"The Planets"

Astro/EPS C12 (CCN 17045 or 32505)

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LEC: 2 LeConte TWTh, 2:40–5:00pm

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Mon 3–4 and Tue 5–6

TEMPERATURE UNITS

Converting between Kelvin and Celcius:

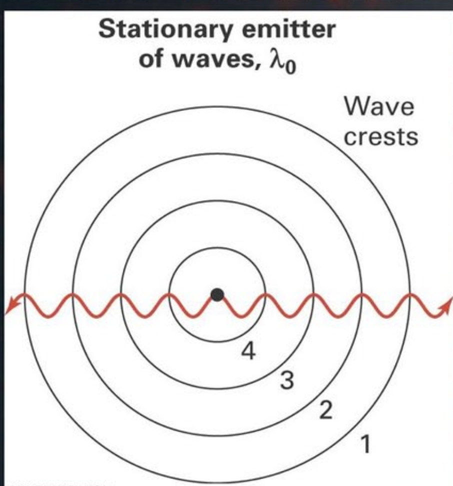
- T[°C] = T[K] – 273

Converting between Kelvin and Fahrenheit :

- T[°F] = T[K] x 9/5 – 459.4

- freezing point of water: 273 K
- boiling point of water: 373 K
- room temperature is about 293 K

DOPPLER SHIFT



Two ways to write the Doppler formula:

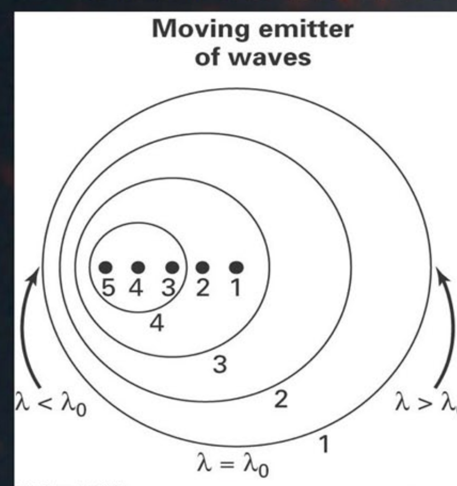
- $\Delta\lambda / \lambda_0 = v / c$
- $\lambda / \lambda_0 = 1 + v / c$

Definition:

- $\Delta\lambda = \lambda - \lambda_0$

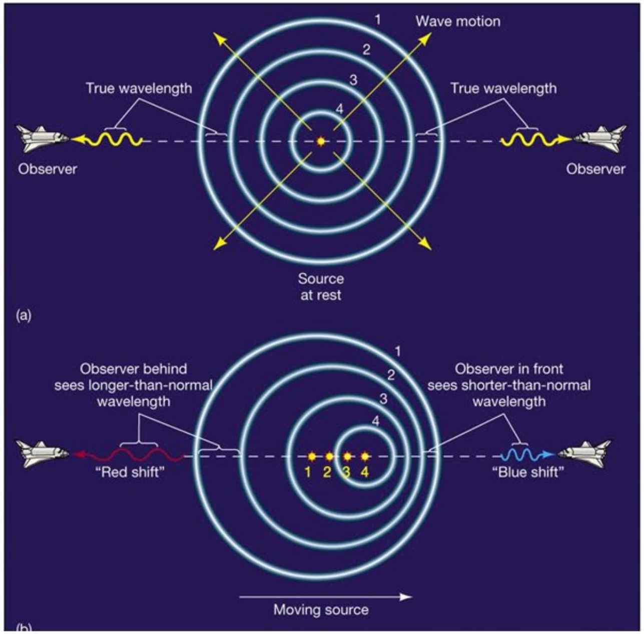
- v = 0 in this picture

DOPPLER SHIFT

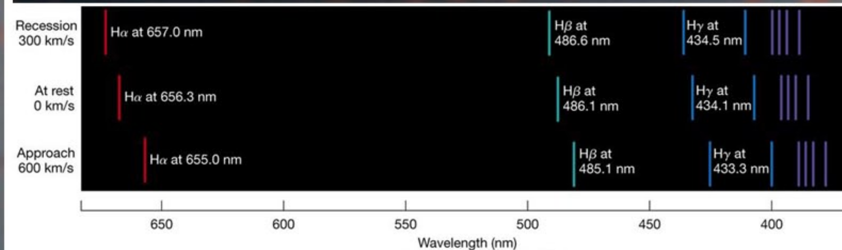


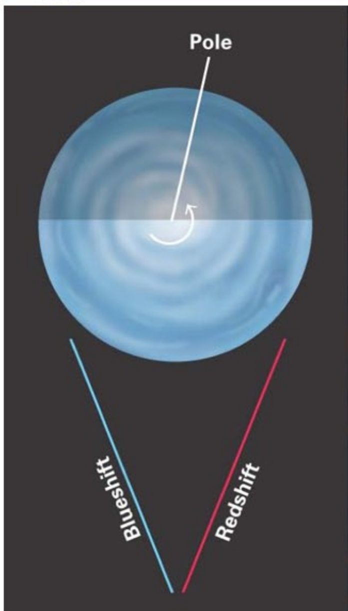
- $\Delta\lambda / \lambda_0 = v / c$

- $v \neq 0$ in this picture



RADIAL VELOCITY

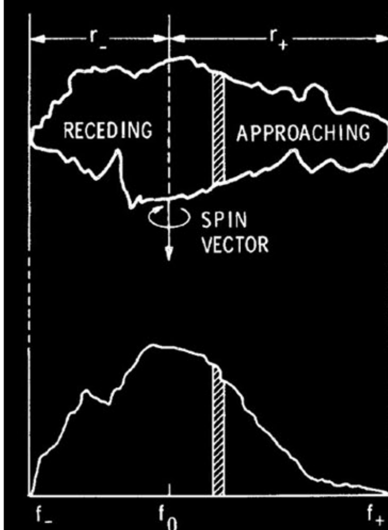




ROTATION

ASTEROID RADAR

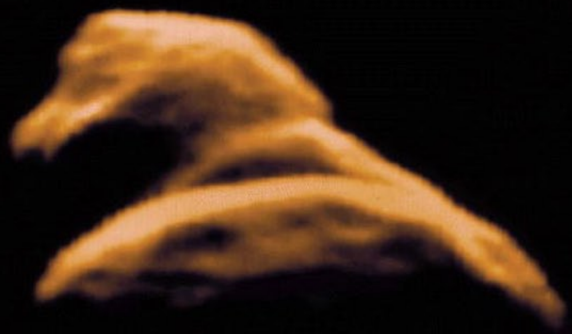
delay-Doppler imaging



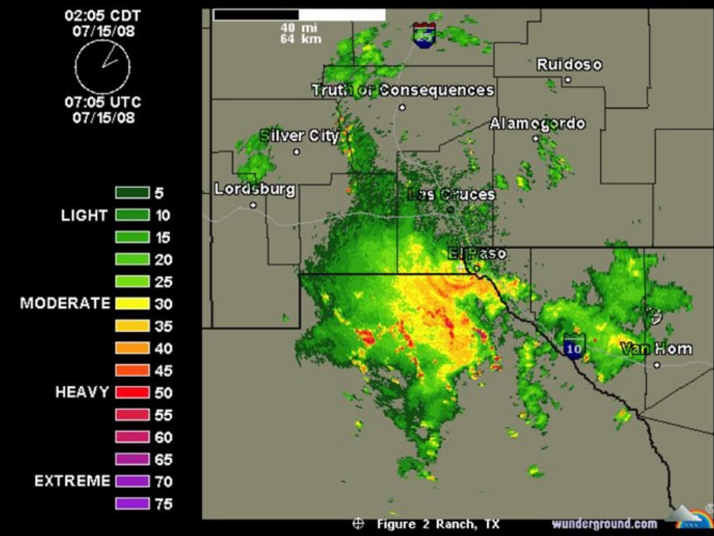
- result is not a "real" image, but can be used to generate models of the shape and spin of asteroids

ASTEROID RADAR

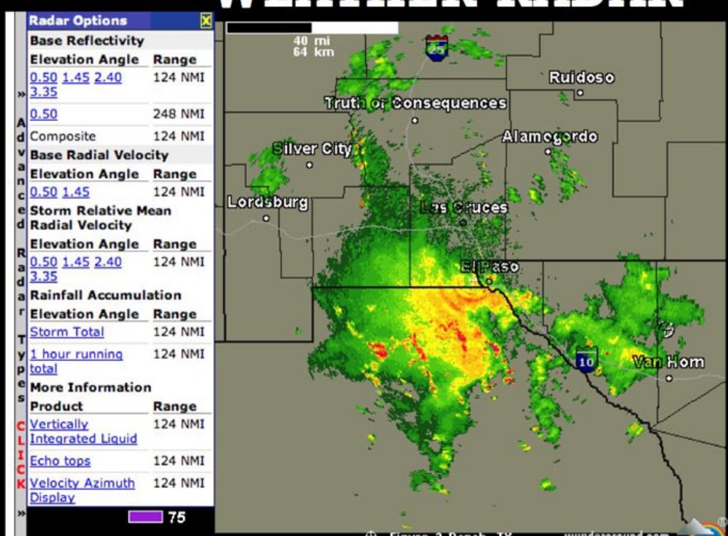
delay-Doppler imaging



WEATHER RADAR

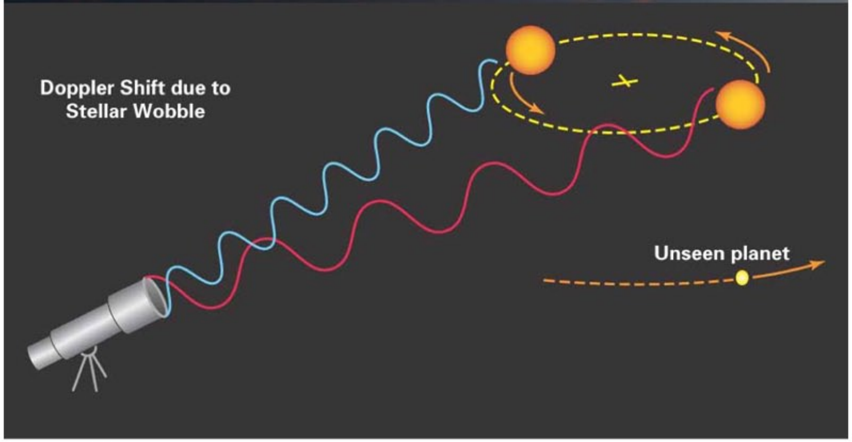


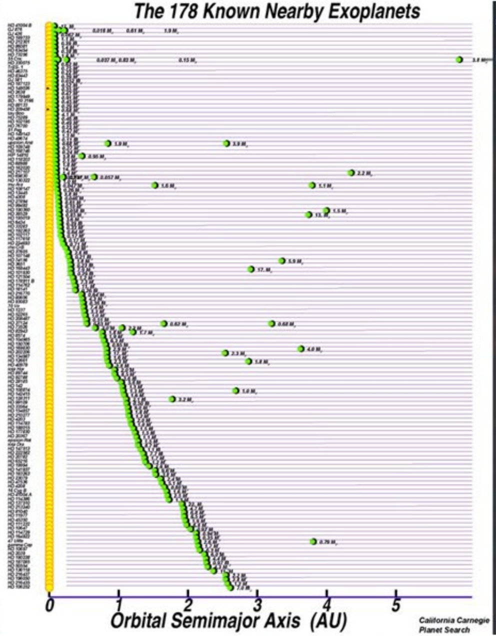
WEATHER RADAR



WEATHER RADAR

EXTRASOLAR PLANET DETECTION

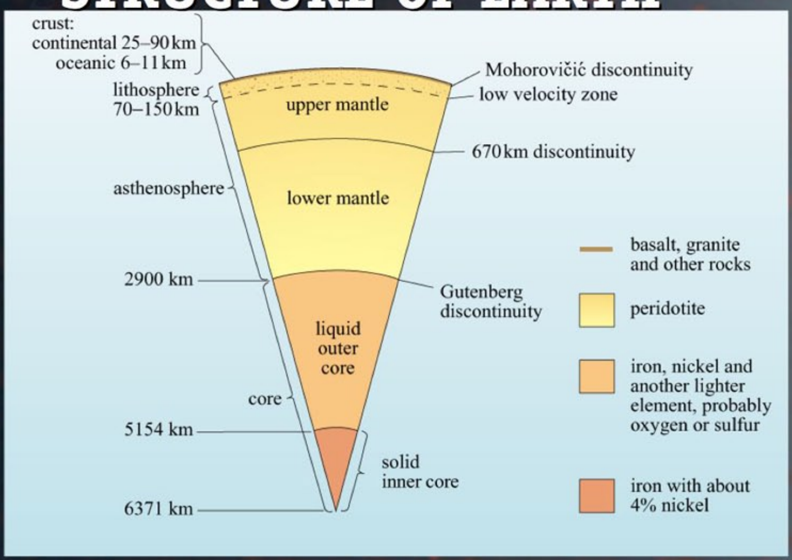


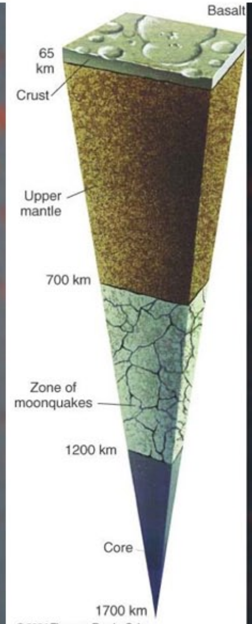


EXOPLANETS (228 now)

1. measure Doppler shifts to get period of revolution and magnitude of shift
2. period gives distance (Kepler's laws)
3. use Newton's law of gravitation to get mass of planet!

STRUCTURE OF EARTH

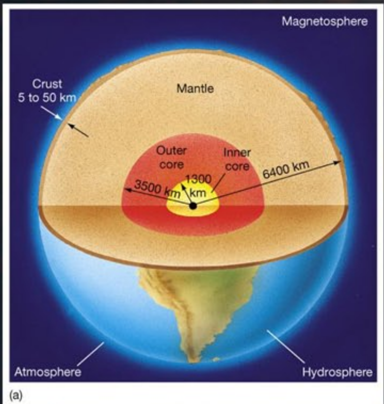




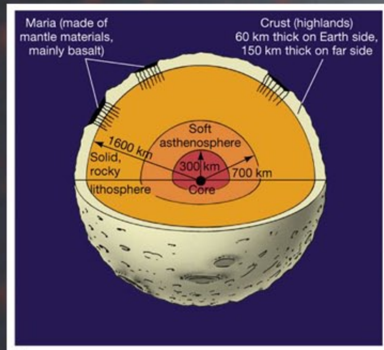
LUNAR INTERIOR

- mostly or all solid
- less iron than in Earth
- studied with seismographs
- moonquake energy equivalent to a firecracker

EARTH AND MOON INTERIORS

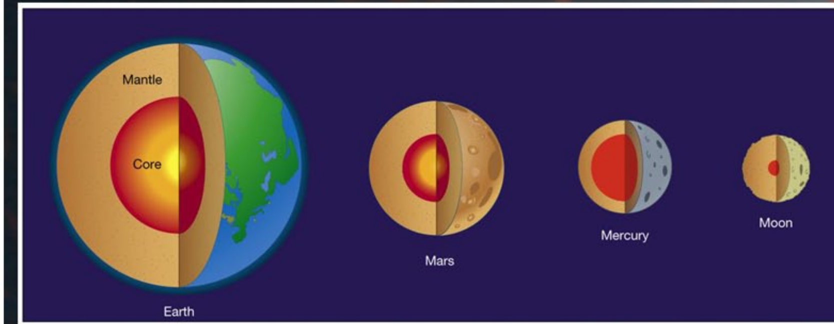


(a)



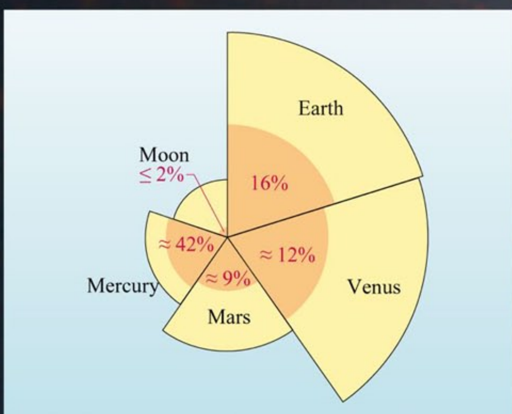
(b)

PLANETARY INTERIORS

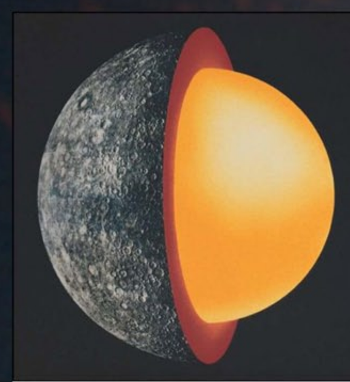


- the terrestrial planets are differentiated
- core-mantle size ratios are different for the different planets

TERRESTRIAL PLANET CORE SIZES

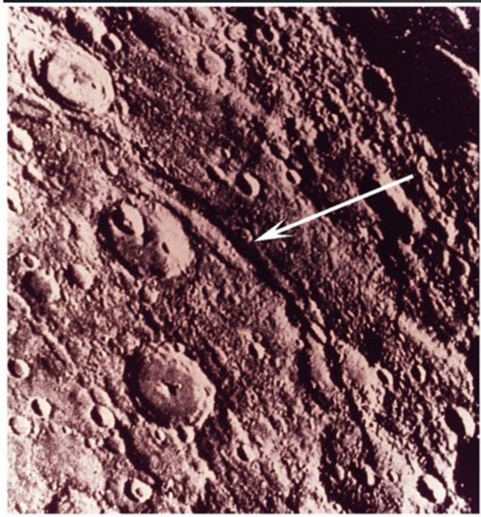


MERCURY'S CORE



- Mercury's core is proportionately the largest out of all terrestrial planets
- possibly due to temperature of formation
- or... ?

MERCURY: SCARPS



- perhaps formed when Mercury cooled, shrank, and cracked

IO

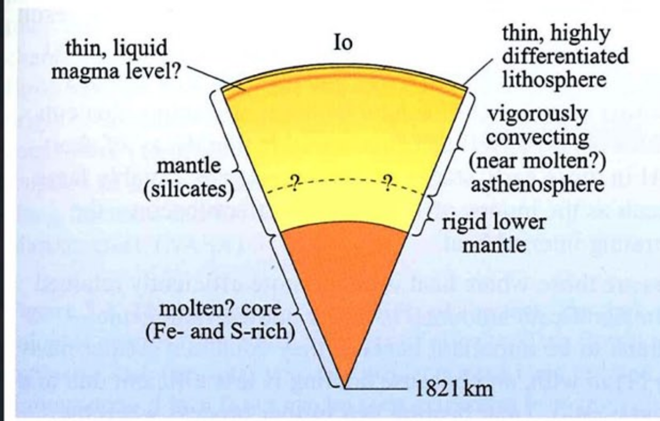


Figure 2.26 Schematic model for the internal structure of Io. The planetary layering within Io is assumed to be highly differentiated because of continual partial melting resulting from the tidally generated high heat flow.

EUROPA

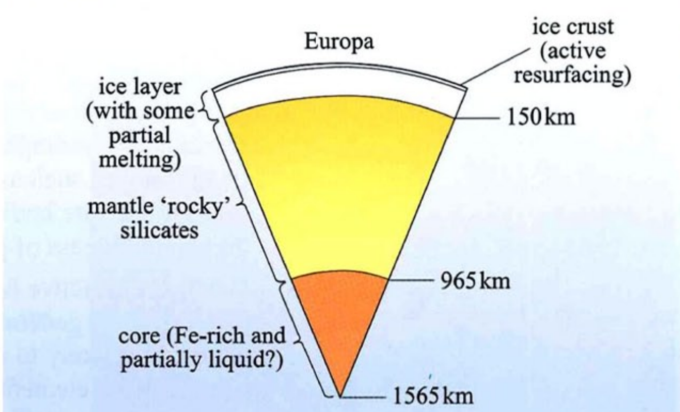
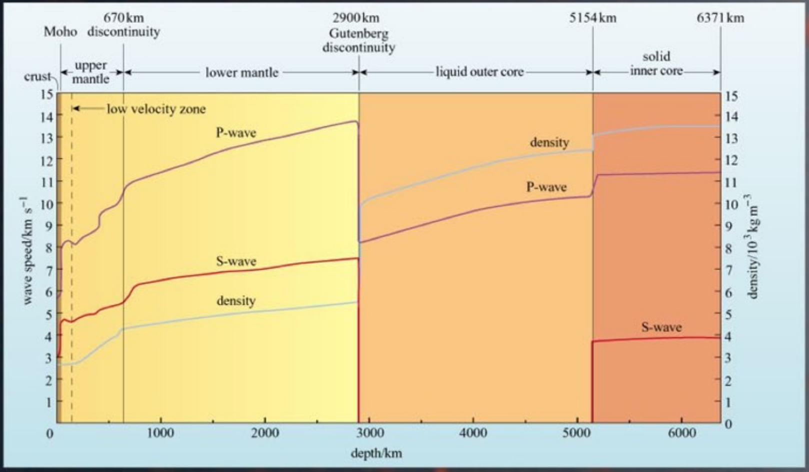


Figure 2.27 Schematic model for the internal structure of Europa.

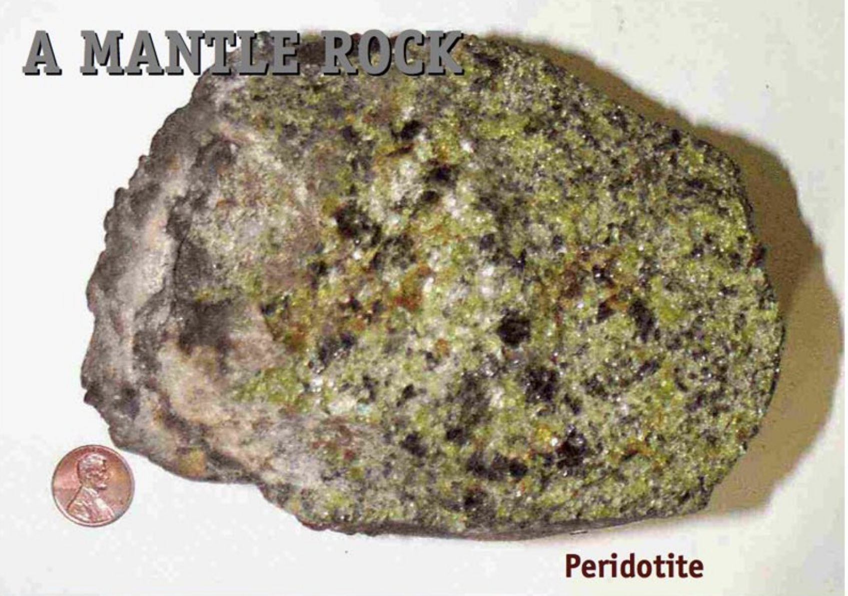
PLANETARY DENSITIES

Planet	Observed Density (g/cm^3)	Uncompressed Density (g/cm^3)
Mercury	5.44	5.4
Venus	5.24	4.2
Earth	5.50	4.2
Mars	3.94	3.3
(Moon)	3.36	3.35

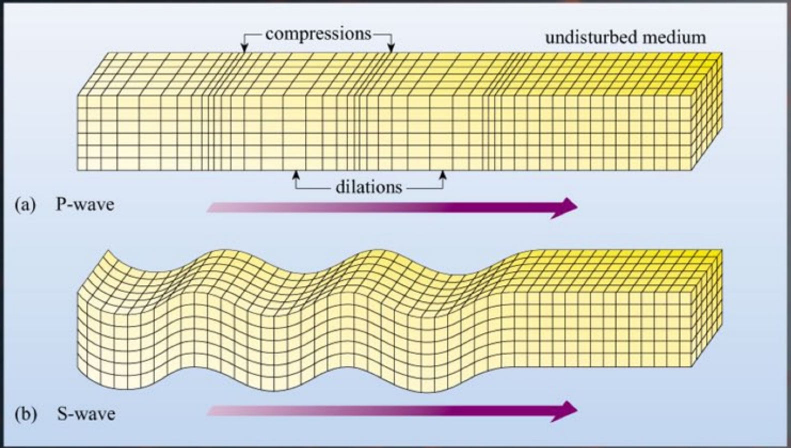
VELOCITY and DENSITY



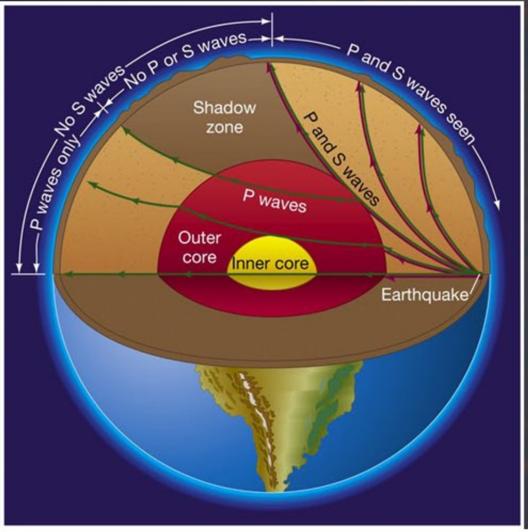
A MANTLE ROCK



SEISMIC WAVES

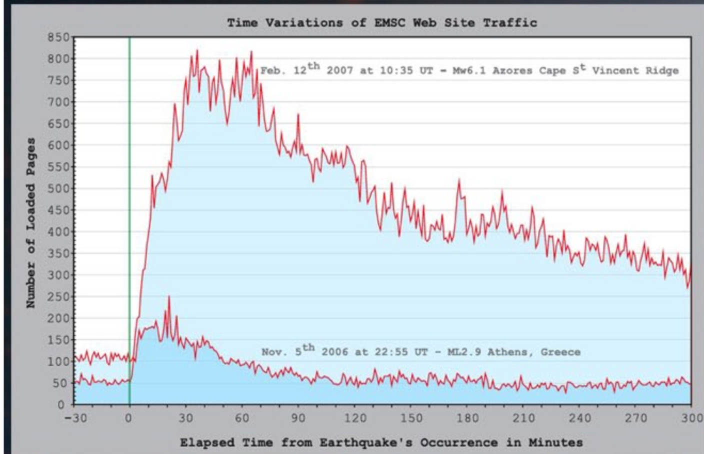


SEISMIC WAVES



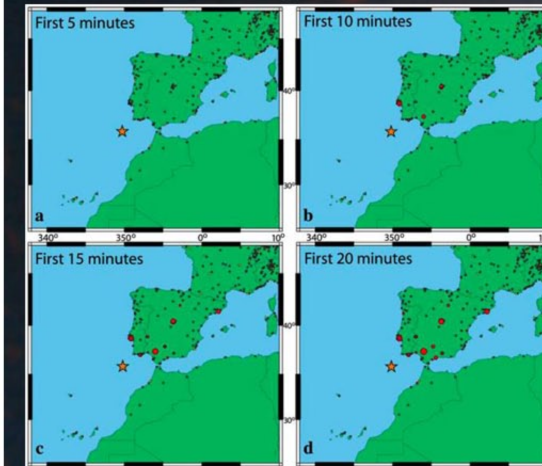
- "P"rimary waves pass through liquid and solid
- "S"econdary waves pass only through solid
- wave speeds depend on density

DETECTING EARTHQUAKES



Bossu (2008), *Eos*

DETECTING EARTHQUAKES



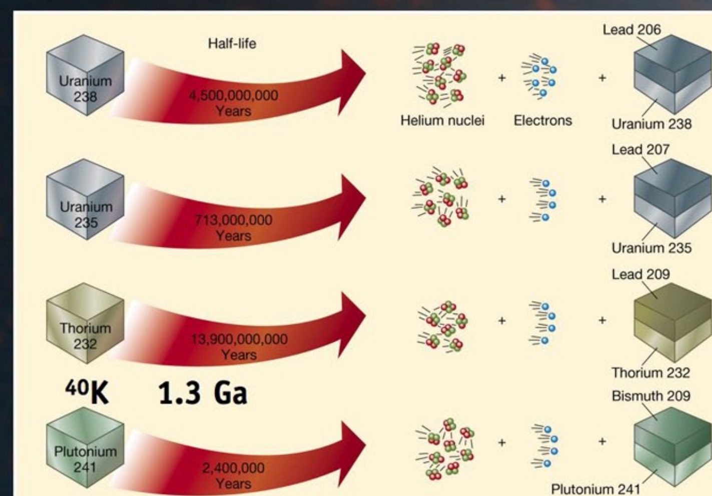
- red dots = abnormally high web traffic to European-Mediterranean Seismic Centre website
- web traffic response can be faster than regular seismological procedures

Bossu (2008), *Eos*

HEATING PLANETARY INTERIORS

- gravitational energy from formation
  - impacts
  - differentiation
- tidal heating
- nuclear energy
  - radioactive decay (fission, not fusion)
  - uranium, thorium, potassium
  - aluminum-26 was important for some asteroids

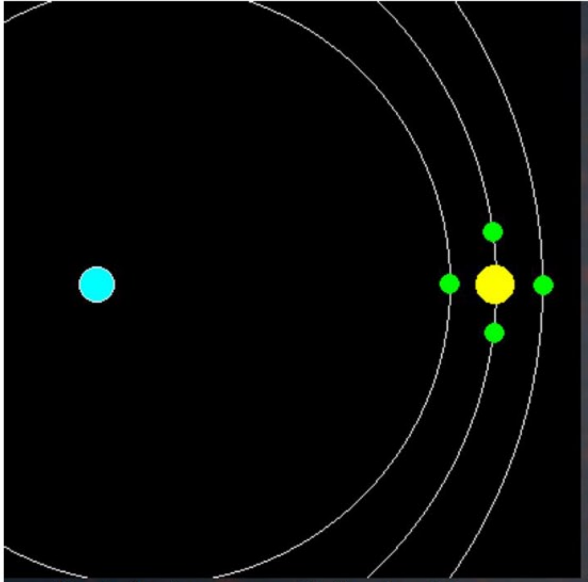
RADIOGENIC HEATING



^{40}K 1.3 Ga

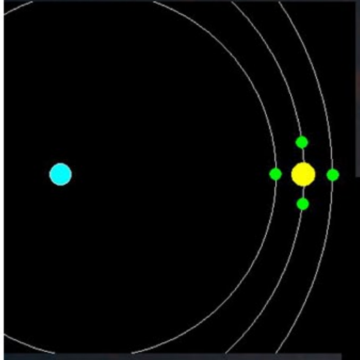
DEPLETED URANIUM

	92 U Uranium 234 250,000 years	92 U Uranium 235 700 million years	92 U Uranium 238 4.5 billion years
Natural Uranium:	0.005%	0.720%	99.274%
Depleted Uranium:			100%

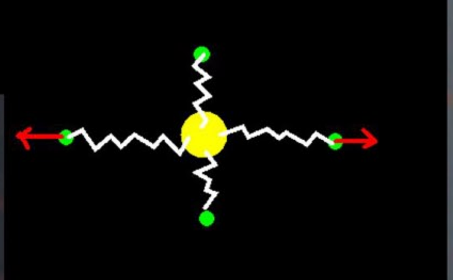


TIDAL FORCES

graphics by Davison Soper at University of Oregon

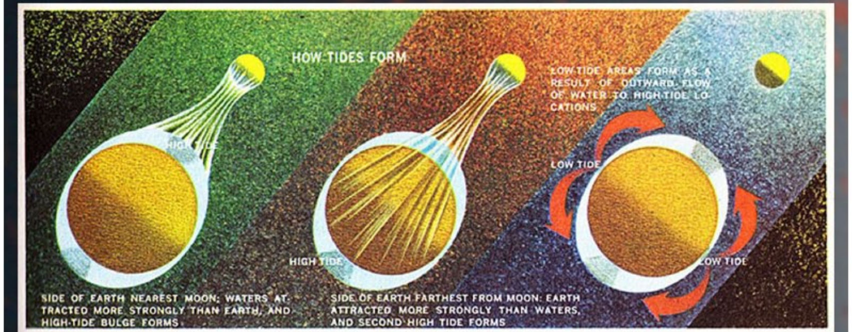


TIDAL FORCES



graphics by Davison Soper at University of Oregon

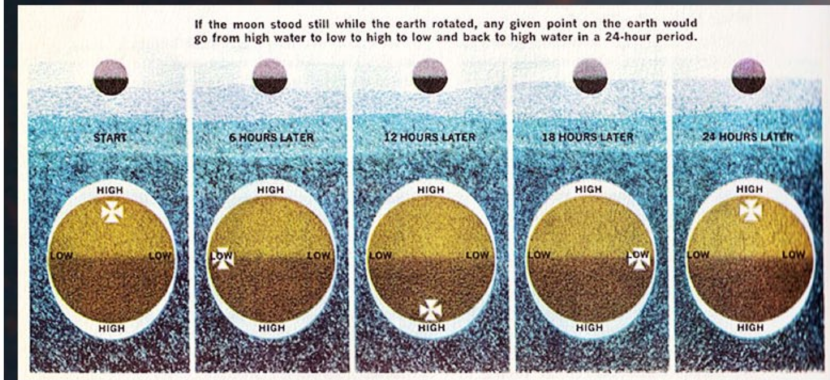
TIDES



Tides are caused mainly by the moon's gravitational pull on the earth and its waters. For example, on the side of the earth nearest the moon, the waters are attracted more strongly than the earth, so a bulge of water—the high tide—forms.

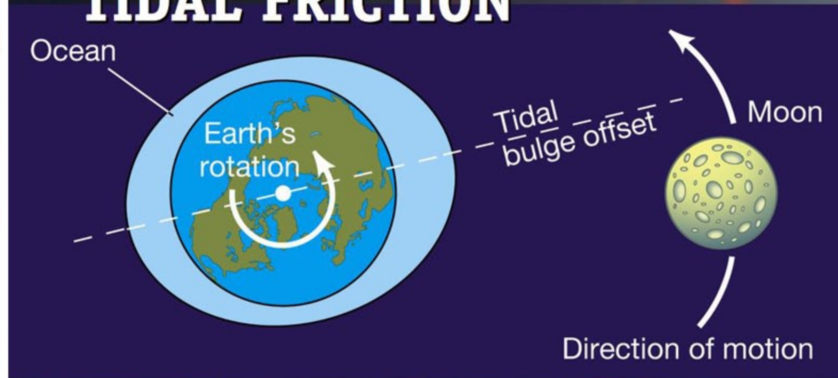
- water closest to moon attracted most strongly
- planet attracted to moon more strongly than far-side water attracted to moon

TIDES



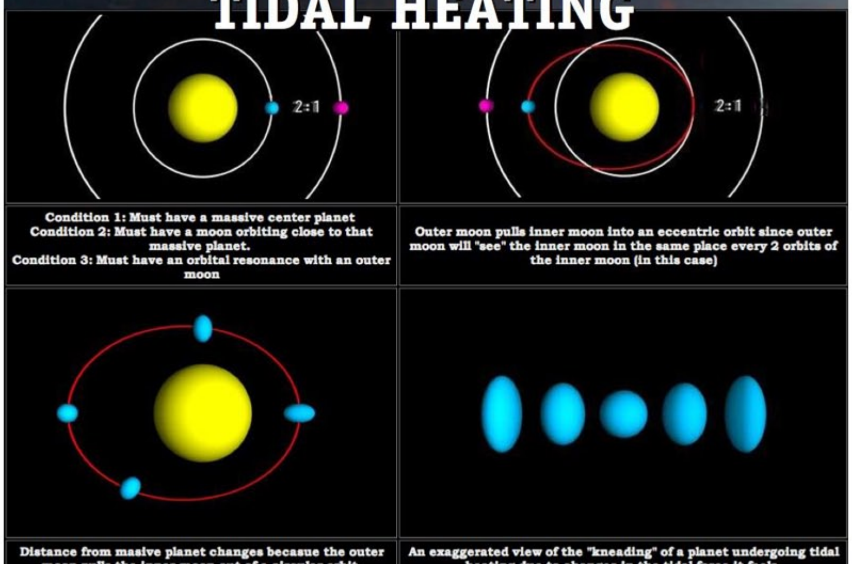
- on average, there is a delay of about an hour due to Earth's rotation

TIDAL FRICTION



- 0.5 billion years ago: 400 days/yr and the Moon was closer
- Future: ~8 days/yr and the Moon will be farther

TIDAL HEATING



Toby Smith & Ana Marie Larson, Washington University

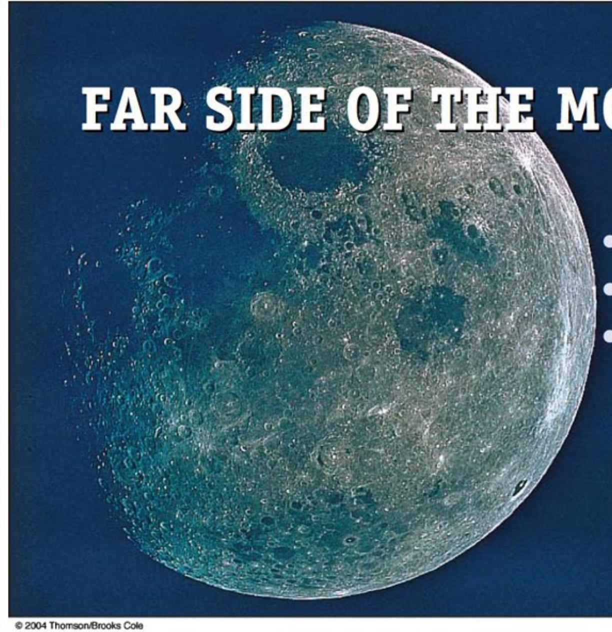
IO and EUROPA

MOON IS TIDALLY LOCKED

- one side always faces the Earth

- future of the Earth-Moon system:
- slower Earth rotation
- farther separation
- synchronous Earth rotation

FAR SIDE OF THE MOON



- thicker crust
- less maria
- "far side" vs. "dark side"

TECTONIC PLATES

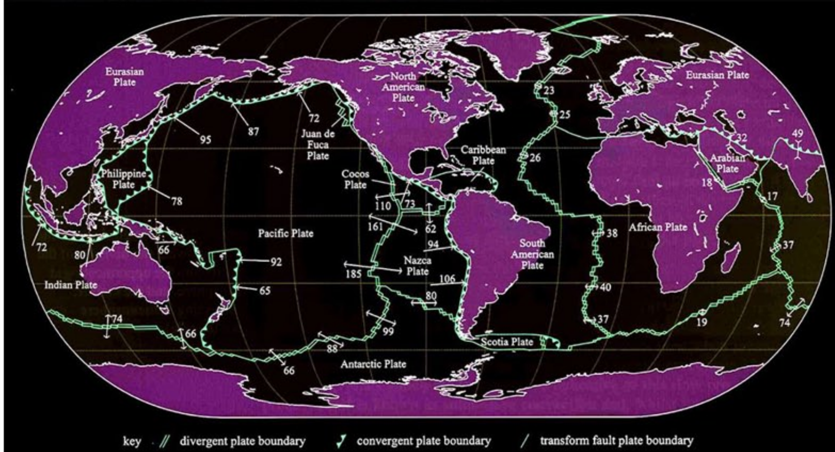
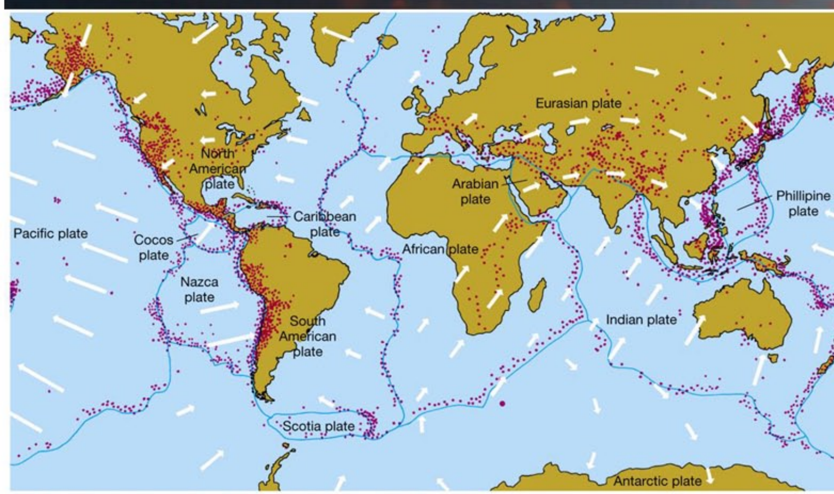
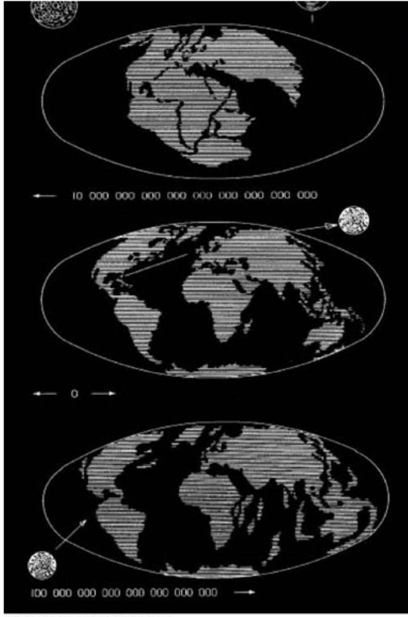


Figure 2.15 Map showing the global distribution of plates and plate boundaries. The black arrows and numbers give the direction and speed of relative motion between plates. Speeds of motion are given in mm yr^{-1}.

ACTIVITY

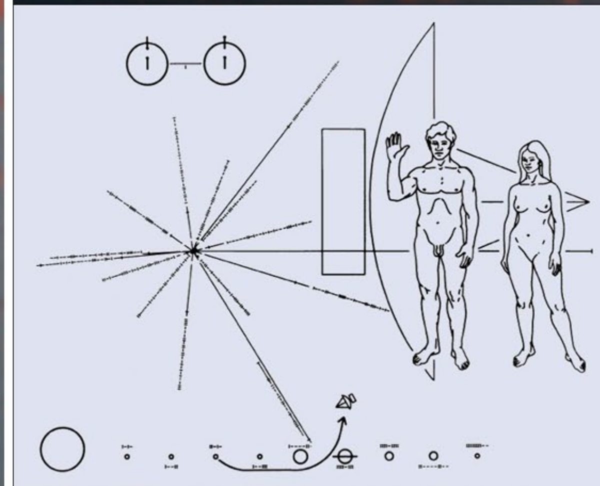




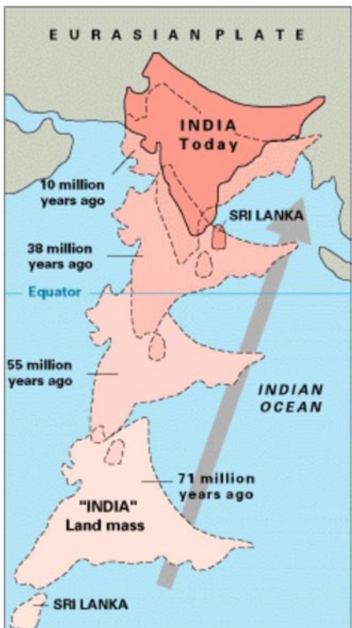
CONTINENTAL DRIFT

- plaque on LAGEOS
  - 270 Mya
  - present
  - 8 My in the future
- CA detaches
- proto-continent called "pangaea"

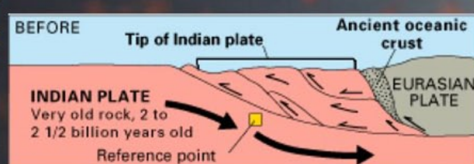
PIONEER PLAQUE

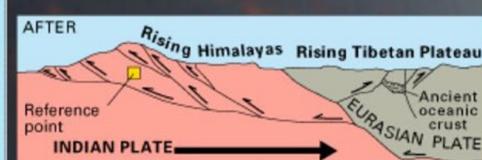


- 21-cm line
- also showed continental drift



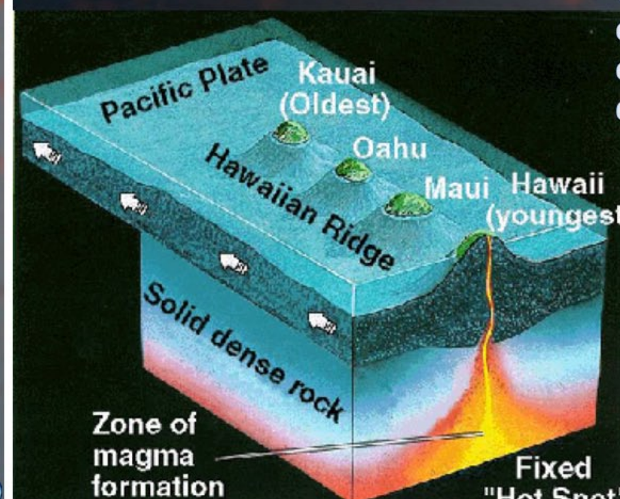
CONTINENTAL DRIFT



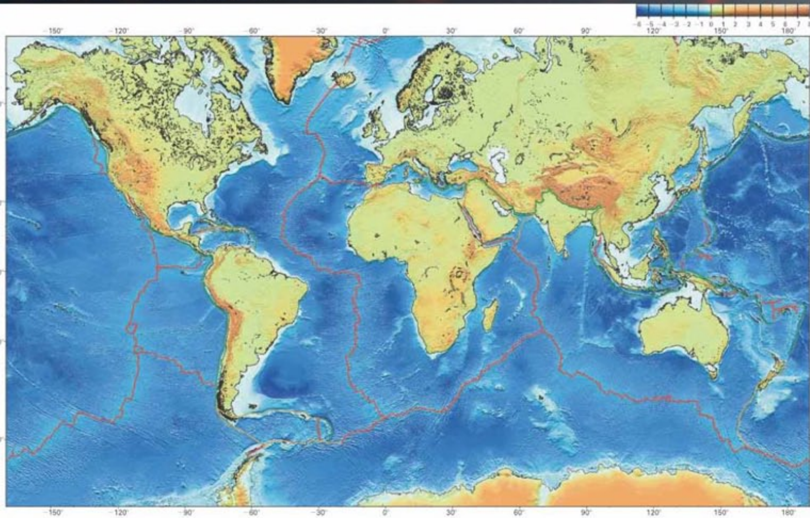


HOT SPOTS

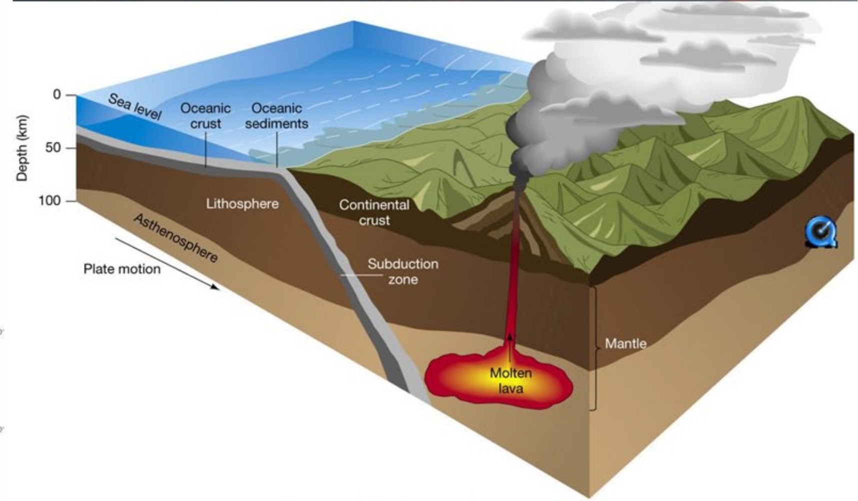
- mantle plumes
- volcanoes not caused by continental drift



RIFT ZONES



SUBDUCTION

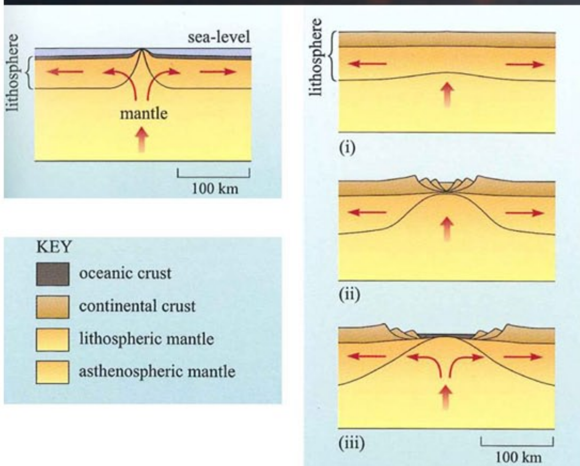


VOLCANOES

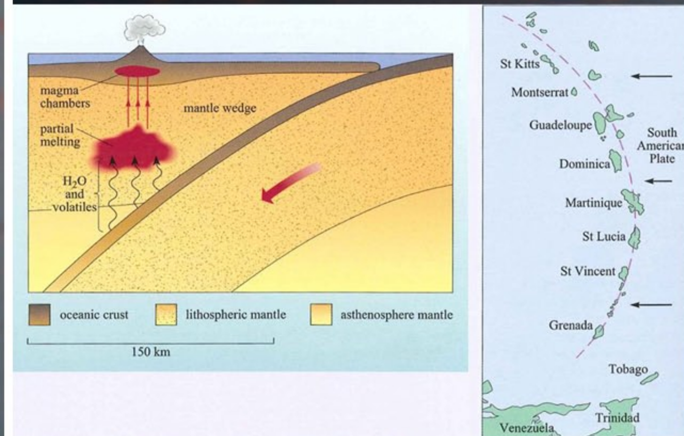
MELTING MAGMAS

- decompression melting
  - materials may be solid at high temp, high pressure, but not at high temp low pressure
- hydration-induced melting
  - subduction introduces volatiles to the mantle
  - volatiles react with mantle material to create new minerals with lower melting temperatures

DECOMPRESSION MELTING



HYDRATION-INDUCED MELTING



ERUPTION TYPES

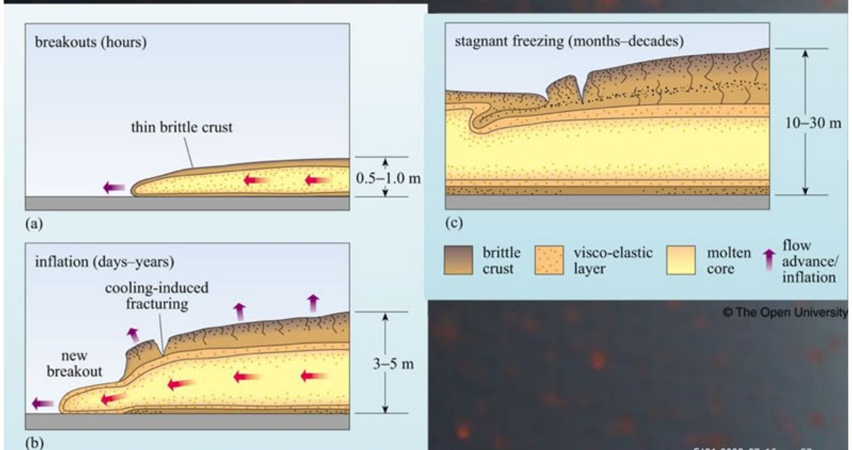
- effusive
  - flowing lava
  - relatively quiescent
  - flows depend on gravity, viscosity, yield strength, flow rates
- explosive
  - pyroclastic materials (mainly ash)
  - caused by high gas contents
  - high viscosity magma resists gas release; the pressurized gas explodes at the surface

EFFUSIVE/EXPLOSIVE

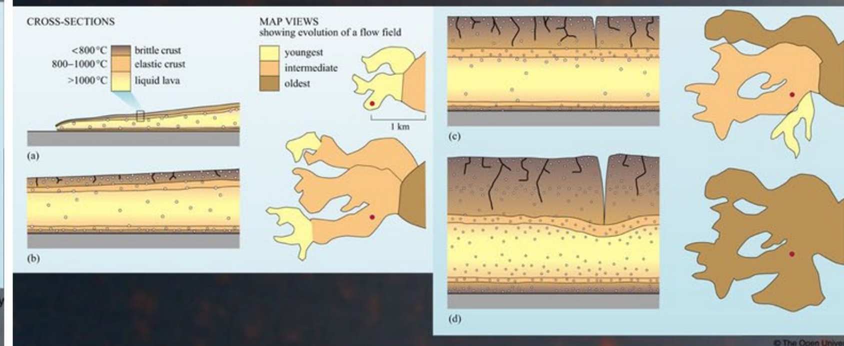
Figure 3.11 Effusive eruptions. (a) Basalt lava oozes from a vent on Etna. (b) Fire fountain during the eruption of basaltic lava at Pu'u'O'o, Hawaii. ((a) Steve Self/Open University; (b) USGS: Photo by J. D. Griggs)

Figure 3.12 Explosive eruption. View of the eruption column from Mount St Helens, May 1980. The prevailing wind was blowing from right to left, and slightly away from the viewpoint. Much of the ash was deposited in the region downwind of the volcano. (USGS)

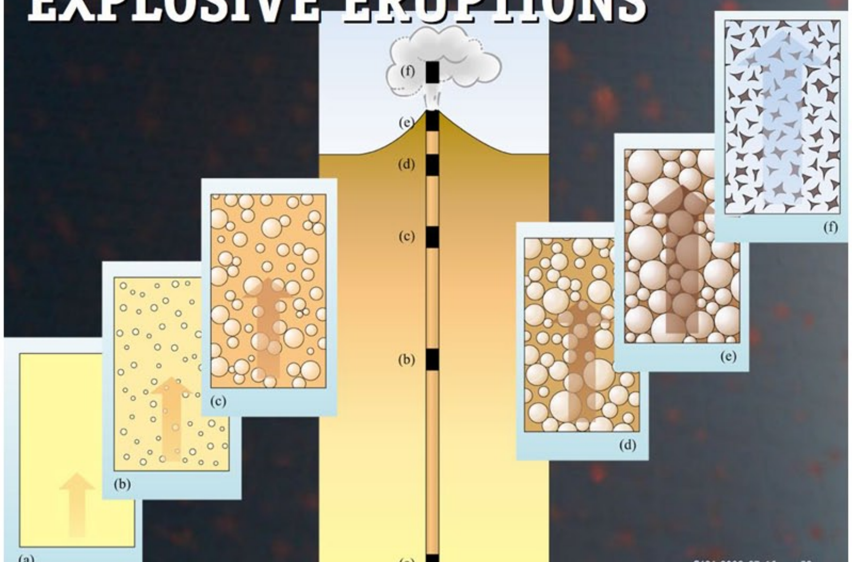
FLOOD BASALT CRUSTS



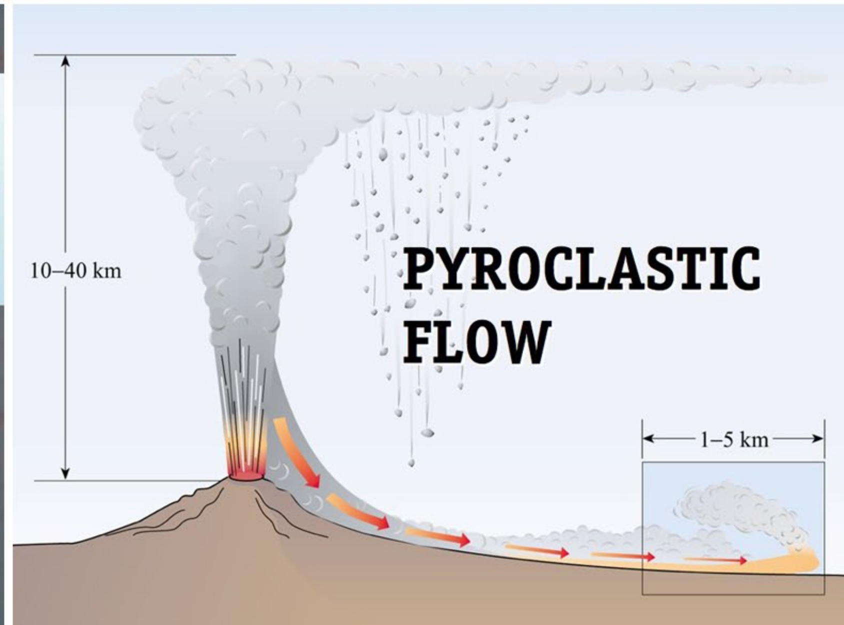
CONTINENTAL FLOOD BASALTS

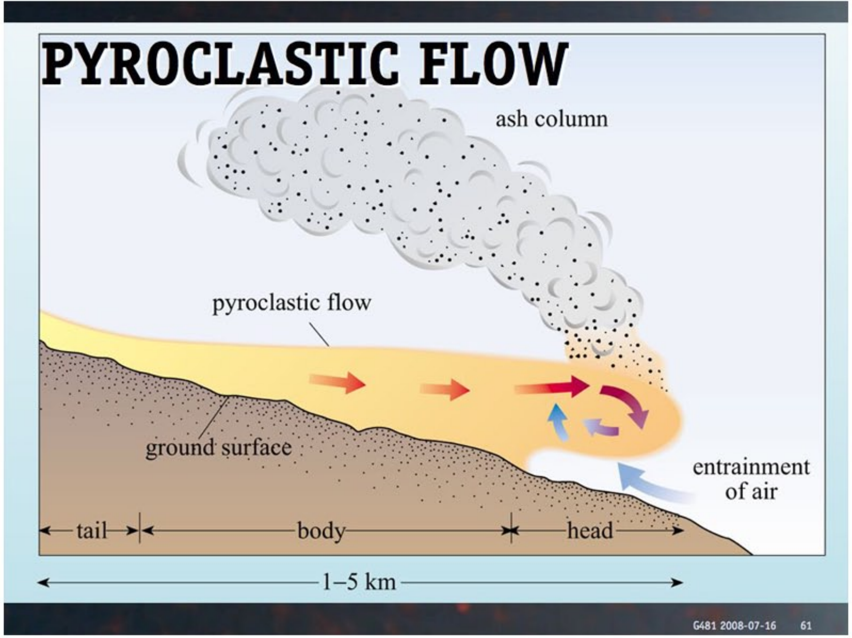


EXPLOSIVE ERUPTIONS

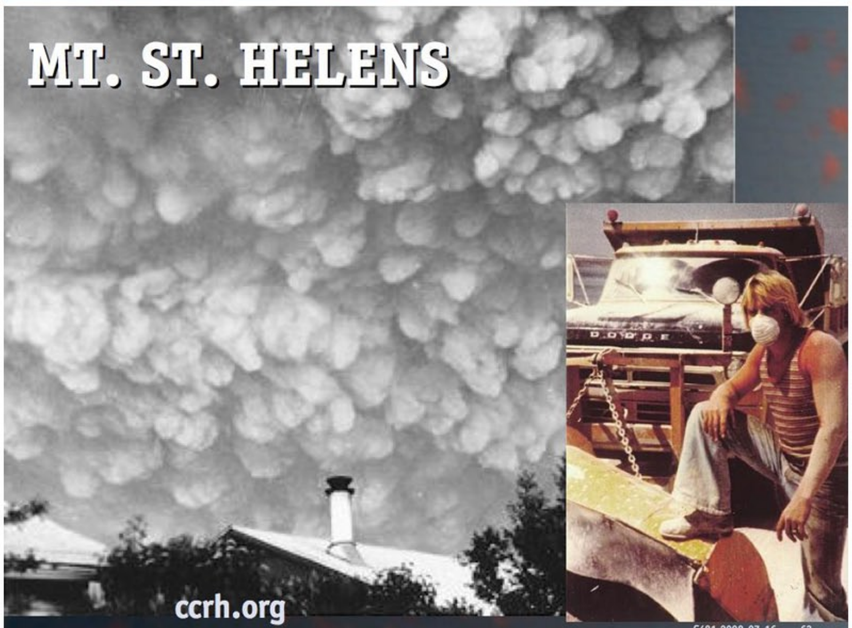


PYROCLASTIC FLOW




PYROCLASTIC FLOW
ash column
pyroclastic flow
ground surface
entrainment of air
tail
body
head
1–5 km
G481 2008-07-16 61

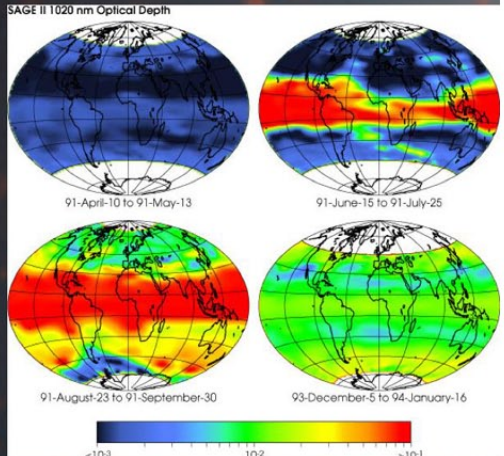

MT. ST. HELENS
G481 2008-07-16 62


MT. ST. HELENS
ccrh.org
DODGE
G481 2008-07-16 63


MT. PINATUBO
G481 2008-07-16 64

MT. PINATUBO

- injected SO_2 into stratosphere
- $SO_2 + H_2O$ --> sulfuric acid
- Earth's temperature was lowered for 2 years



CRATER LAKE, OR

VOLCANO EXPLOSIVITY INDEX

Table 3.2 Relative sizes of terrestrial volcanic eruptions and the volcanic explosivity index (VEI) showing the importance of pyroclastic materials according to the degree of explosivity of the eruption.

	Volcanic explosivity index (VEI)								
	0	1	2	3	4	5	6	7	8
general description	non-explosive	small	moderate	moderate –large	large	very large			
qualitative description	gentle	effusive	←	explosive	→←	cataclysmic or paroxysmal	→←	super-eruptions	→
maximum erupted pyroclastic volume (m^3)	10^4	10^6	10^7	10^8	10^9 (1 km^3)	10^{10} (10 km^3)	10^{11} (100 km^3)	10^{12} (1000 km^3)	10^{13}
eruption cloud column height (km)	<0.1	0.1–1	1–5	3–15	10–25	>25	>25	>25	>25

VOLCANO EXPLOSIVITY INDEX

Table 3.3 Eruption examples: volcanic explosivity index (VEI) and eruption column height.

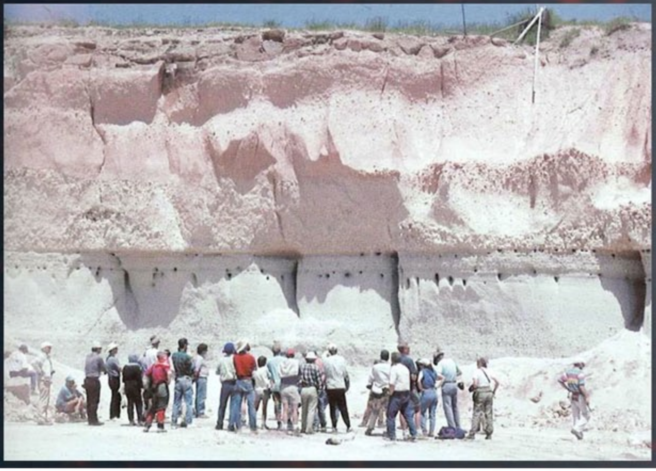
VEI rating	Eruption column height (km)	Example
0	<0.1	basalt lava eruptions, e.g. Hawaii and Iceland
1	0.1–1	fire fountains in basaltic lavas, e.g. Hawaii and Iceland
2	1–5	Hekla, Iceland, 2000
3	3–15	El Chichon, Mexico, 1982
4	10–25	Mount St Helens, USA, 1980
5	>25	Krakatau, Indonesia, 1883; Pinatubo, Philippines, 1991
6	>25	Bishop Tuff pyroclastic deposit, Long Valley caldera, California, USA, 700 000 years ago
7	>25	Toba, Lake Toba caldera, Sumatra, Indonesia, 75 000 years ago
8	>25	Yellowstone, USA, 2 Ma, 1.3 Ma and 640 000 years ago

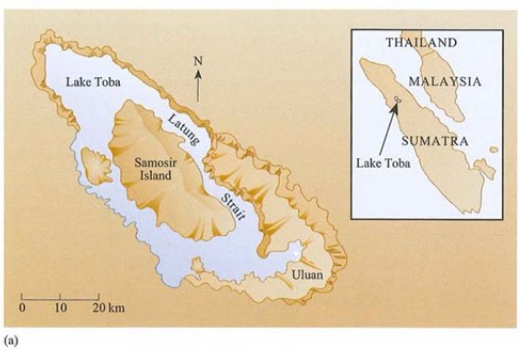
SUPER-ERUPTIONS

- large amounts of viscous gassy magma collect near surface
- sudden explosive release
- collapse forms a caldera
- volcanic winter

YELLOWSTONE ASH DEPOSITS

- 1.3 million years old





(a)

(b)

Figure 3.20 (a) Topographic sketch and regional setting (inset), of the giant Toba caldera, Sumatra, which is 100 km in length. The caldera consists of a vast, elongate depression, now filled by Lake Toba. Towards the centre, Samosir Island marks a site where later magmatic movements have elevated the caldera floor by about 500 m. (b) View of part of the western caldera rim of Lake Toba. (Steve Blake/Open University)

SUPER-ERUPTION: TOBA

VESUVIUS ASH DISTRIBUTION

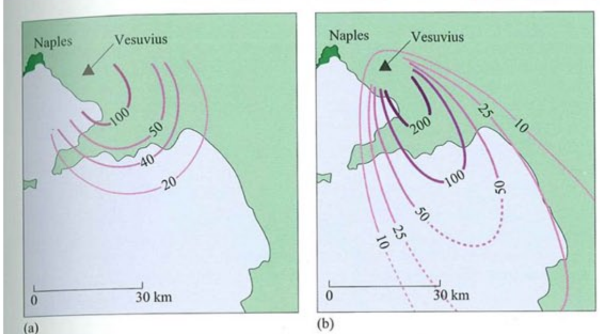
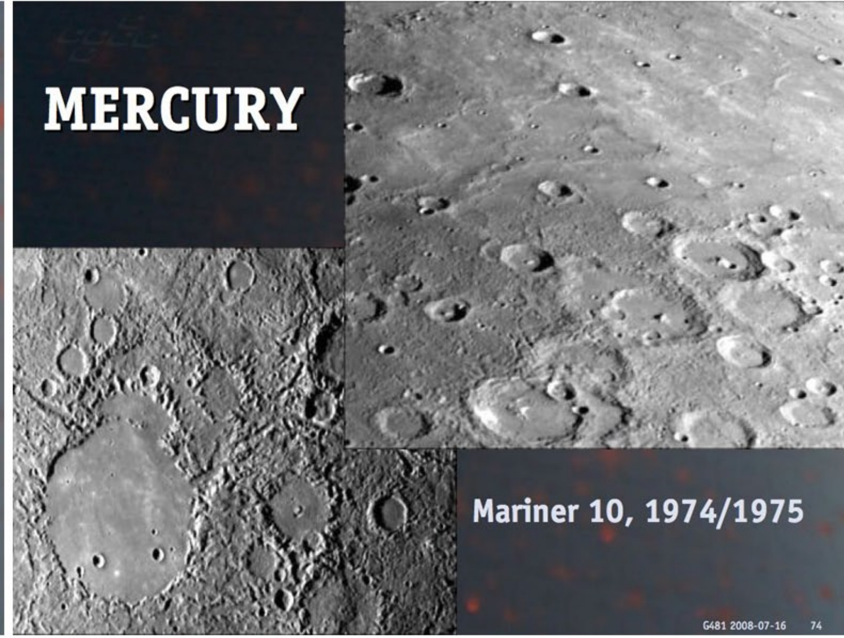
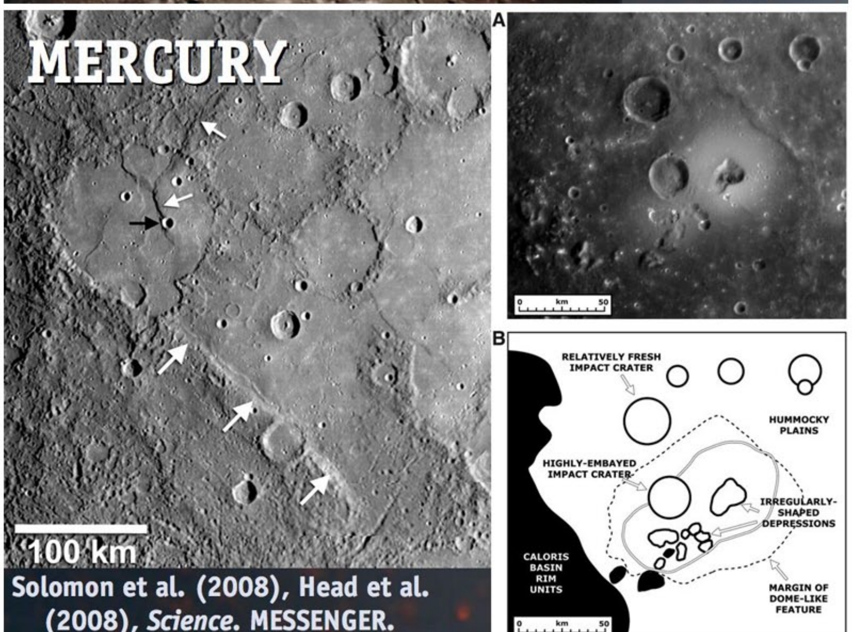


Figure 3.24 Examples of *isopleth* and *isopach* maps for the ash deposited by the famous AD 79 eruption of Vesuvius, which obliterated the city of Pompeii. (a) An isopleth map shows the distribution of maximum sizes (in millimetres) of pumice fragments in the deposit. (b) An isopach map shows the thickness of the deposit in centimetres. The effect of the northwesterly wind is evident from the asymmetrical distribution of ash. (Lirer *et al*., 1973)

- terminal fall speed is a function of particle size and density


LUNAR
VOLCANISM
G481 2008-07-16 73


MERCURY
Mariner 10, 1974/1975
G481 2008-07-16 74


MERCURY
100 km
Solomon et al. (2008), Head et al. (2008), *Science*. MESSENGER.
A
0 km 50
B
RELATIVELY FRESH IMPACT CRATER
HUMMOCKY PLAINS
HIGHLY-EMBAYED IMPACT CRATER
IRREGULARLY-SHAPED DEPRESSIONS
CALORIS BASIN RIM UNITS
MARGIN OF DOME-LIKE FEATURE
0 km 50


VENUS: DOMES
• NASA Magellan radar
• 25-km diameter
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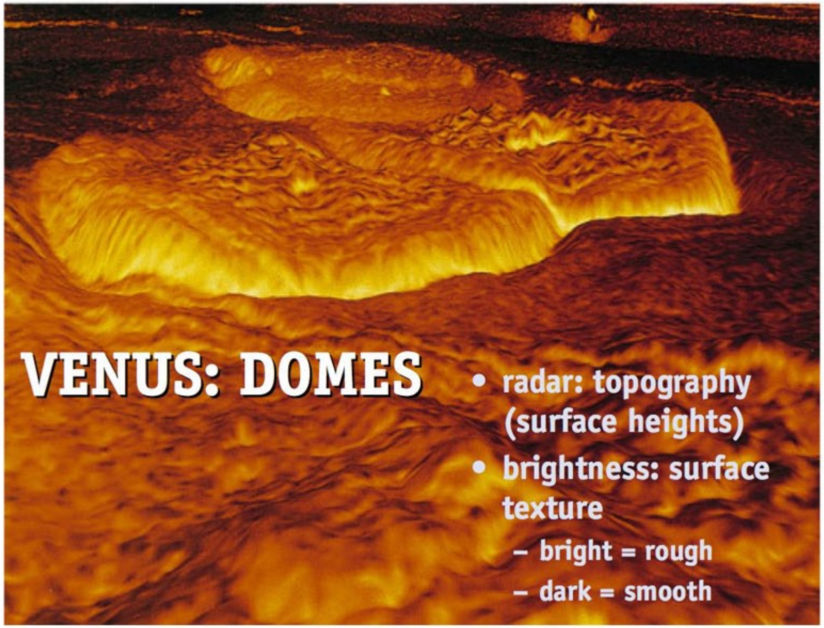
VENUS: DOMES
• radar: topography (surface heights)
• brightness: surface texture
– bright = rough
– dark = smooth


VENUSIAN CHANNEL
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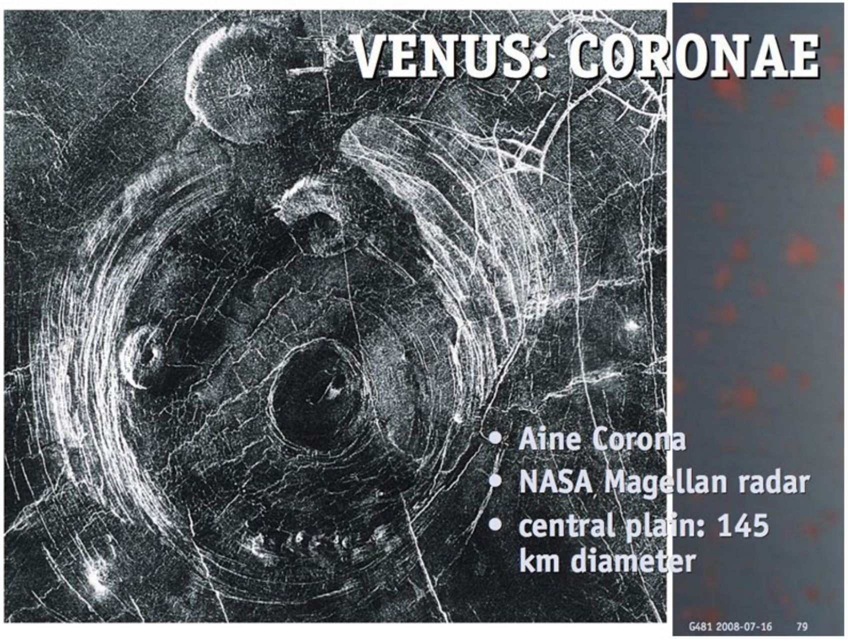
VENUS: CORONAE
• Aine Corona
• NASA Magellan radar
• central plain: 145 km diameter
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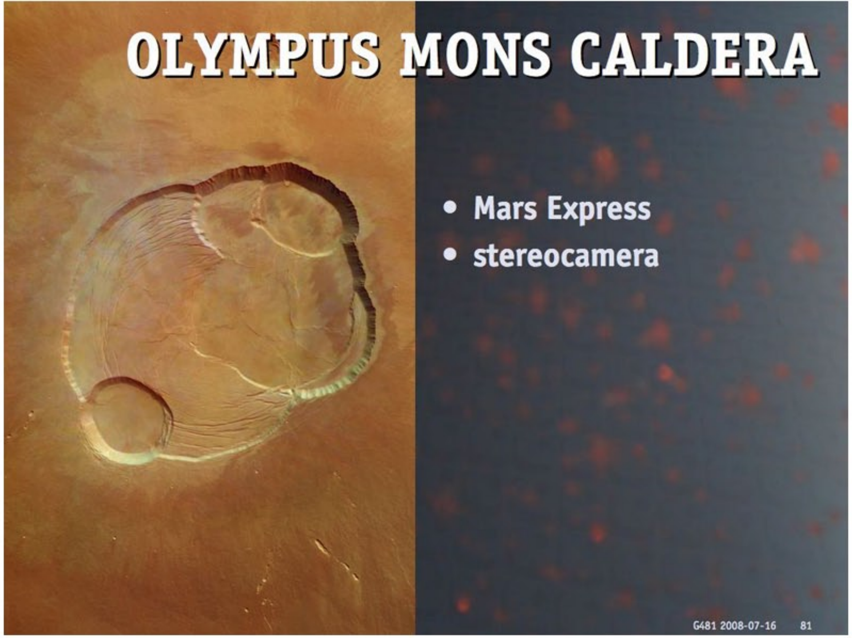
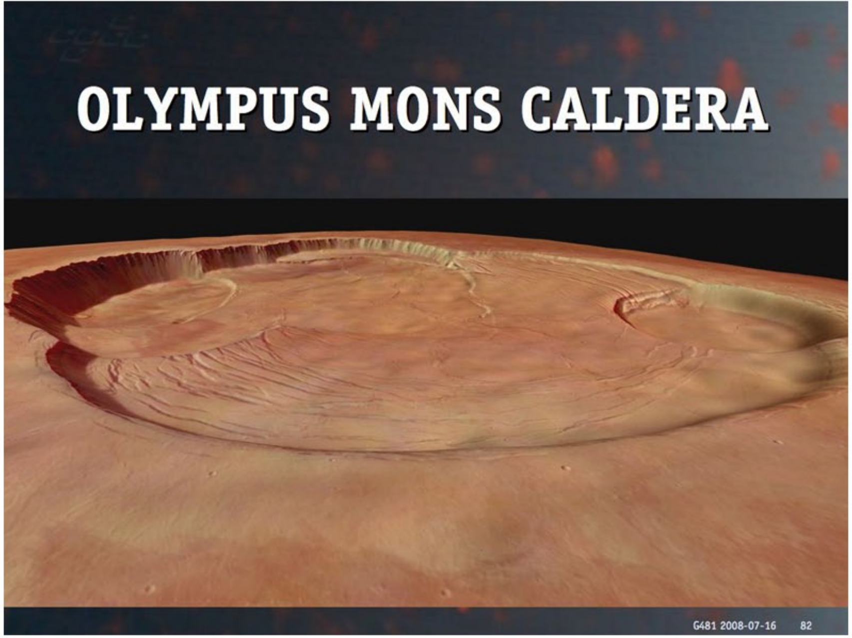
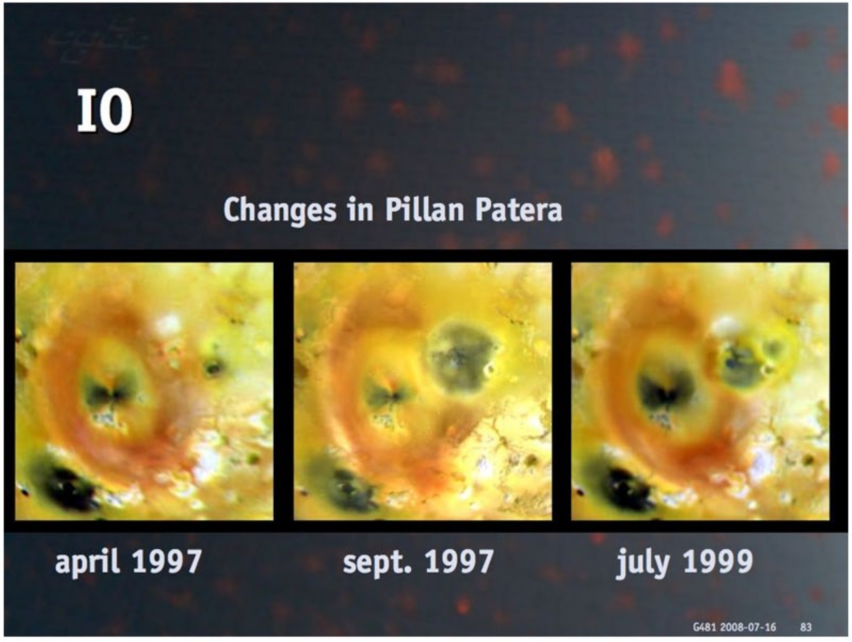
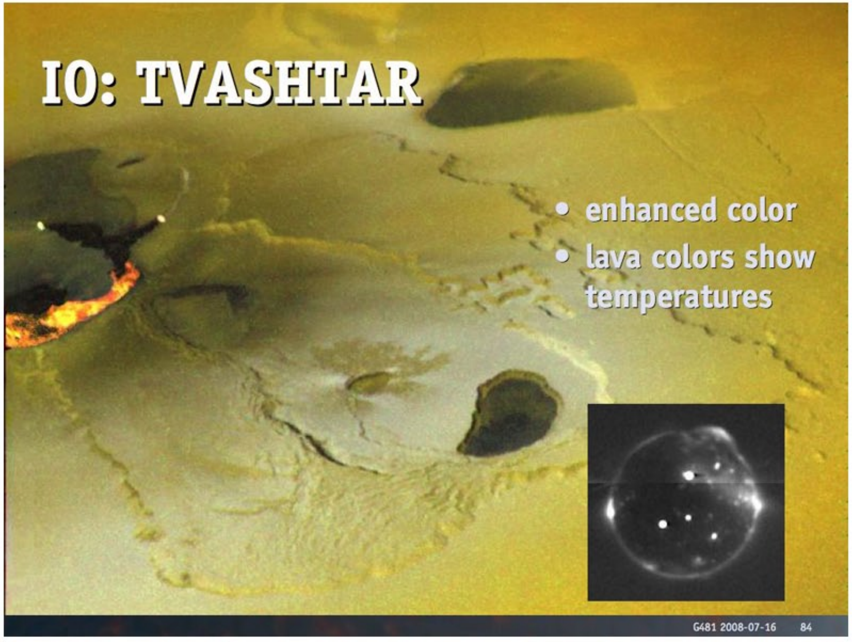
• Mars Odyssey images
• Olympus Mons is "young:" 400-500 million years
G481 2008-07-16 80

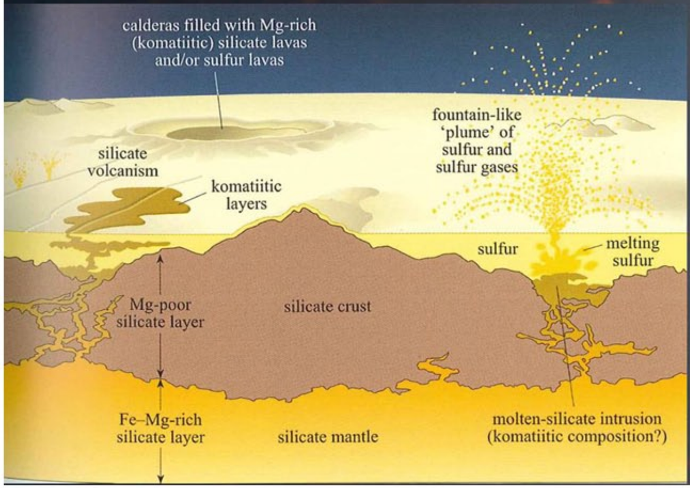

OLYMPUS MONS CALDERA
• Mars Express
• stereocamera
G481 2008-07-16 81


OLYMPUS MONS CALDERA
G481 2008-07-16 82


IO
Changes in Pillan Patera
april 1997
sept. 1997
july 1999
G481 2008-07-16 83


IO: TVASHTAR
• enhanced color
• lava colors show temperatures
G481 2008-07-16 84

VOLCANISM ON IO

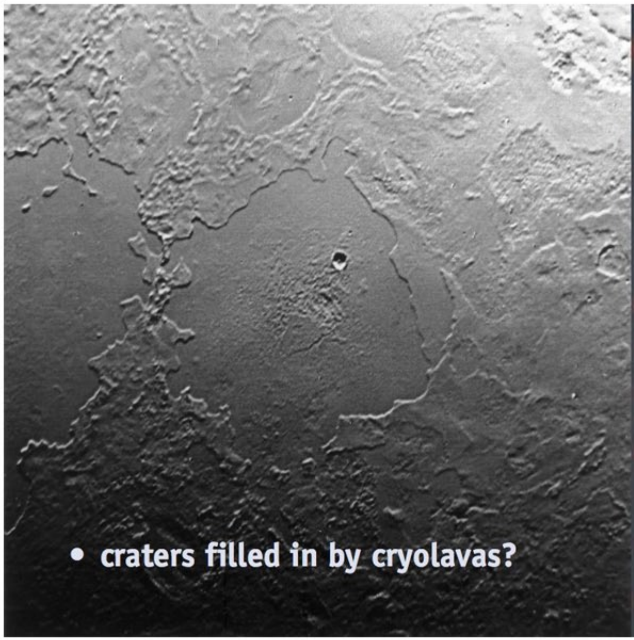


TRITON

- Surface temp 38 K (−391° F, −235° C)

TRITON'S GEYSERS

TRITON



- craters filled in by cryolavas?