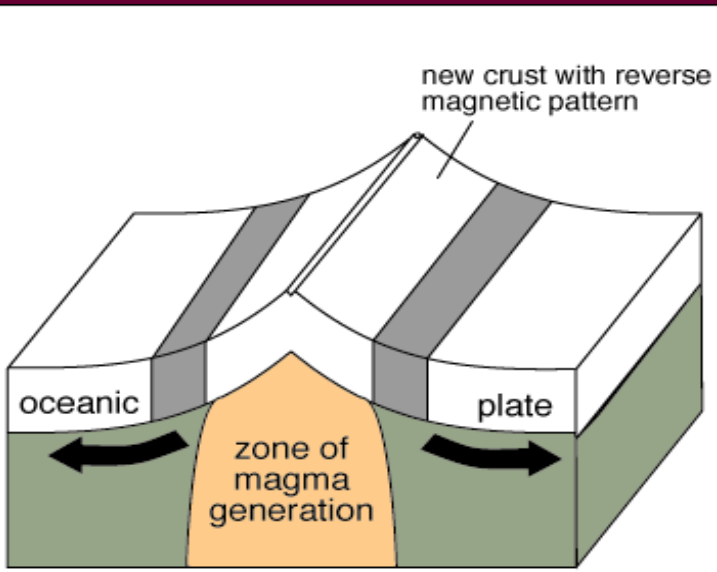
- Lava is a mixture of melted minerals (some are magnetic).
- While lava is liquid, the minerals will tend to line up with a magnetic orientation pointing at the North Pole.
- When the lava solidifies, the magnetic orientation is frozen into the rock- essentially; it will have a “north end” and a “south end.”

http://www.mrsciguy.com/sciimages/polarity.jpg

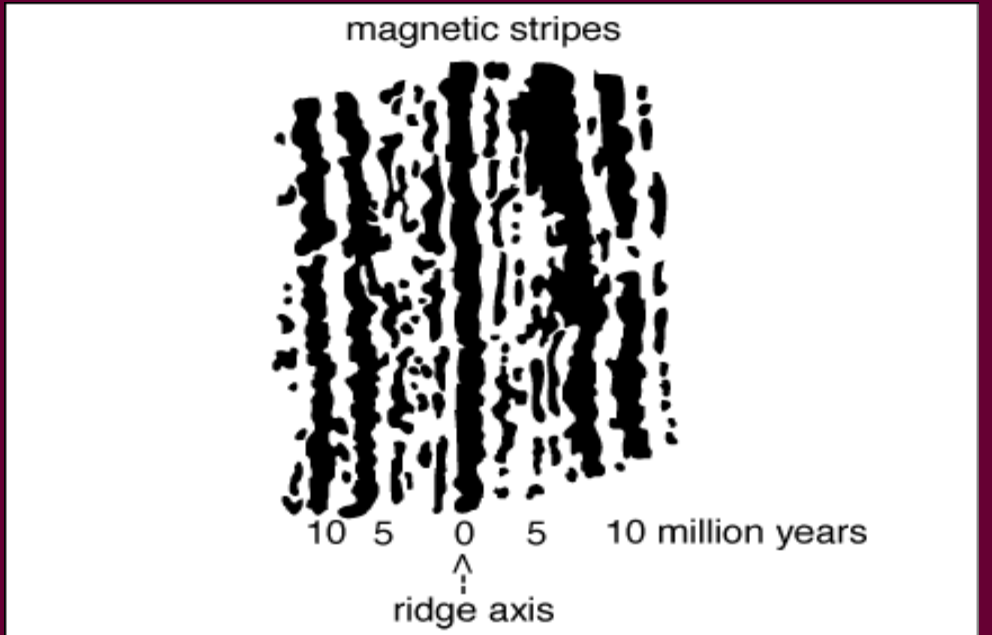


As magma solidifies along the edge of the oceanic plate it preserves a magnetic record of the Earth's magnetic field at that time. In this case, the north magnetic pole is in the northern hemisphere.



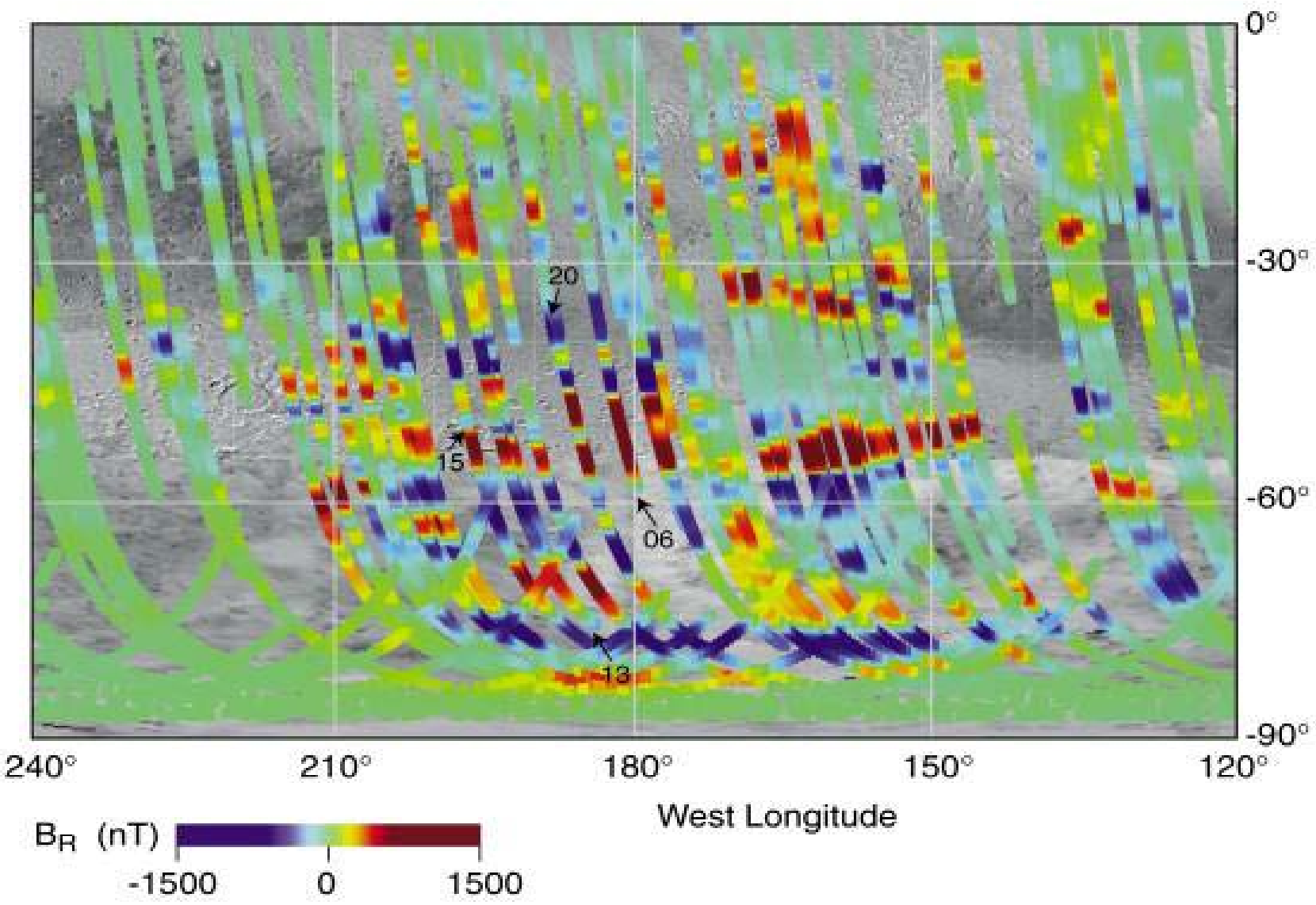


If the magnetic pole is in the southern hemisphere, the rocks record a reverse magnetic pattern.

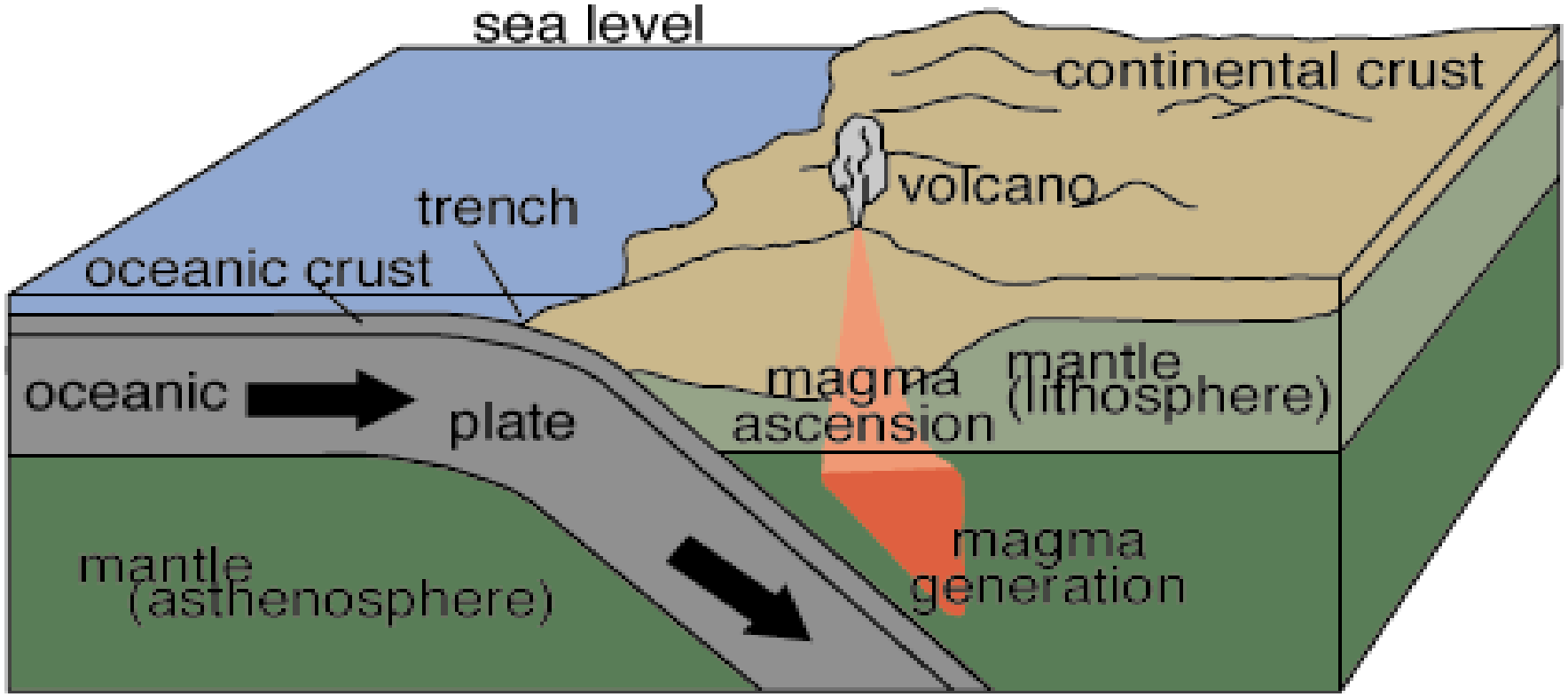


Pattern created by magnetic stripes along the Mid-Atlantic Ridge south of Iceland.

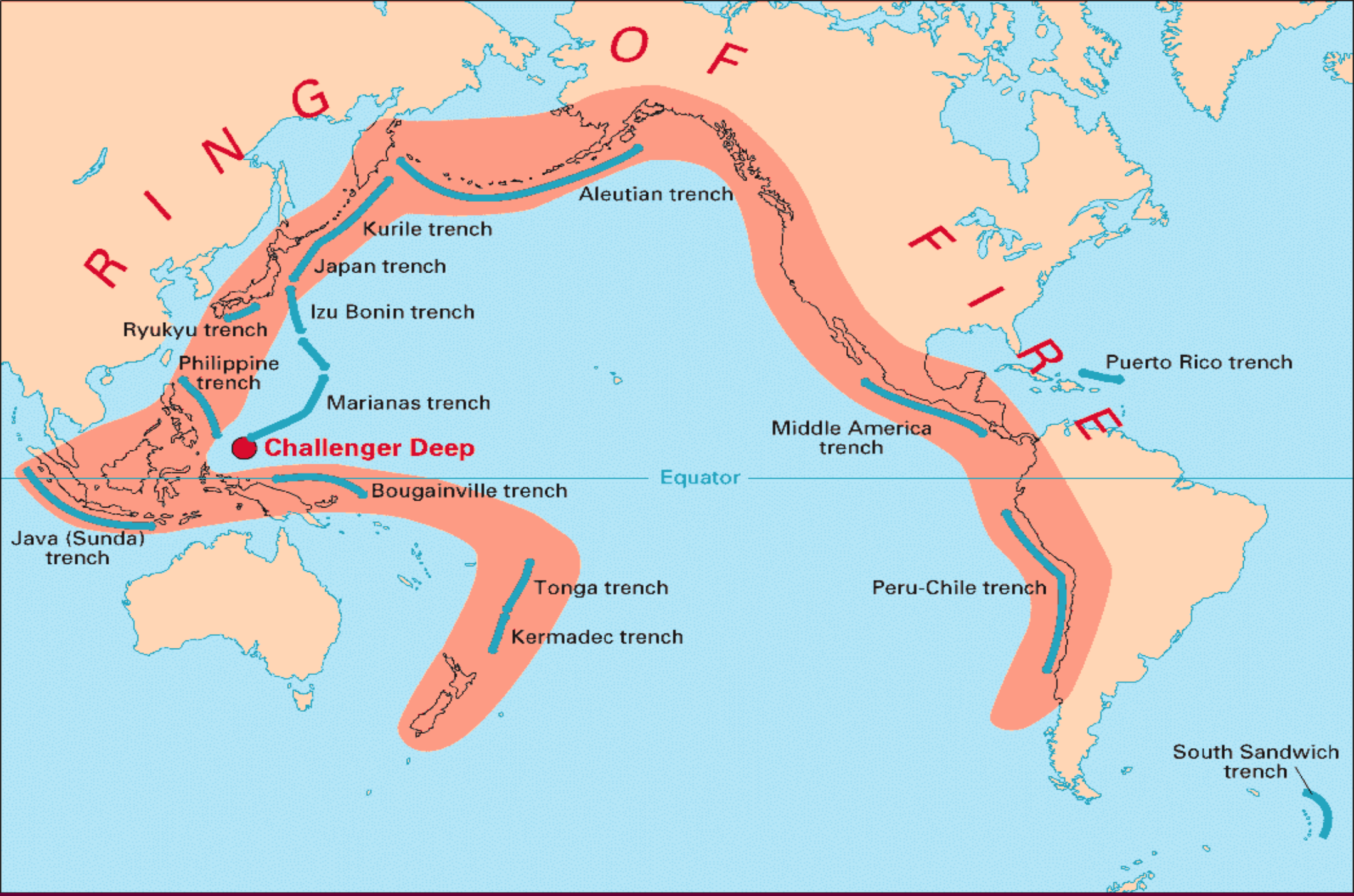
Magnetic stripes on Mars

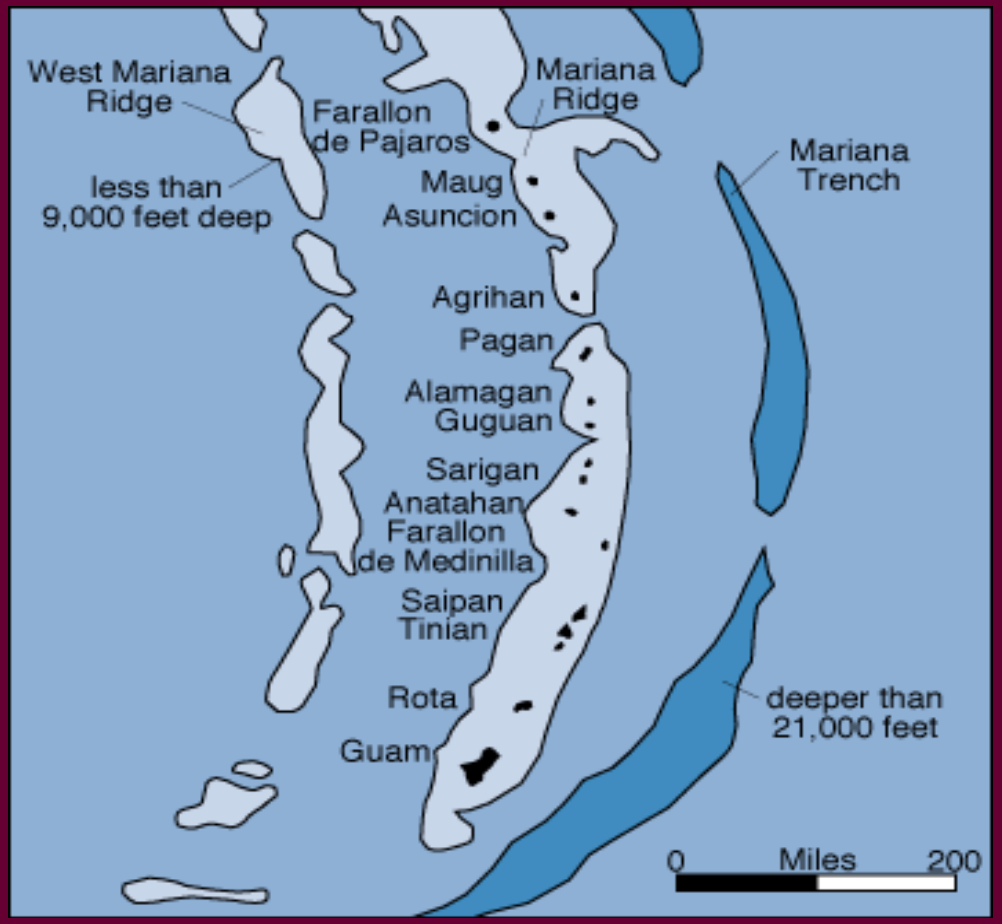


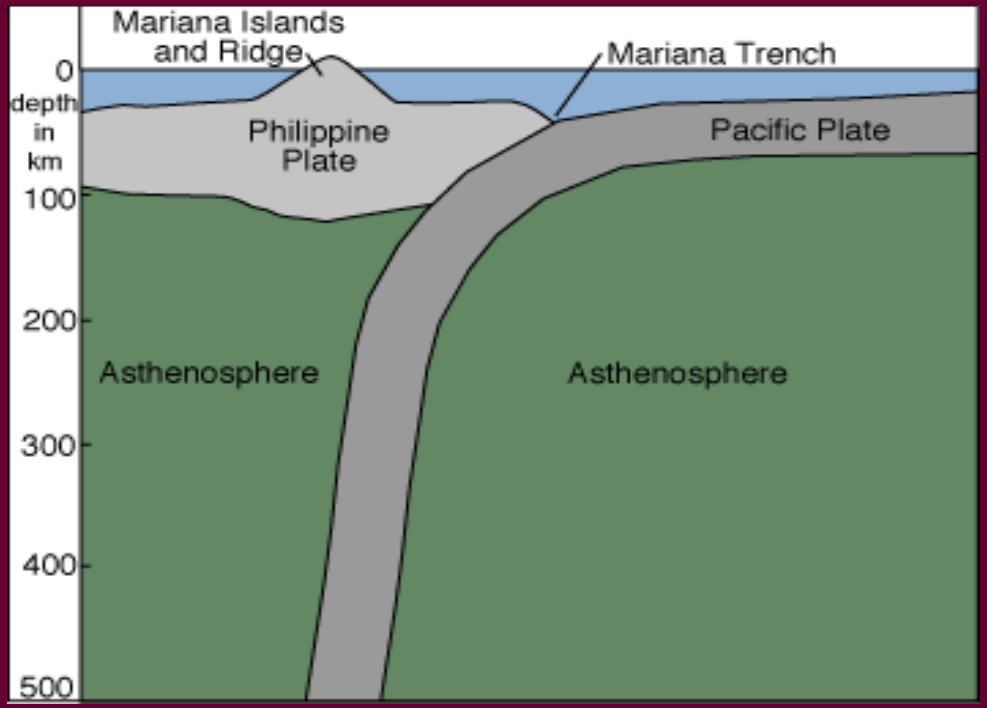
Convergent Plate Boundary

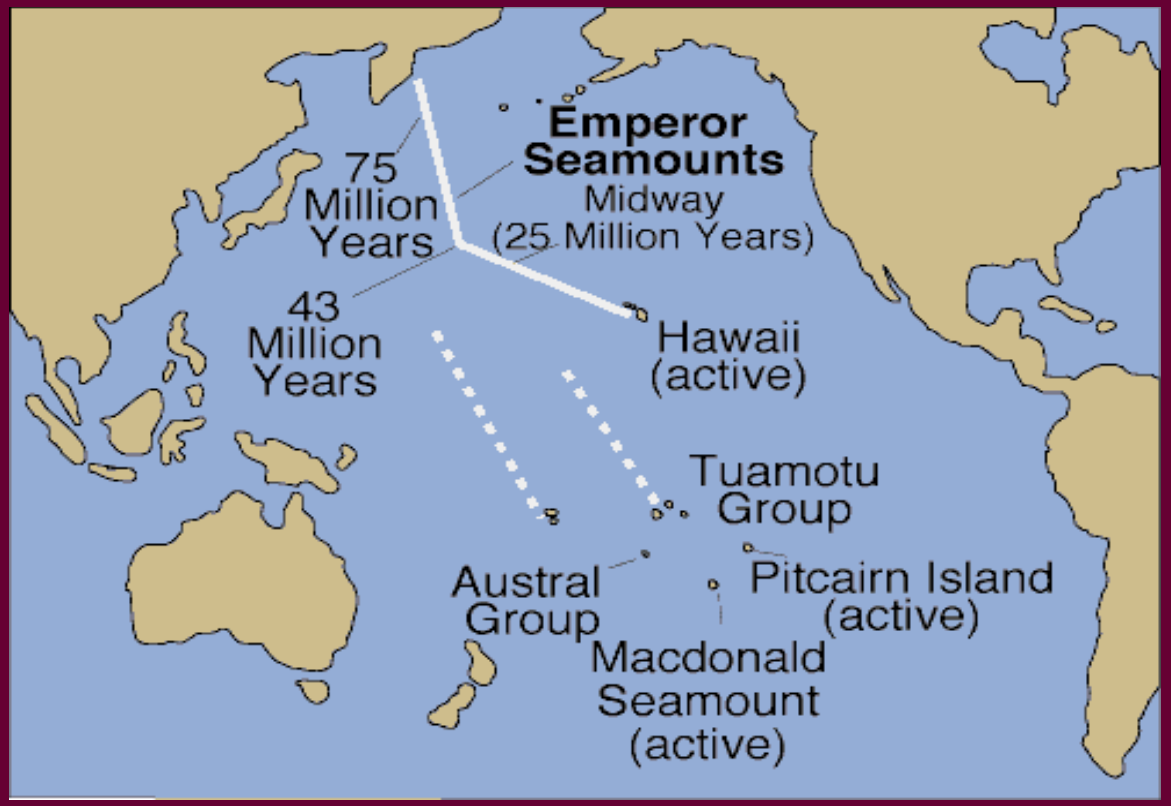


Magma is generated at subduction zones where dense oceanic plates are pushed under lighter continental plates.

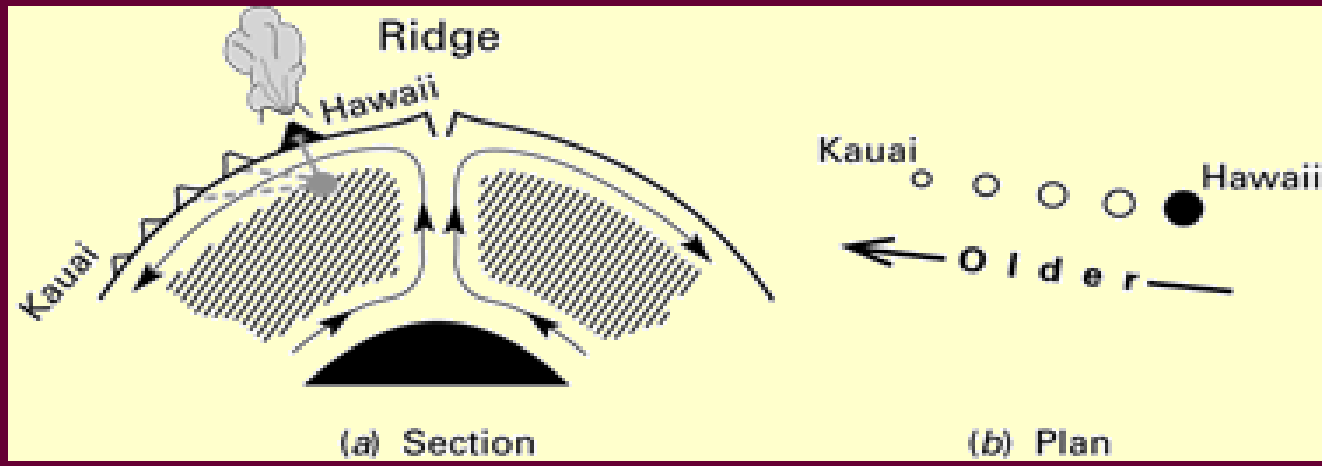

RING OF FIRE
Aleutian trench
Kurile trench
Japan trench
Izu Bonin trench
Ryukyu trench
Philippine trench
Marianas trench
Challenger Deep
Bougainville trench
Java (Sunda) trench
Tonga trench
Kermadec trench
Puerto Rico trench
Middle America trench
Equator
Peru-Chile trench
South Sandwich trench

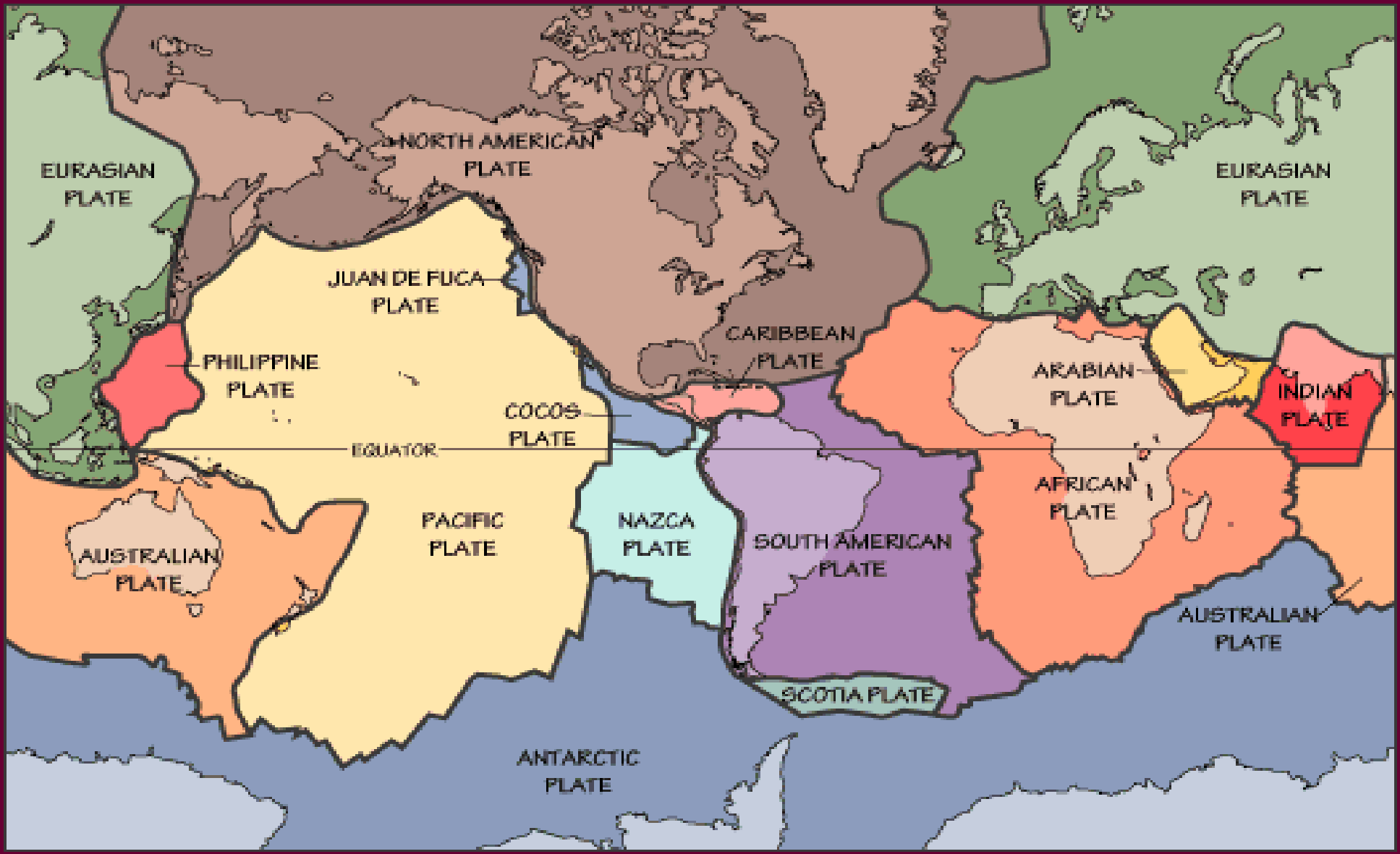

West Mariana Ridge
Farallon de Pajaros
Mariana Ridge
Mariana Trench
less than 9,000 feet deep
Maug
Asuncion
Agrihan
Pagan
Alamagan
Guguan
Sarigan
Anatahan
Farallon de Medinilla
Saipan
Tinian
Rota
Guam
deeper than 21,000 feet
0
Miles
200


Mariana Islands and Ridge
Mariana Trench
0
depth in km
100
200
300
400
500
Philippine Plate
Pacific Plate
Asthenosphere
Asthenosphere

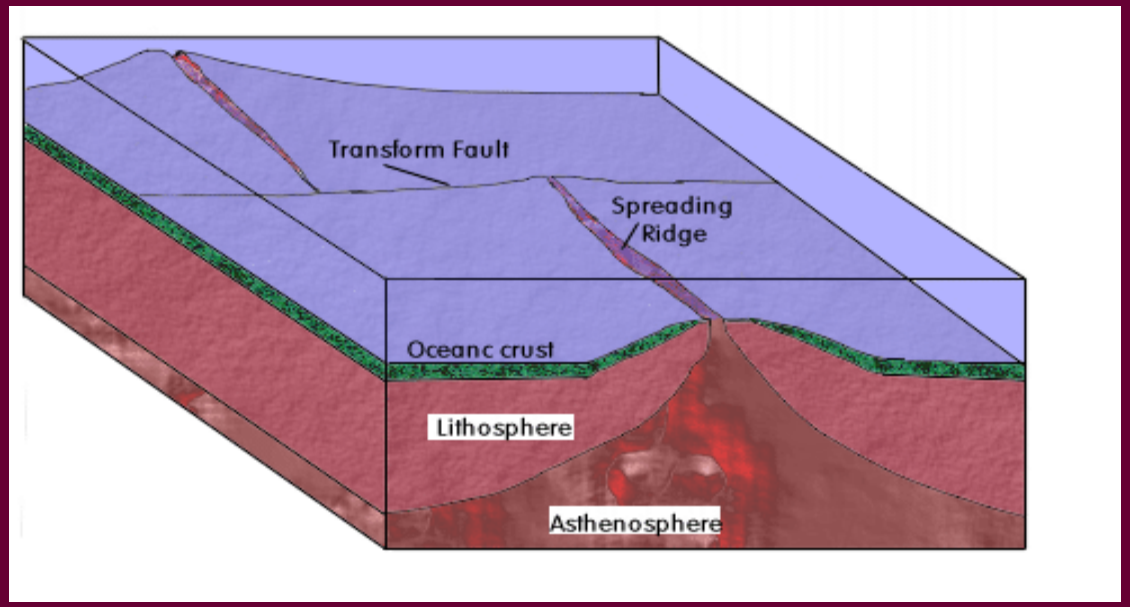

Emperor
Seamounts
Midway
(25 Million Years)
75
Million
Years
43
Million
Years
Hawaii
(active)
Tuamotu
Group
Austral
Group
Pitcairn Island
(active)
Macdonald
Seamount
(active)

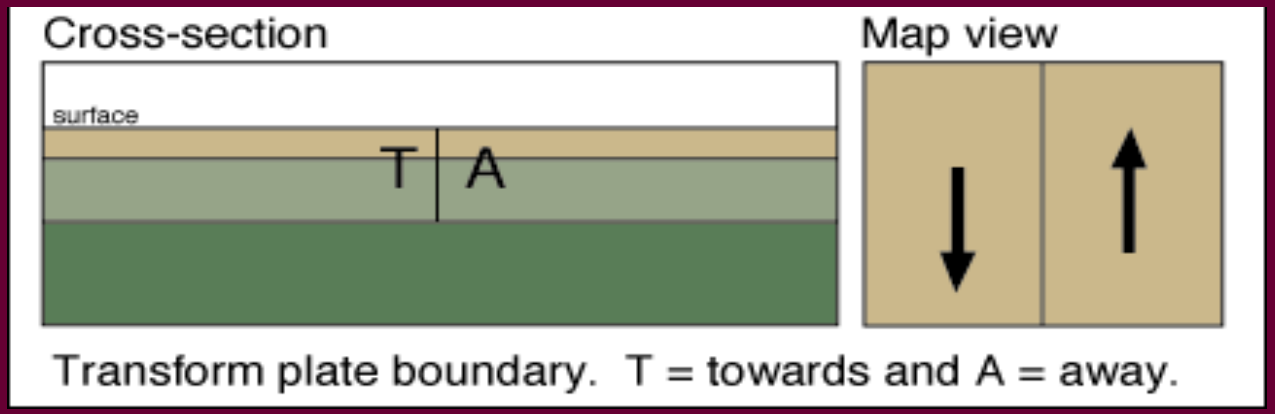
Hot spots


Ridge
Hawaii
Kauai
(a) Section
Kauai
Hawaii
Older
(b) Plan


EURASIAN PLATE
NORTH AMERICAN PLATE
EURASIAN PLATE
JUAN DE FUCA PLATE
CARIBBEAN PLATE
PHILIPPINE PLATE
ARABIAN PLATE
INDIAN PLATE
COCOS PLATE
EQUATOR
AFRICAN PLATE
PACIFIC PLATE
NAZCA PLATE
SOUTH AMERICAN PLATE
AUSTRALIAN PLATE
AUSTRALIAN PLATE
SCOTIA PLATE
ANTARCTIC PLATE

Transform Boundaries





Earth’s Atmosphere

- Layer of gases surrounding the planet Earth that is retained by Earth's gravity
- The atmosphere
  - protects life on Earth by absorbing ultraviolet solar radiation
  - warming the surface through heat retention (greenhouse effect)
  - reduces temperature extremes between day and night.

Air

(by volume)

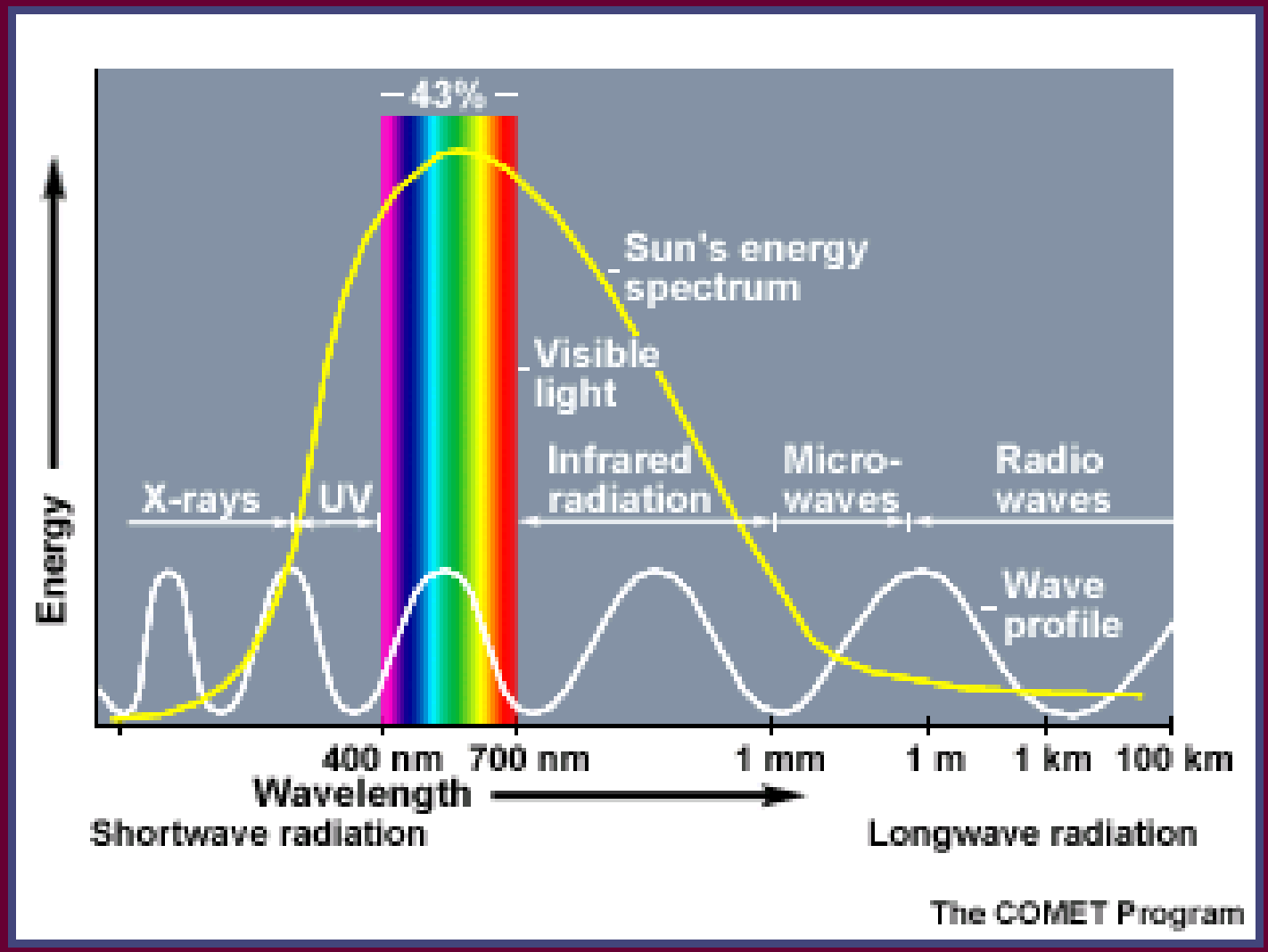
- 78% nitrogen
- 21% oxygen
- 1% argon
- 0.04% carbon dioxide
- ~1% water vapor

- http://en.wikipedia.org/wiki/File:Atmosphere_layers-en.svg

- http://en.wikipedia.org/wiki/File:Atmospheric_electromagnetic_opacity.svg

Greenhouse Effect

- The greenhouse effect is the rise in temperature that a planet experiences because certain gases in the atmosphere (H_2O, CO_2, CH_4, O_3) trap energy emitted from the surface.
- Visble light hits the surface
- Surface warms and emits infrared radiation
- Atmospheric gases absorb some of the infrared light
- Surface and atmosphere heat up


43%
Sun's energy spectrum
Visible light
Infrared radiation
Micro-waves
Radio waves
X-rays
UV
Wave profile
Energy
400 nm
700 nm
1 mm
1 m
1 km
100 km
Wavelength
Shortwave radiation
Longwave radiation
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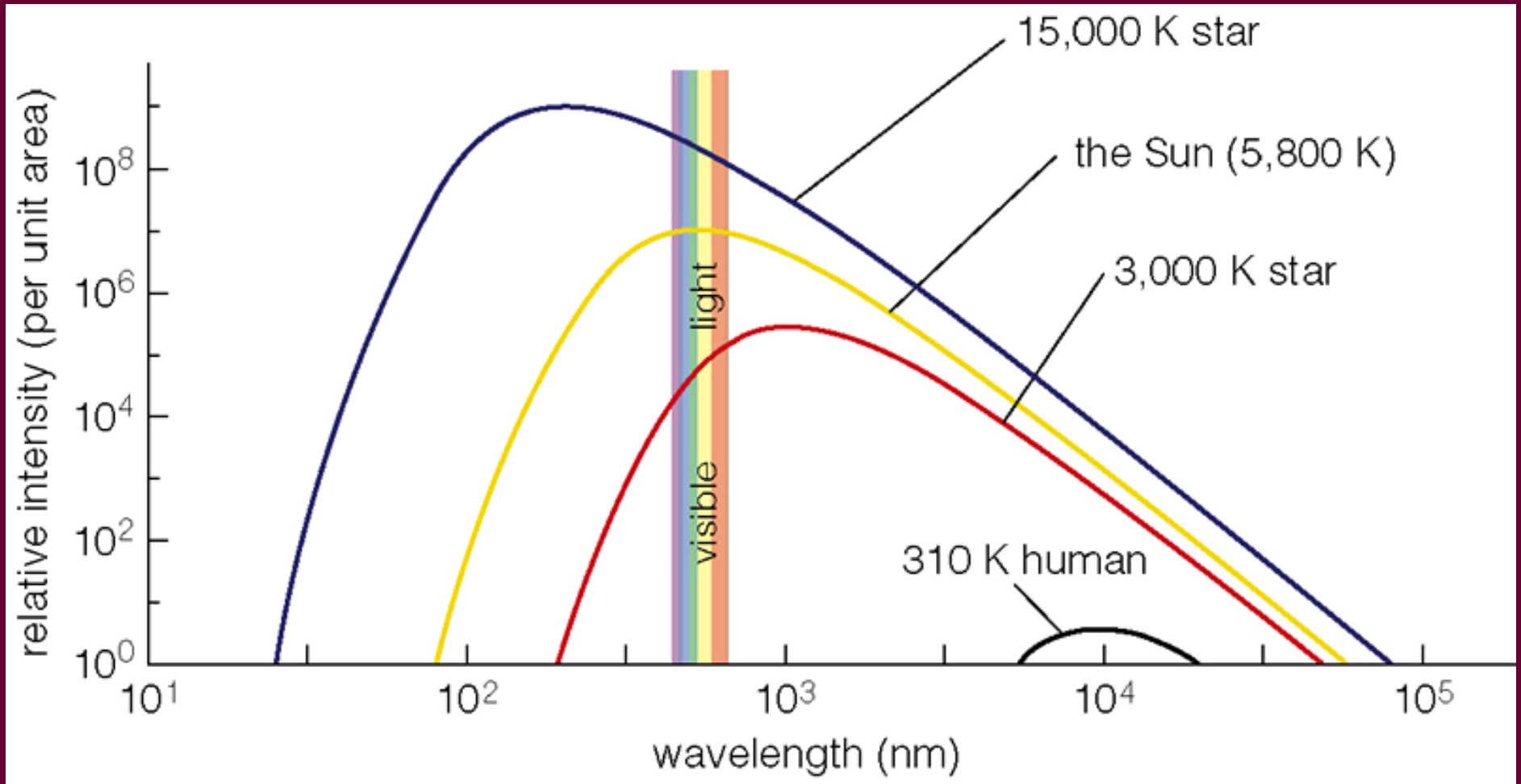
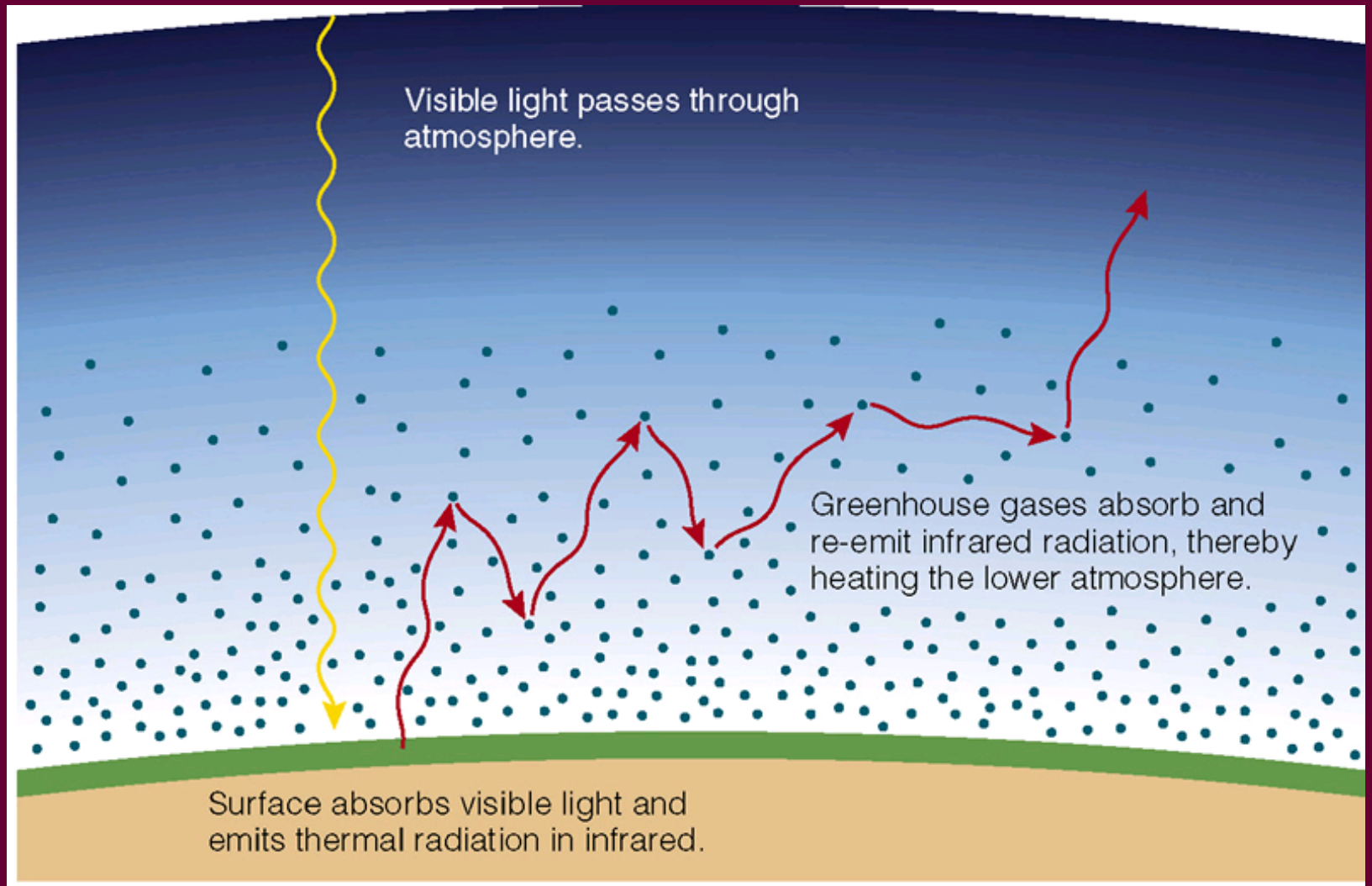
Stefan-Boltzman Law



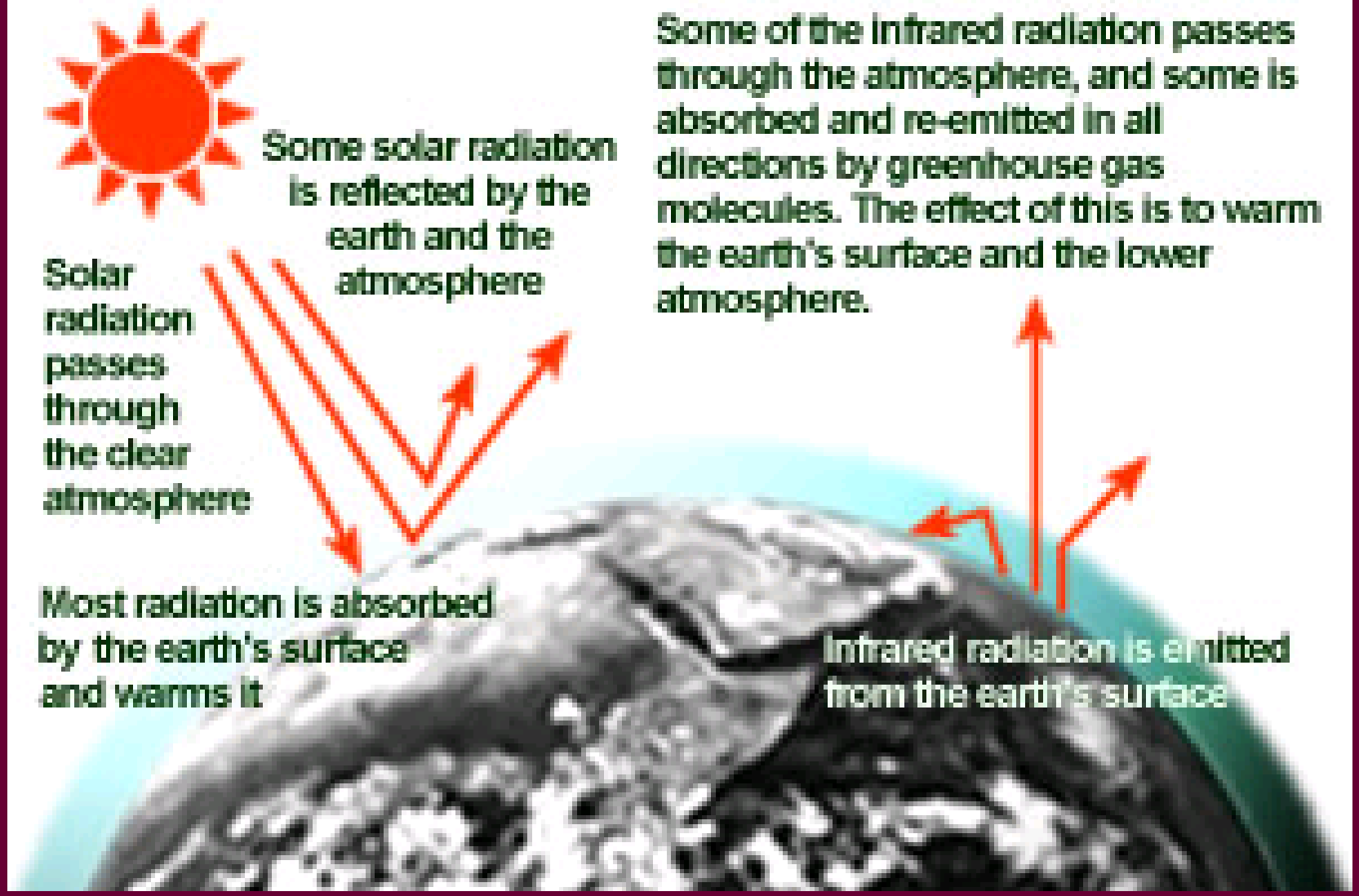
Emitted power (per square meter of surface) = σT^4

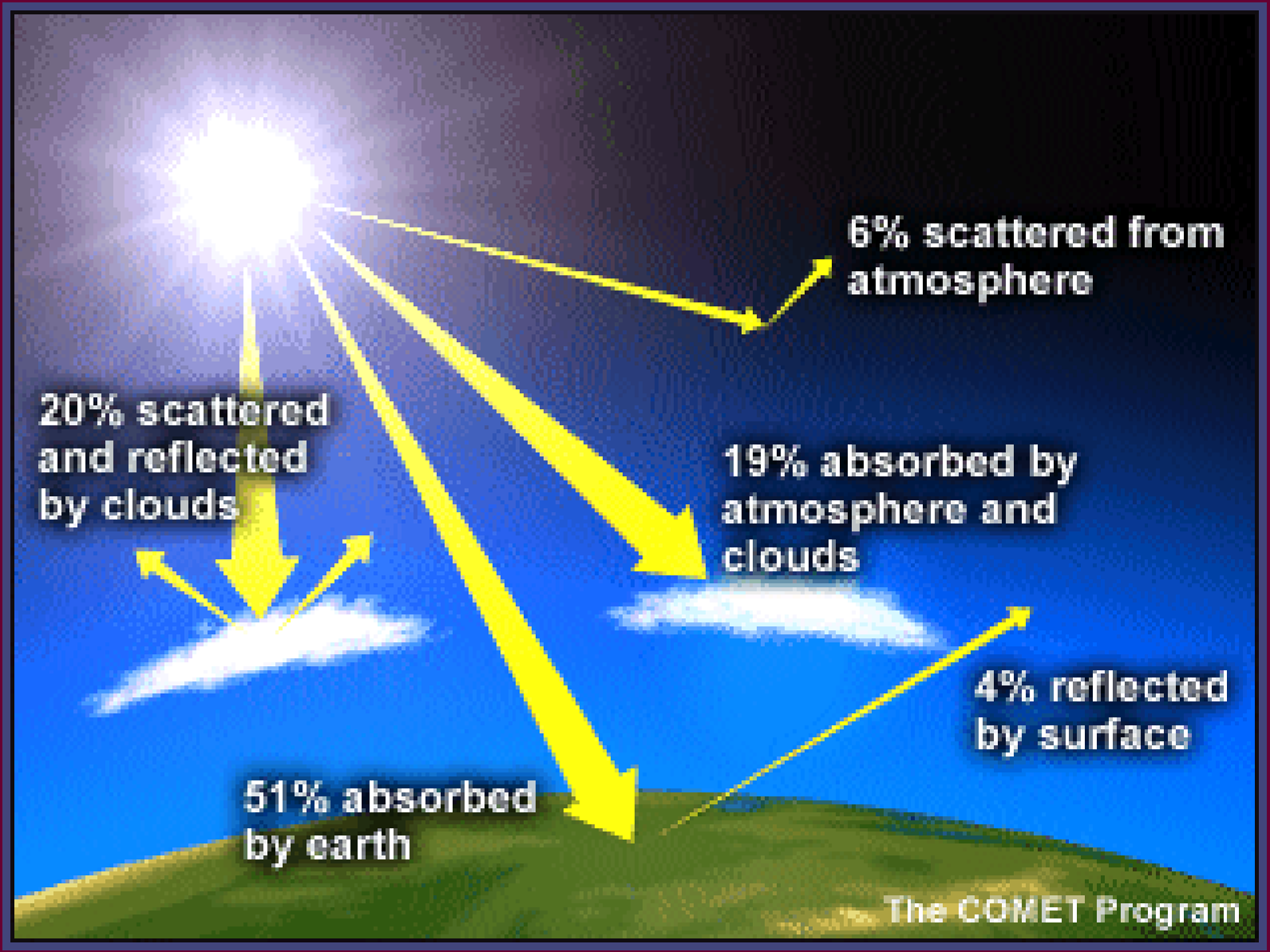
$\lambda \cdot T_{max} = 2{,}900{,}00$ nm



http://www.ucar.edu/learn/1_3_1.htm

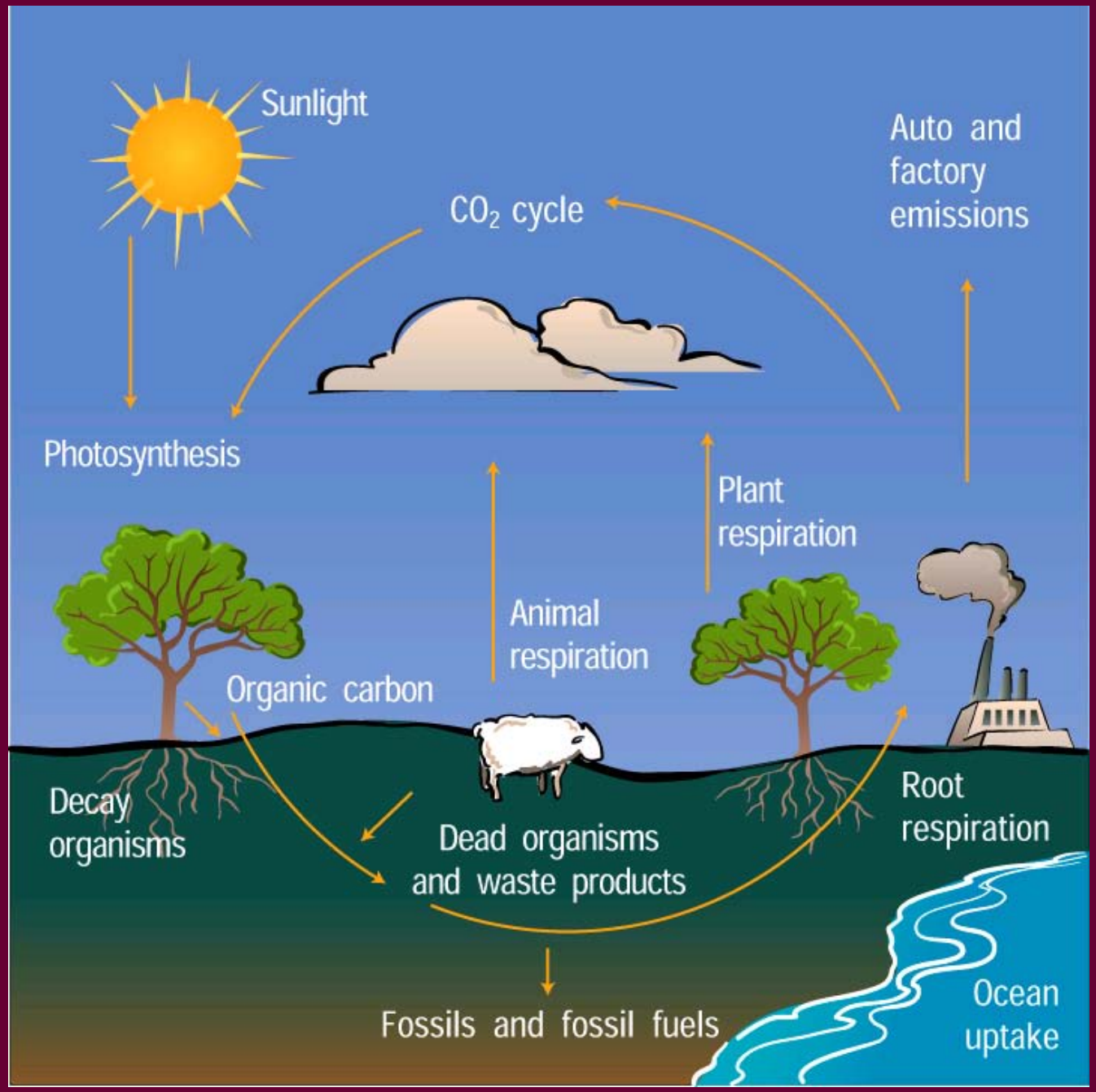
The Greenhouse Effect



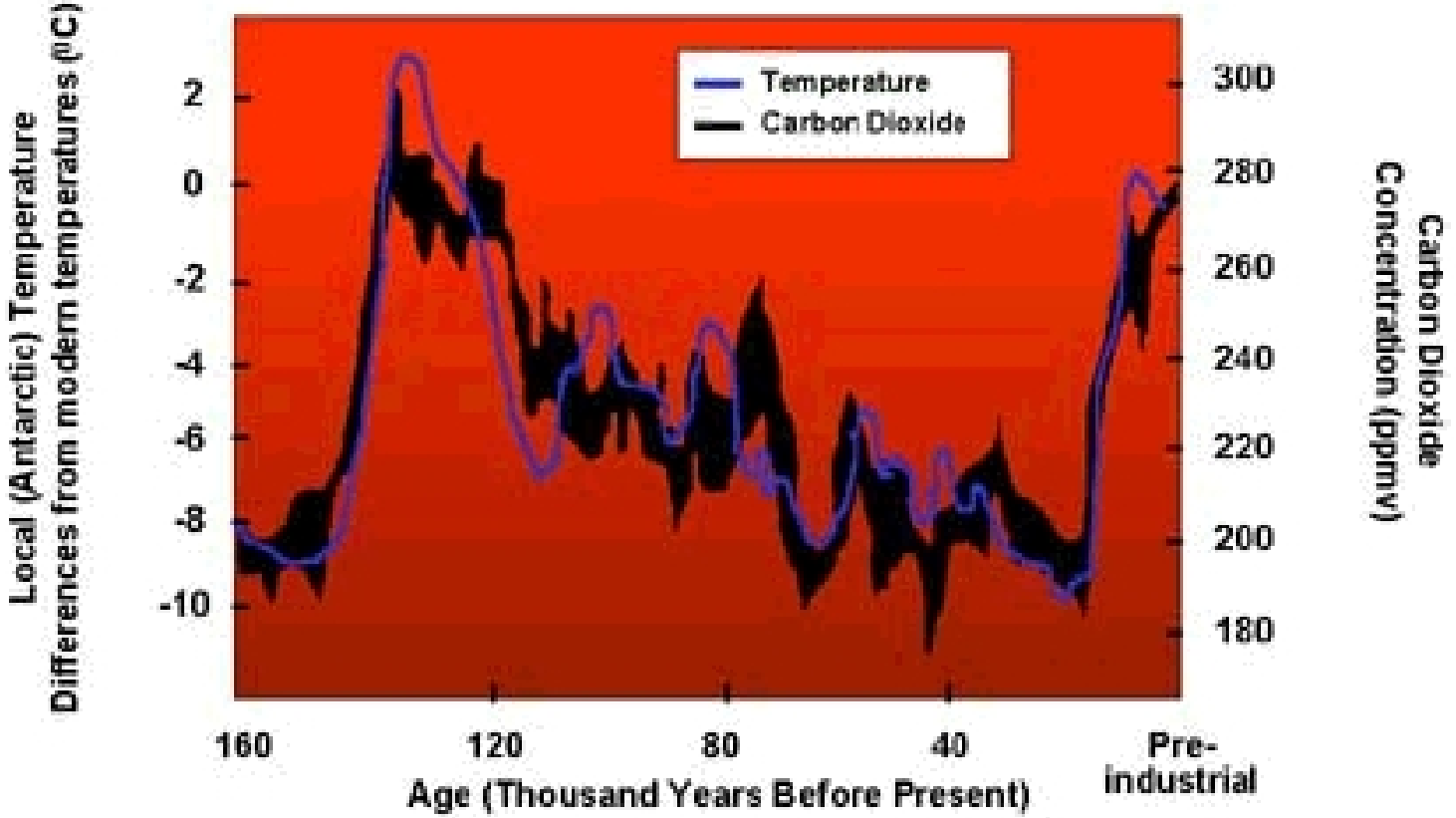

6% scattered from atmosphere
20% scattered and reflected by clouds
19% absorbed by atmosphere and clouds
4% reflected by surface
51% absorbed by earth
The COMET Program

Contribution to Greenhouse Effect

- water vapor (H_2O) 36–72%
- carbon dioxide (CO_2) 9–26%
- methane (CH_4) 4-9%
- ozone (O_3) 3–7%


Sunlight
CO_2 cycle
Auto and factory emissions
Photosynthesis
Plant respiration
Animal respiration
Organic carbon
Decay organisms
Dead organisms and waste products
Root respiration
Fossils and fossil fuels
Ocean uptake

Local Temperature Change and CO_2 Concentrations Over the Past 160,000 Years



Derived from Antarctic ice cores

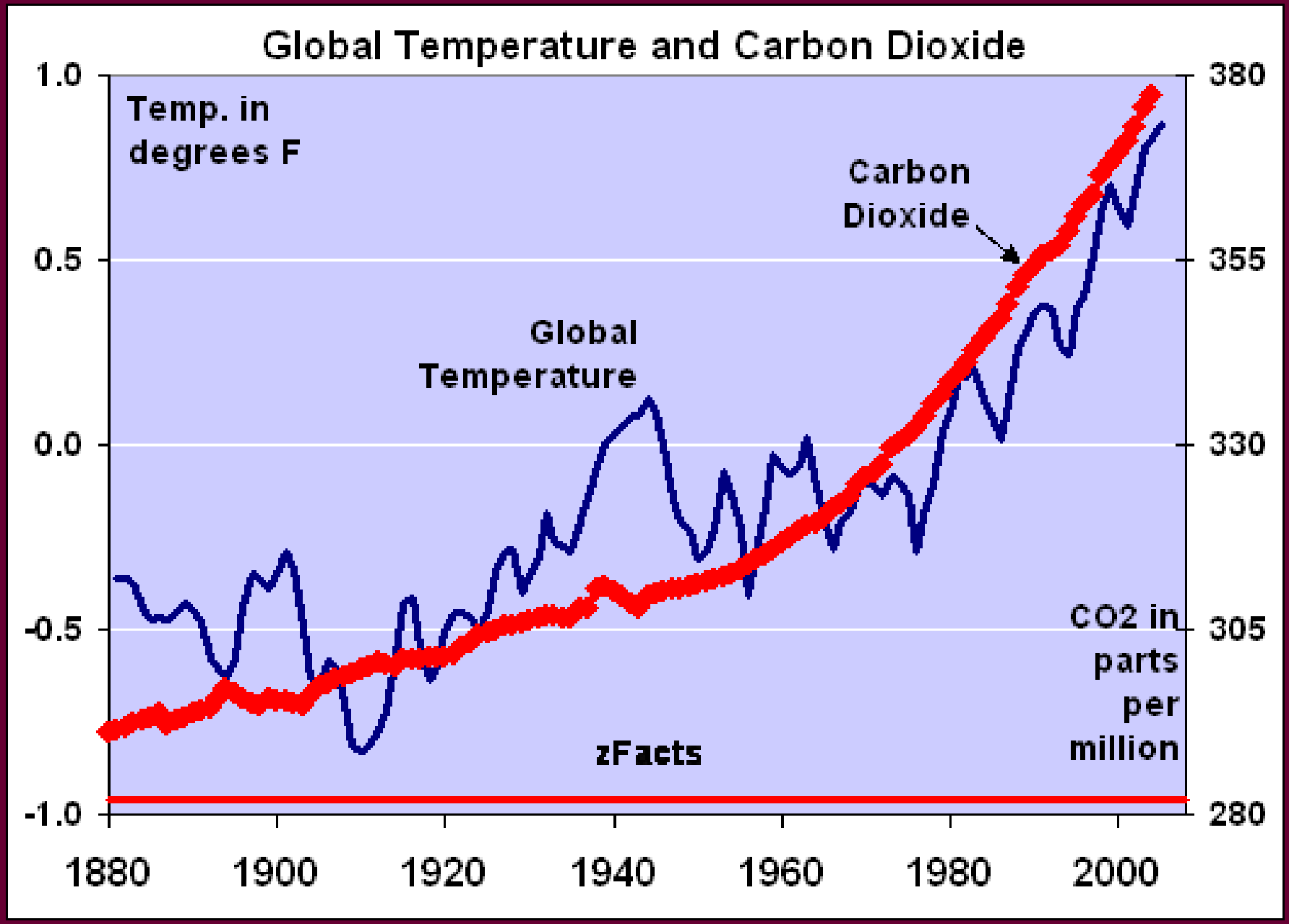
Source: Based on IPCC (1990)

EPA

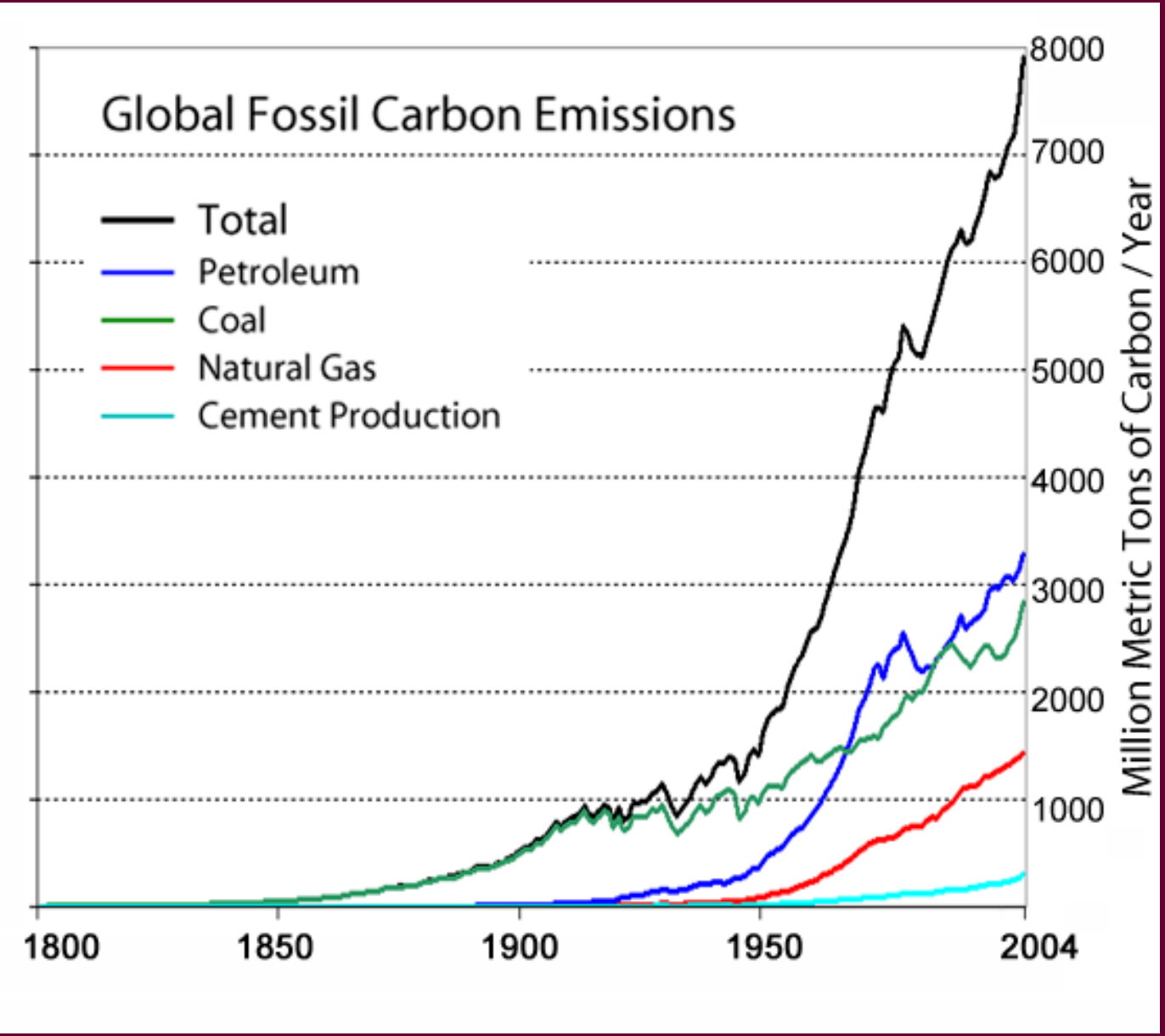
United States Environmental Protection Agency

TEMPER~1.JPG

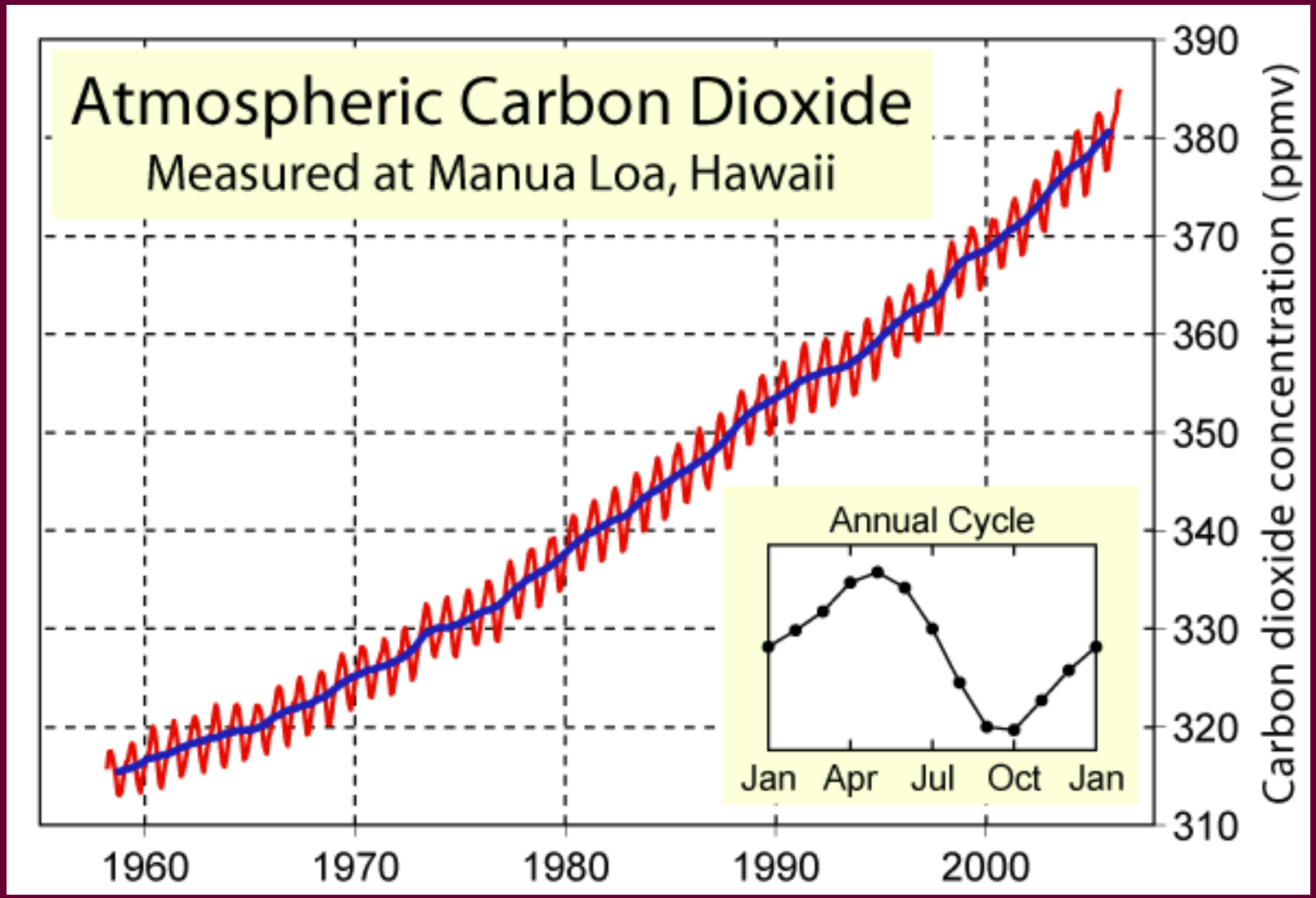
http://www.ems.psu.edu/~radovic/image0O3.JPG



http://zfacts.com/metaPage/lib/zFacts-CO2-Temp.gif



http://en.wikipedia.org/wiki/File:Global_Carbon_Emission_by_Type_to_Y2004.png



http://scottthong.files.wordpress.com/2007/02/mauna_loa_carbon_dioxide.png

Table 11.2. The Greenhouse Effect on the Terrestrial Worlds

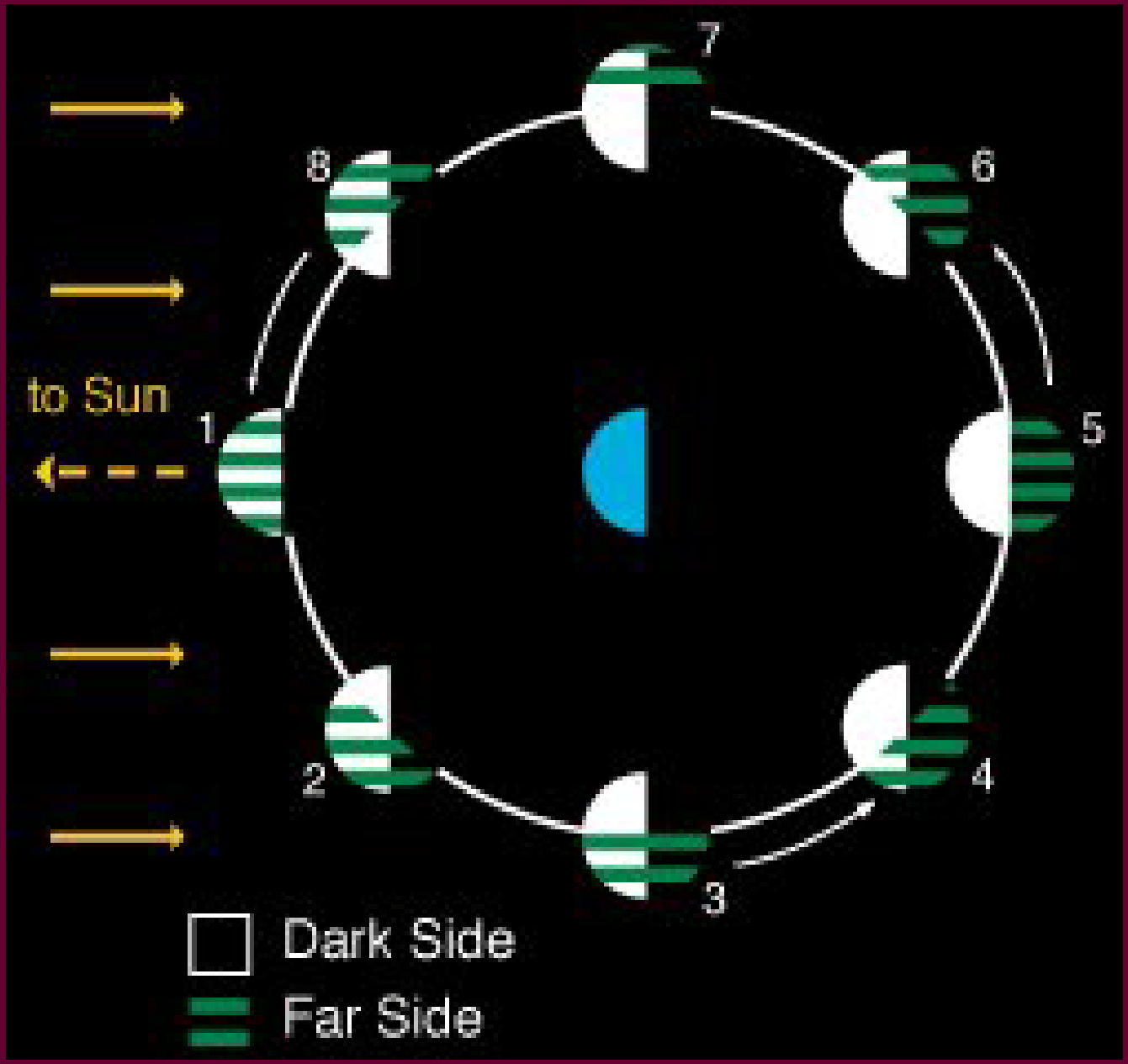
World	Average Distance from Sun (AU)	Reflectivity	"No Greenhouse" Average Surface Temperature*	Actual Average Surface Temperature	Greenhouse Warming (actual temperature minus "no greenhouse" temperature)
Mercury	0.387	11%	164°C	425°C (day), −175°C (night)	—
Venus	0.723	72%	−43°C	470°C	513°C
Earth	1.00	36%	−17°C	15°C	32°C
Moon	1.00	7%	0°C	125°C (day), −175°C (night)	—
Mars	1.52	25%	−55°C	−50°C	5°C

*The "no greenhouse" temperature is calculated by assuming no change to the atmosphere other than lack of greenhouse warming. Thus, for example, Venus ends up with a lower "no greenhouse" temperature than Earth even though it is closer to the Sun, because the high reflectivity of its bright clouds means that it absorbs less sunlight than Earth.

Moon

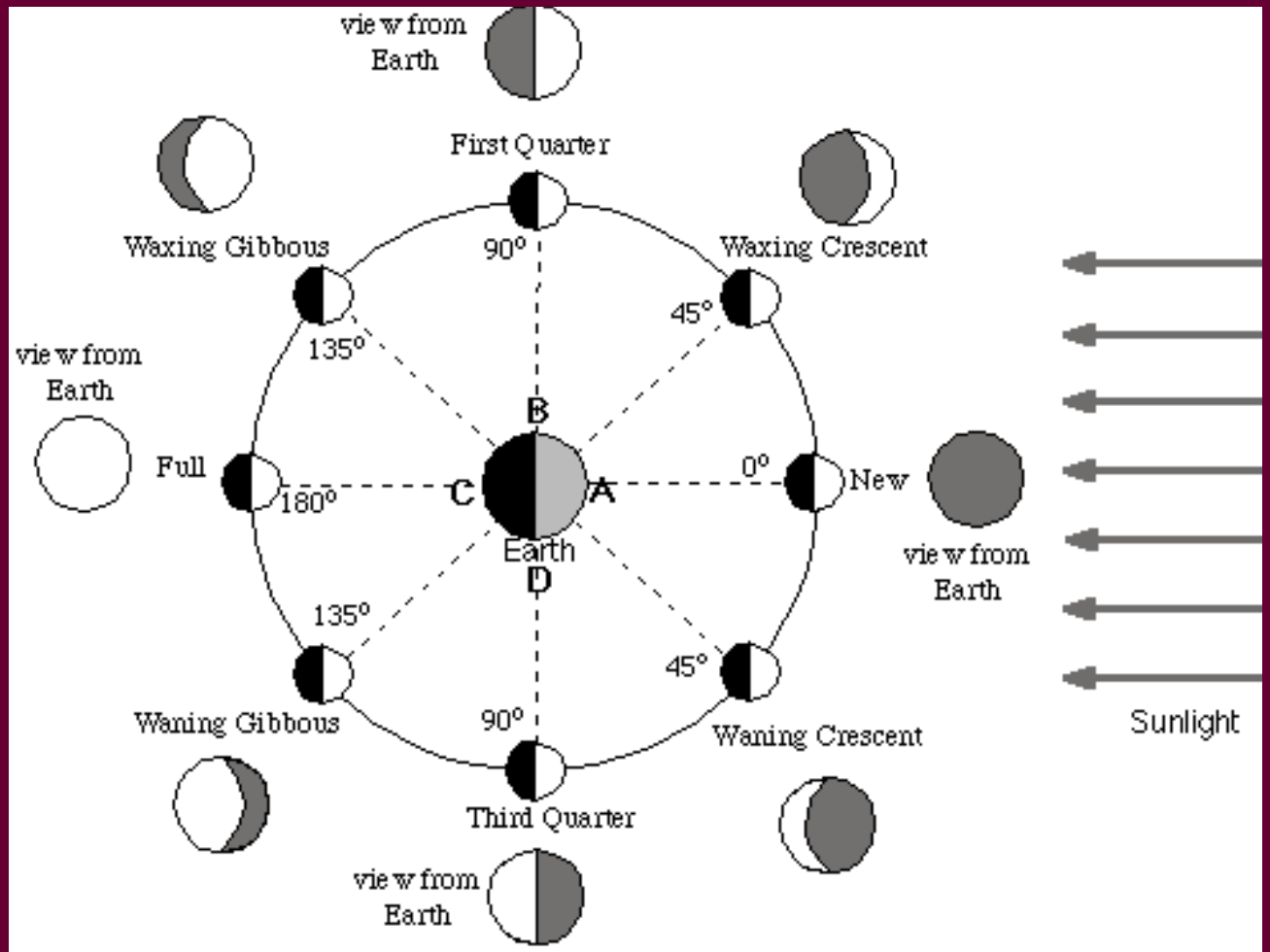
- http://www.youtube.com/watch?v=hTKedyQQkZQ

- http://apod.nasa.gov/apod/ap010218.html
- The Moon's orbital period is 27.322 days
- Rotation period and orbital period are the same
- This means we keep on seeing the same side of the Moon



http://home.xtra.co.nz/hosts/Wingmakers/Moon.html

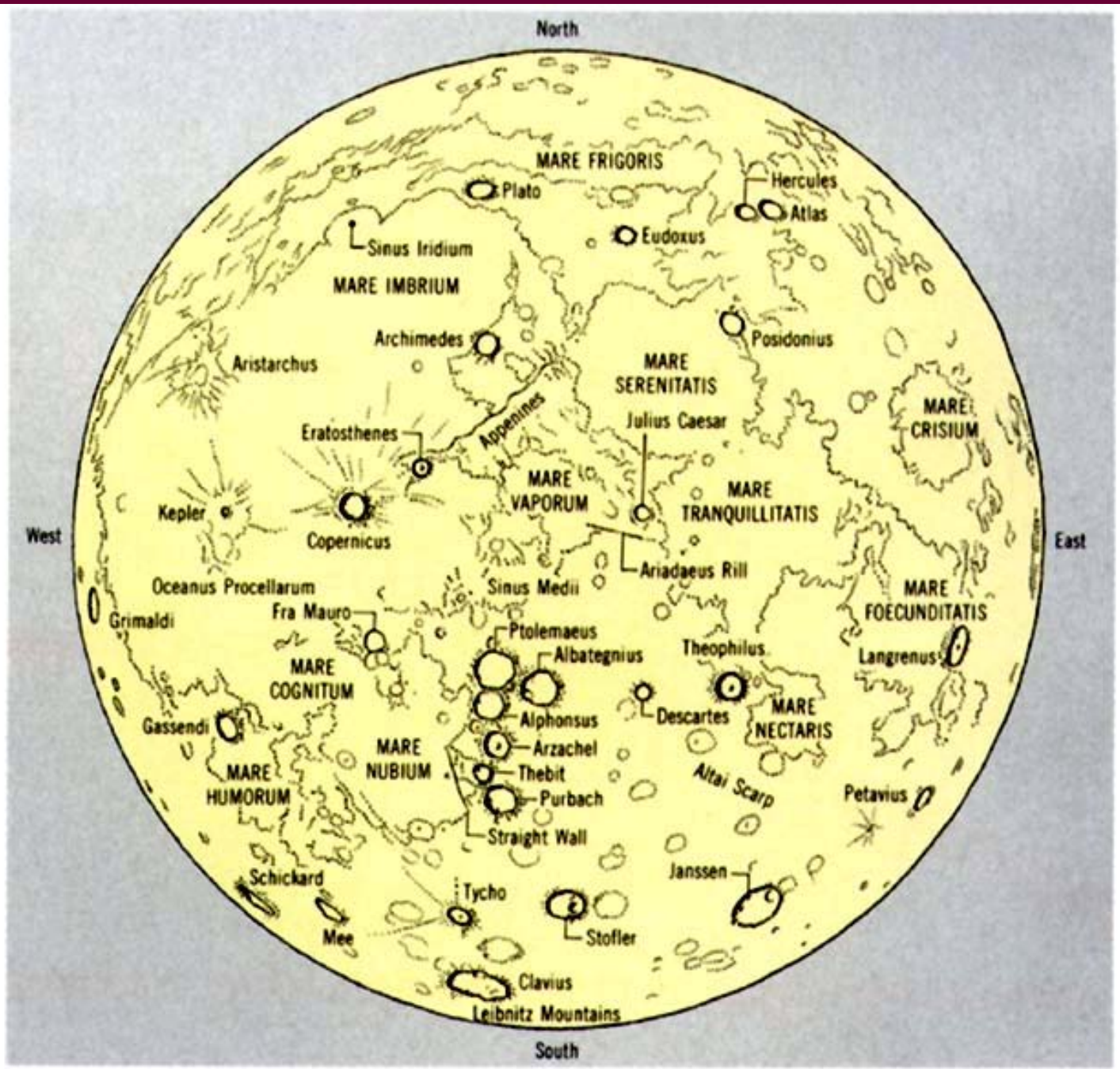
Phases of Moon



The Sun-Moon angle is the angle defined by Sun->Earth->Moon with Earth (where *you* are) as the angle vertex. As the Sun-Moon angle increases we see more of the sunlit part of the Moon. Note that if this drawing were to scale, then the Moon would be half this size and its orbit would be about 22 **times** larger in diameter and the Sun would be about 389 **times** farther away than the Moon!

http://www.moonphases.info/images/moon-phases-diagram.gif

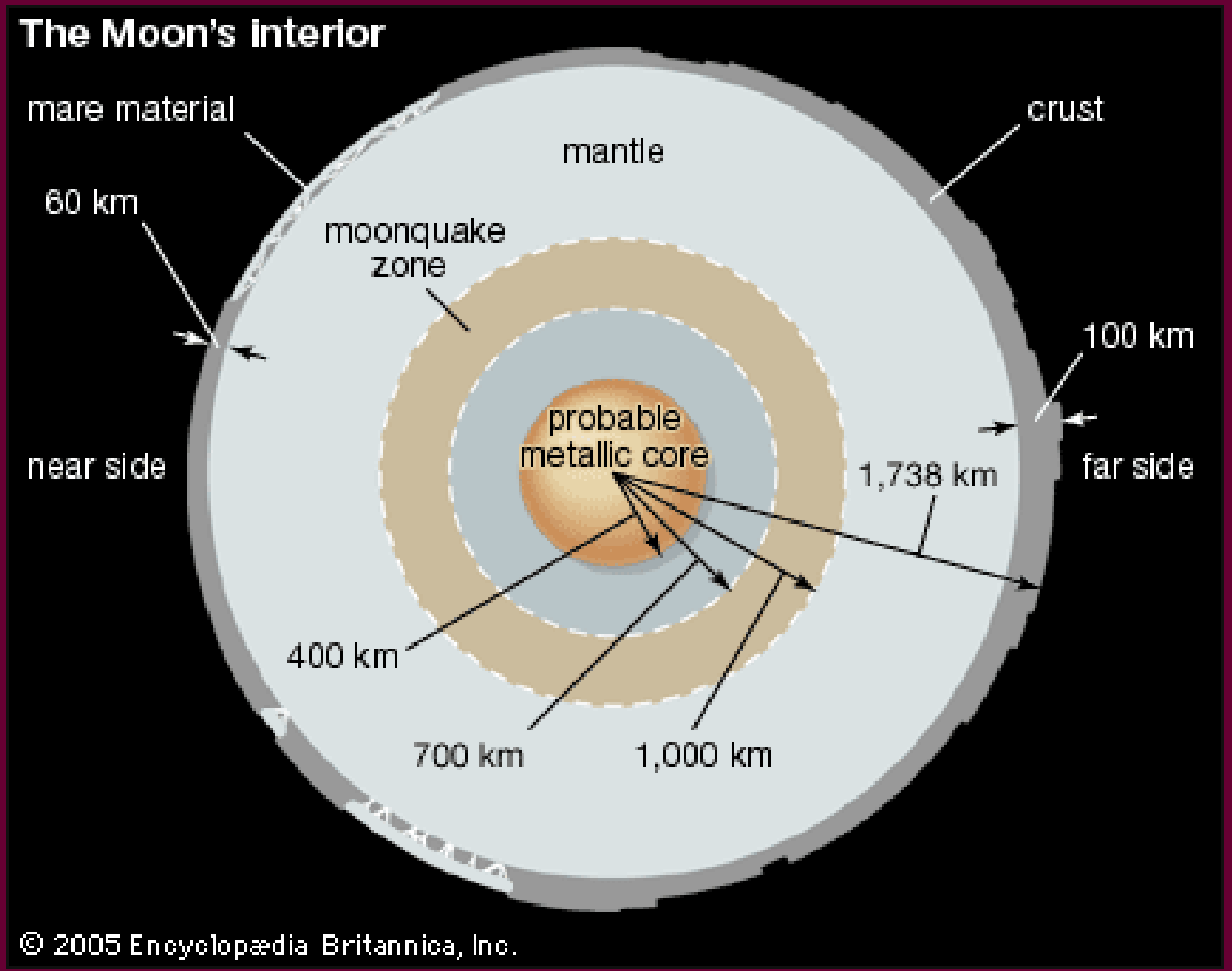
http://media.skyandtelescope.com/images/Moon-Phases-3x3-lbl.jpg


North
South
West
East
MARE FRIGORIS
Plato
Hercules
Atlas
Eudoxus
Sinus Iridium
MARE IMBRIUM
Archimedes
Posidonius
Aristarchus
MARE SERENITATIS
Julius Caesar
MARE CRISIUM
Eratosthenes
Apennines
MARE VAPORUM
MARE TRANQUILLITATIS
Kepler
Copernicus
Ariadaeus Rill
Oceanus Procellarum
Sinus Medii
MARE FOECUNDITATIS
Grimaldi
Fra Mauro
Ptolemaeus
Albategnius
Theophilus
Langrenus
MARE COGNITUM
Alphonsus
Descartes
MARE NECTARIS
Gassendi
Arzachel
MARE NUBIUM
Thebit
Altai Scarp
Petavius
MARE HUMORUM
Purbach
Straight Wall
Janssen
Schickard
Tycho
Stofler
Mee
Clavius
Leibnitz Mountains

(b)

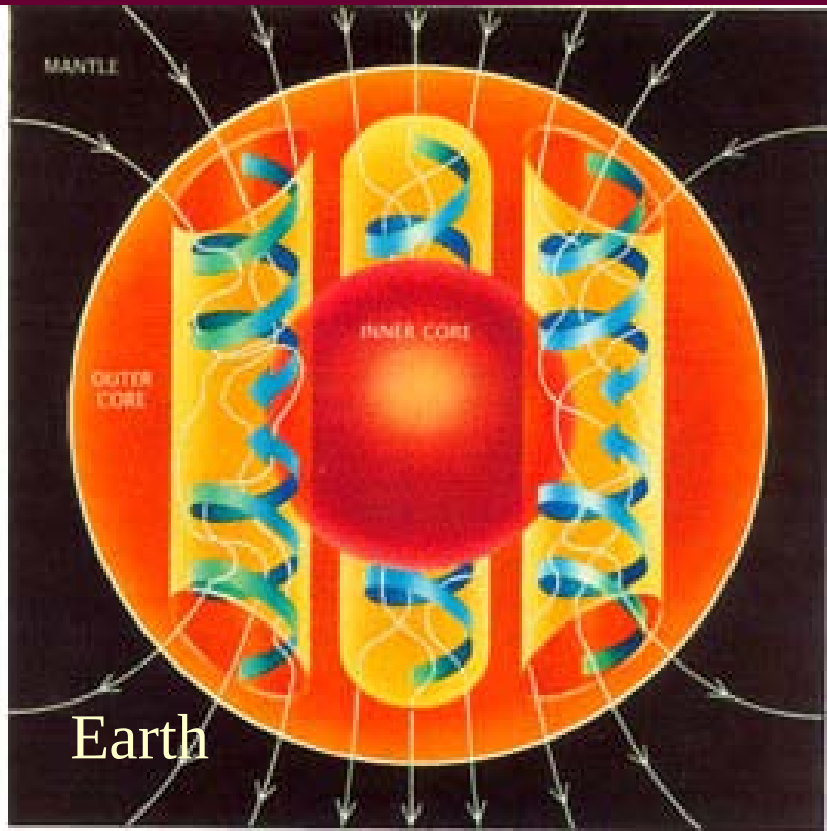
Moon

- The Moon is the only know natural satellite of Earth.
- Compared with the satellites of other planets of the solar system, The Moon is a large moon with a diameter of 3476 km and a mass of 7.349×10^{22} kg.
- The Moon is an average distance of 384,400 km from Earth and completes its revolution of Earth in 27.32 days.


The Moon's Interior
mare material
crust
mantle
60 km
moonquake zone
100 km
probable metallic core
near side
far side
1,738 km
400 km
700 km
1,000 km
© 2005 Encyclopædia Britannica, Inc.

- The Earth's magnetic field strength is about 100 times higher than the highest value measured on the Moon by the Apollo missions
- The Moon does not have a magnetic field like the Earth (North and South Poles) due most likely to having a solid (or only partially molten) core
- Earth’s core is convecting
- A flowing molten iron-nickel material can produce electrical current, which, in turn produces a magnetic field that surrounds the Earth

http://geomag.usgs.gov/images/faq/Q6.jpg



Earth

- The first manmade object to land on the Moon was Luna 2 in 1959
- The first photographs of the far side of the Moon were made by Luna 3 that same year

Who proposed an American mission to the Moon in 1962?

Houston, Texas
September 12, 1962

- **We choose to go to the Moon. We choose to go to the moon in this decade and do the other things, not only because they are easy, but because they are hard, because that goal will serve to organize and measure the best of our energies and skills, because that challenge is one that we are willing to accept, one we are unwilling to postpone, and one which we intend to win, and the others, too.**

- The first people to land on the Moon came aboard Apollo 11 in 1969.

Regolith – Lunar soil

No moisture or organic component compared to terrestrial soil

Who was the 1st person to walk on the Moon

Who was the 1st person to walk on the Moon

- Neil Armstrong
- Apollo 11

Who was the 2nd person to walk on the Moon

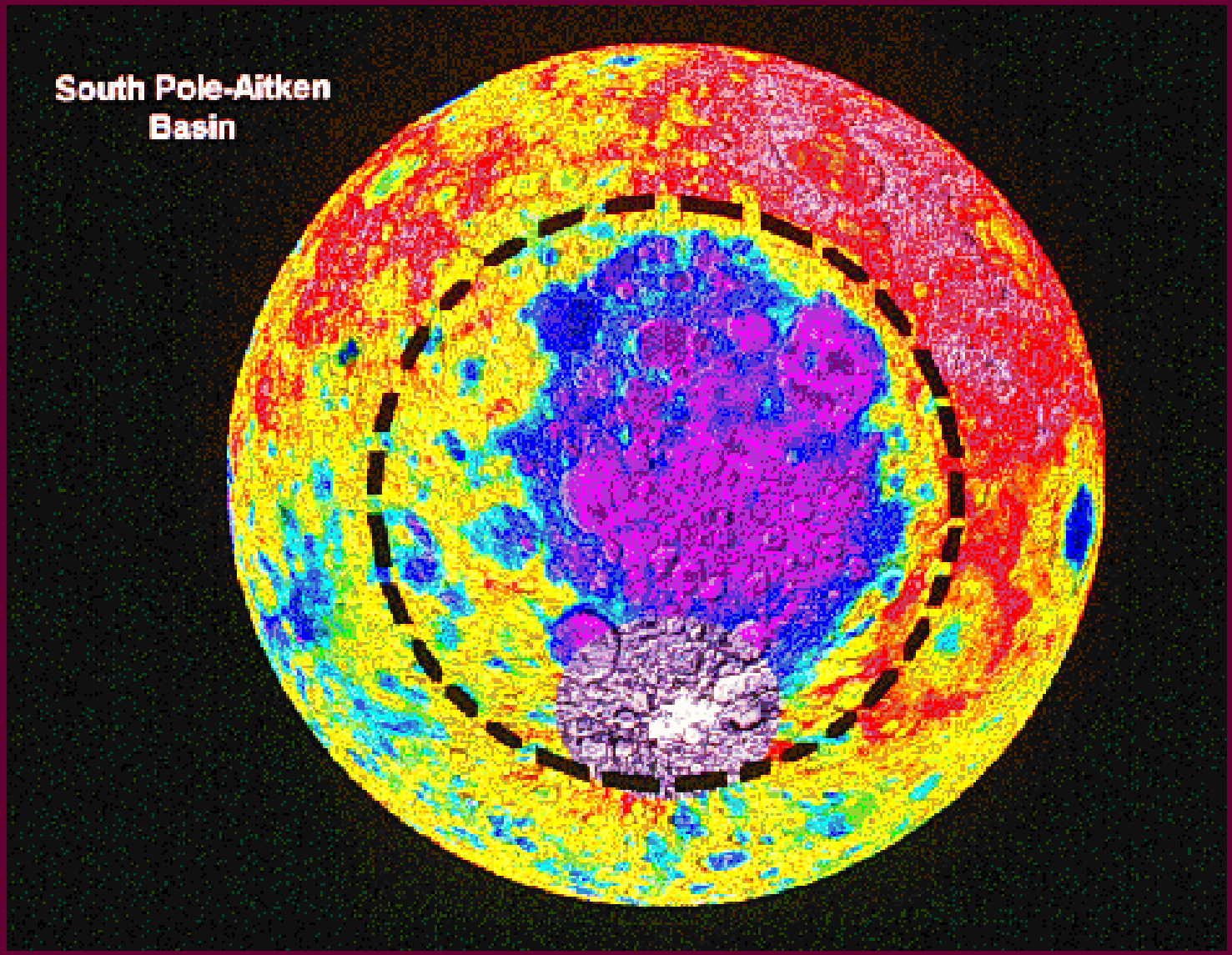
Who was the 2nd person to walk on the Moon

- Buzz Aldrin
- Apollo 11

Moon

- 30,000 craters having a diameter of at least 1 kilometers
- Large craters are named after famous deceased scientists, scholars, artists

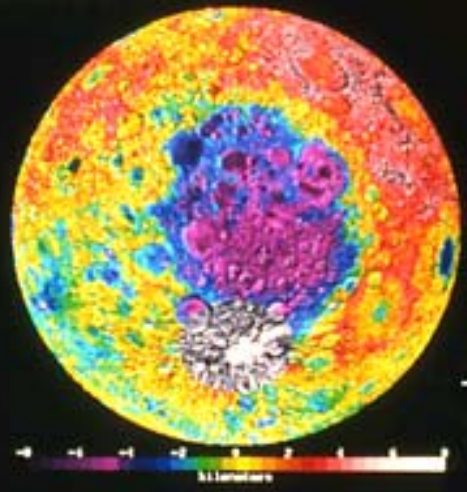
- The largest crater on the Moon, and indeed the largest known crater within the solar system, forms the South Pole-Aitken basin.
- Roughly 2,500 kilometers in diameter and 13 kilometers deep


South Pole-Aitken
Basin

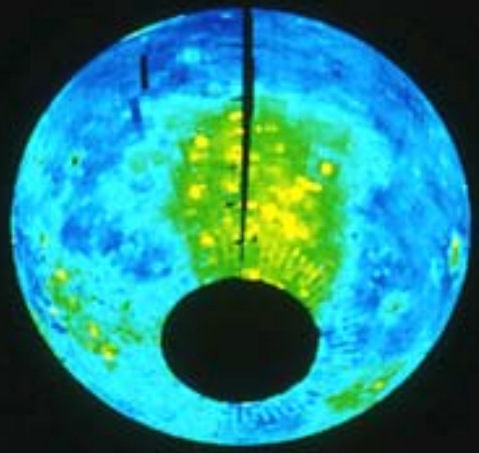
South Pole-Aitken Basin

Orthographic Projections centered at -56, 180

Albedo



Topography



Iron

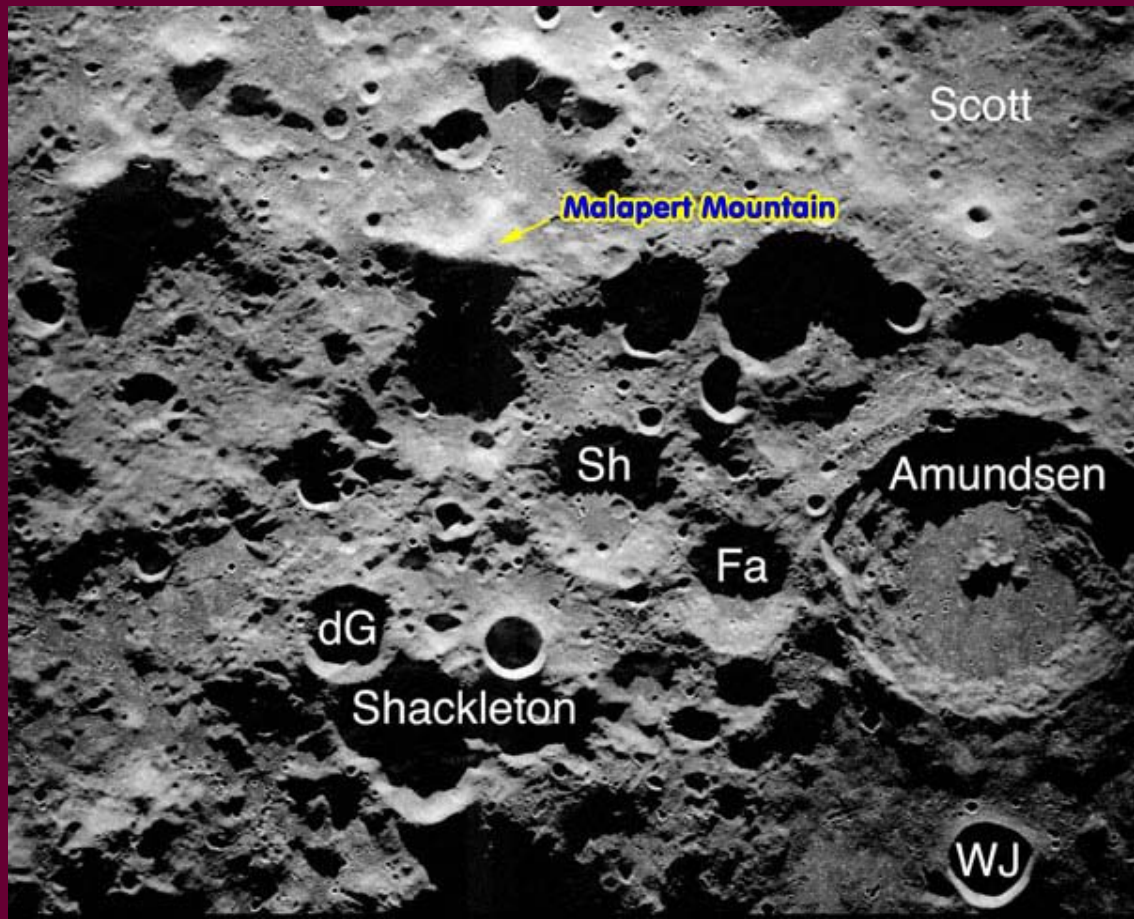
Titanium

Central part of South Pole-Aitken Basin

http://www.nhk.or.jp/kaguya/archive/index_e.html

South Pole of Moon

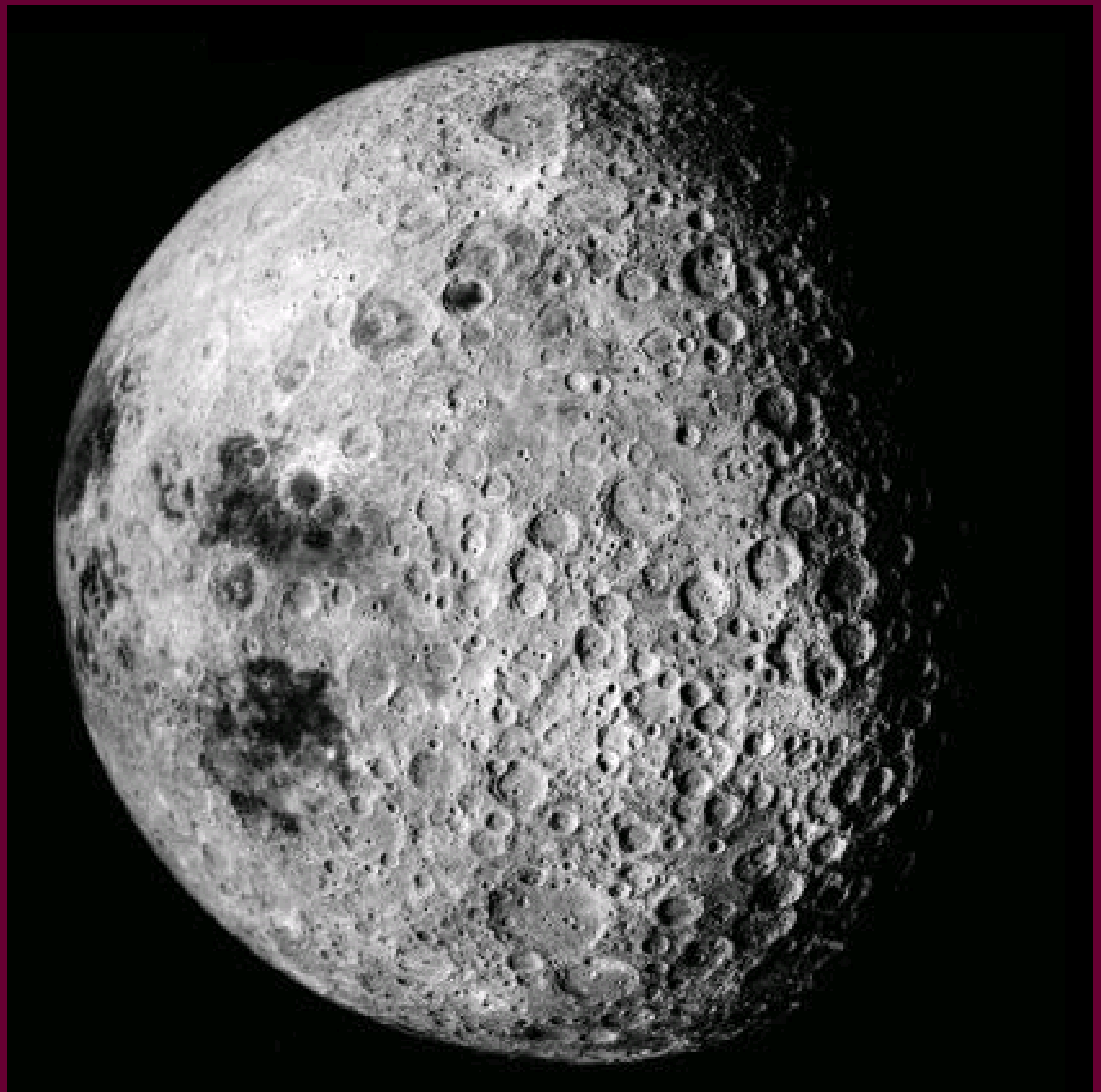
- Some craters on Moon are permanently shaded from the Sun
- May contain water ice



http://shaunmoss.id.au/articles/Billabong.php

- The dark and relatively featureless lunar plains are called maria, Latin for seas, since they were believed by ancient astronomers to be water-filled seas.
- They are actually vast ancient basaltic lava flows that filled the basins of large impact craters.
- Maria are found almost exclusively on the Lunar nearside, with the Lunar farside having only a few scattered patches.

Far Side of Moon



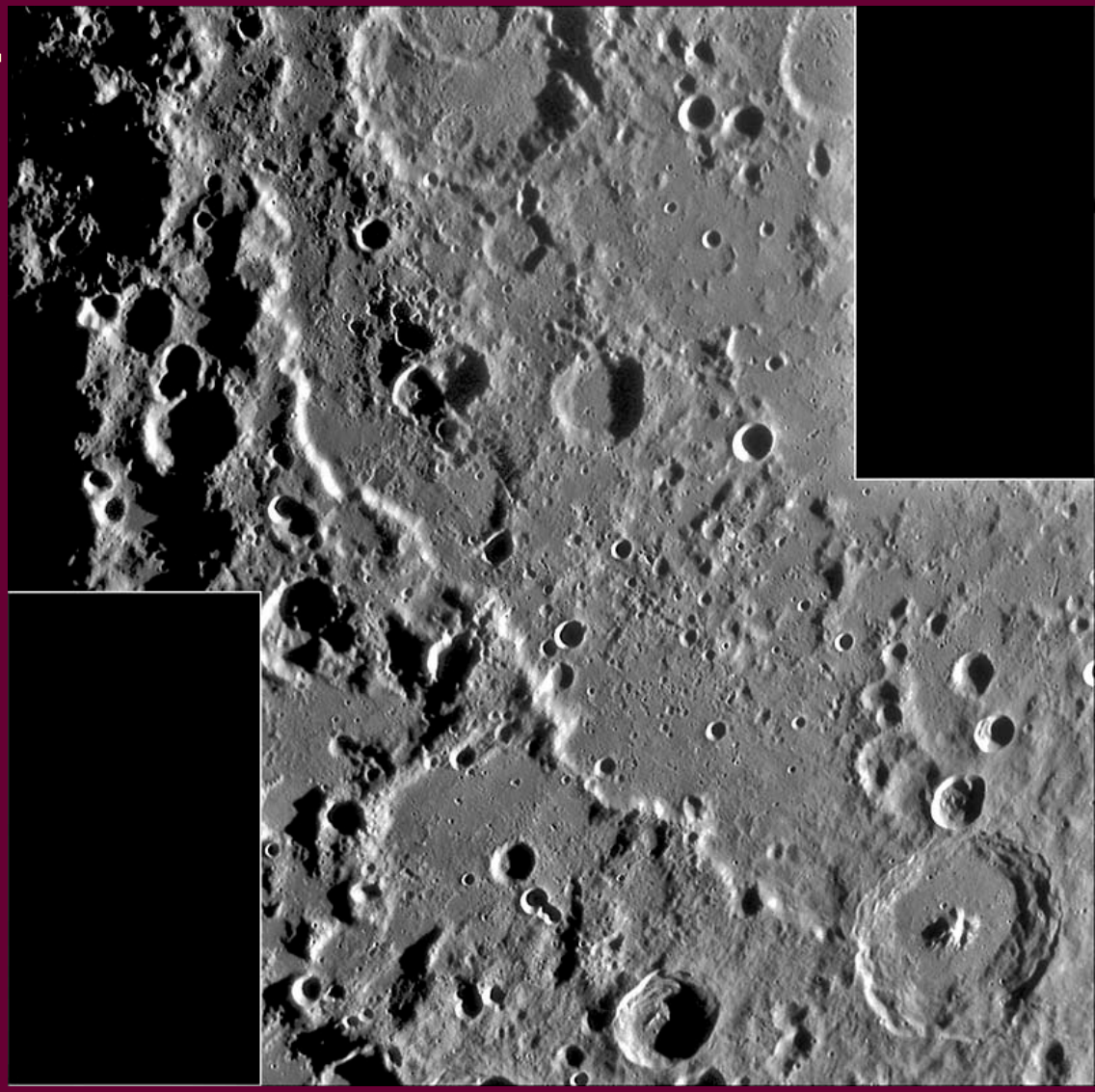
Other features on Moon

- Rille - long, narrow depressions in the lunar surface that resemble channels.
- Floor of Gassendi crater
- Leading theories for rille formation include collapsed lava tubes and tectonic extension.

http://en.wikipedia.org/wiki/Image:AS16-120-19295.jpg

Other features on Moon

- Scarp – steep slope or cliff
- The Altai Scarp, which is the rim of the 860 km wide Nectaris impact basin, is nearly 500 km long and 3 to 4 km high.

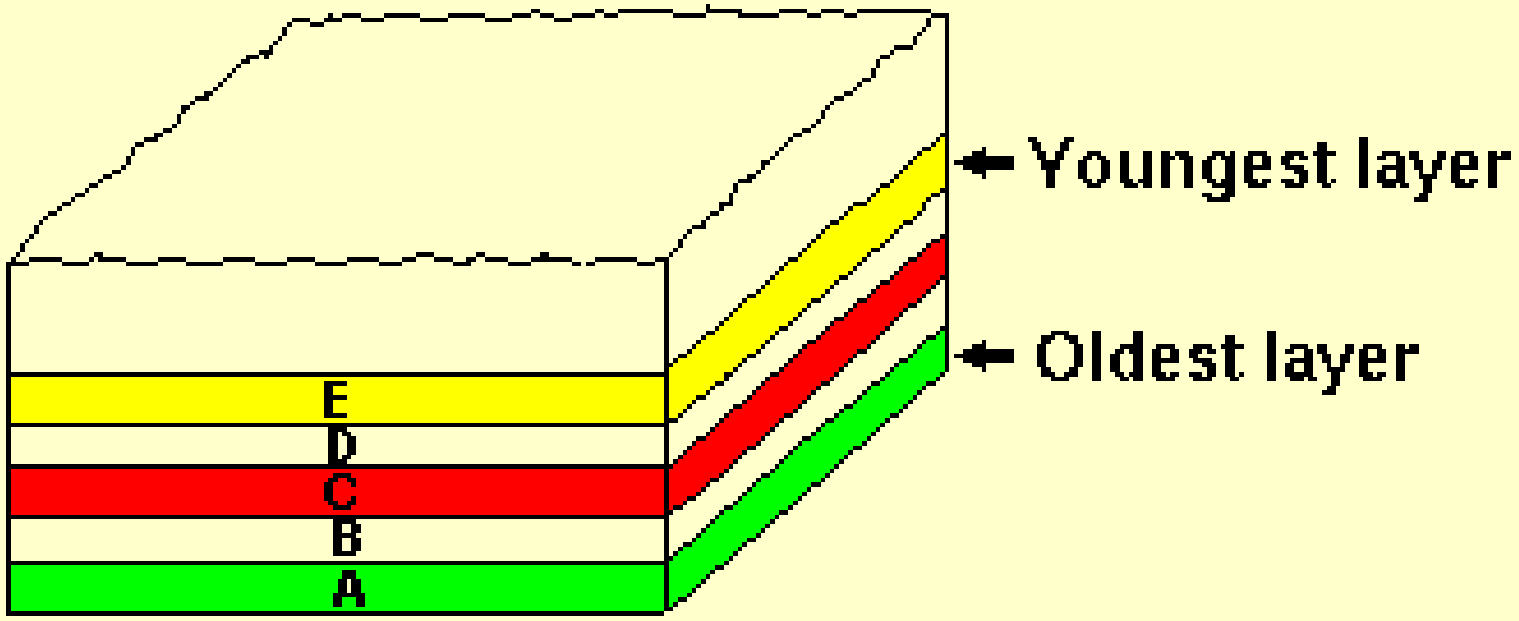


http://www.lpod.org/?m=20060517

Stratigraphy

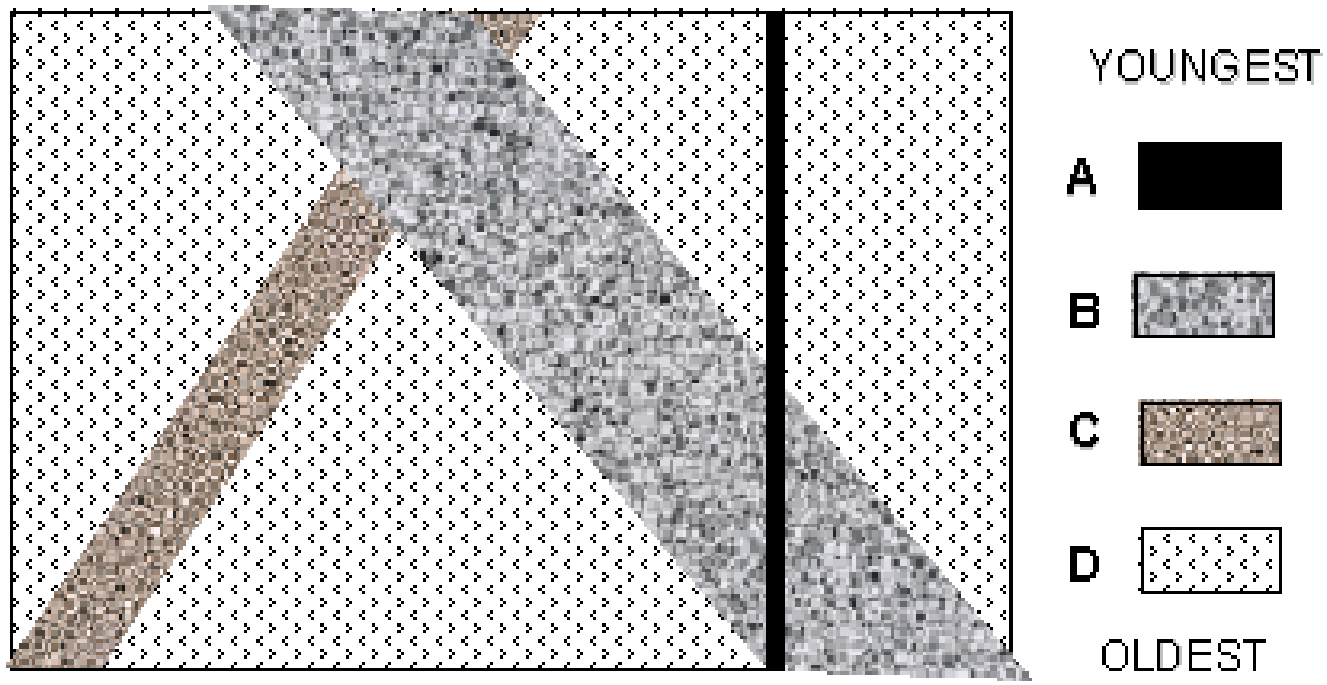
- Stratigraphy – studies rock layers and layering
- On planetary bodies, we try to determine the relative ages when things formed

Principle of Superposition



http://earthsci.org/fossils/geotime/time/Super.gif

Principles of cross-cutting relationships



http://dept.kent.edu/geology/ehlab/fundamentals/cross_cut.gif

Crater Rays

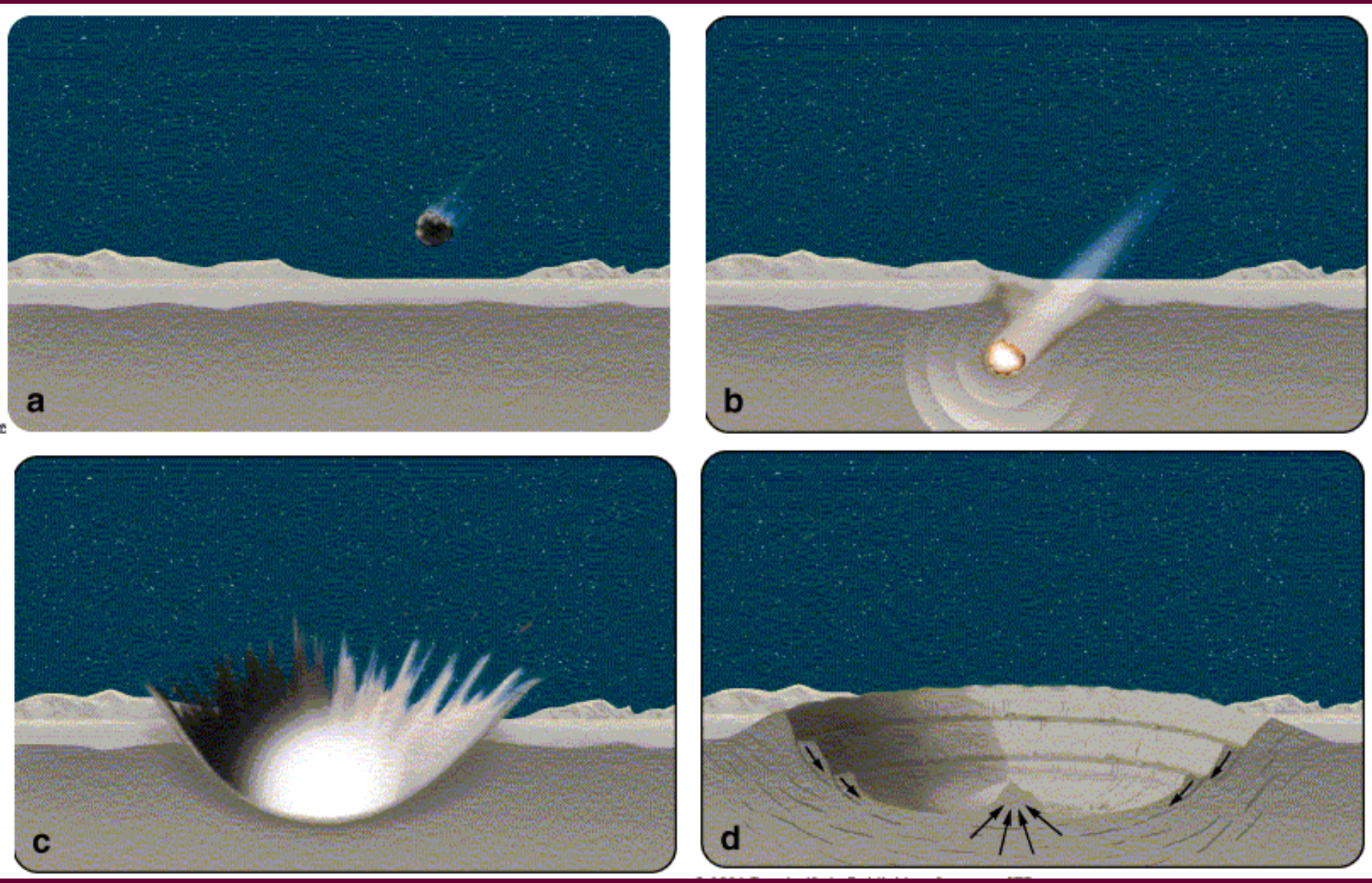
- Historically, they were once regarded as salt deposits from evaporated water (early 1900s) and volcanic ash or dust streaks (late 1940s).
- Now rays are recognized as fragmental material ejected from primary and secondary craters during impact events

Crater Rays

- In laboratory sand-layer vertical impacts, the ejecta does come out evenly around the crater.
- But in a real impact, there are a number of complicating factors.
- There can be variations in the strength (from pre-existing fractures in the surface, or inhomogeneties in the target rock) that lead to "jetting" of ejecta and presumably the rays.

http://en.wikipedia.org/wiki/Image:AS11-42-6285.jpg

http://apod.nasa.gov/apod/image/0503/moon8_mandel.jpg


a
b
c
d

- Only 2.5% of the surface of the far side is covered by mare, compared to 31.2% on the near side.
- The likely explanation is that the far side crust is thicker, making it harder for molten material from the interior to flow to the surface and form the smooth maria.

Why do we always see the same side of the Moon?

- Tidal locking of the Moon's rotation to its orbit (the phenomenon whereby the Moon spins on its axis in the same timespan as it takes to orbit the Earth).

- The lighter-colored areas are called the highlands

Any Questions?