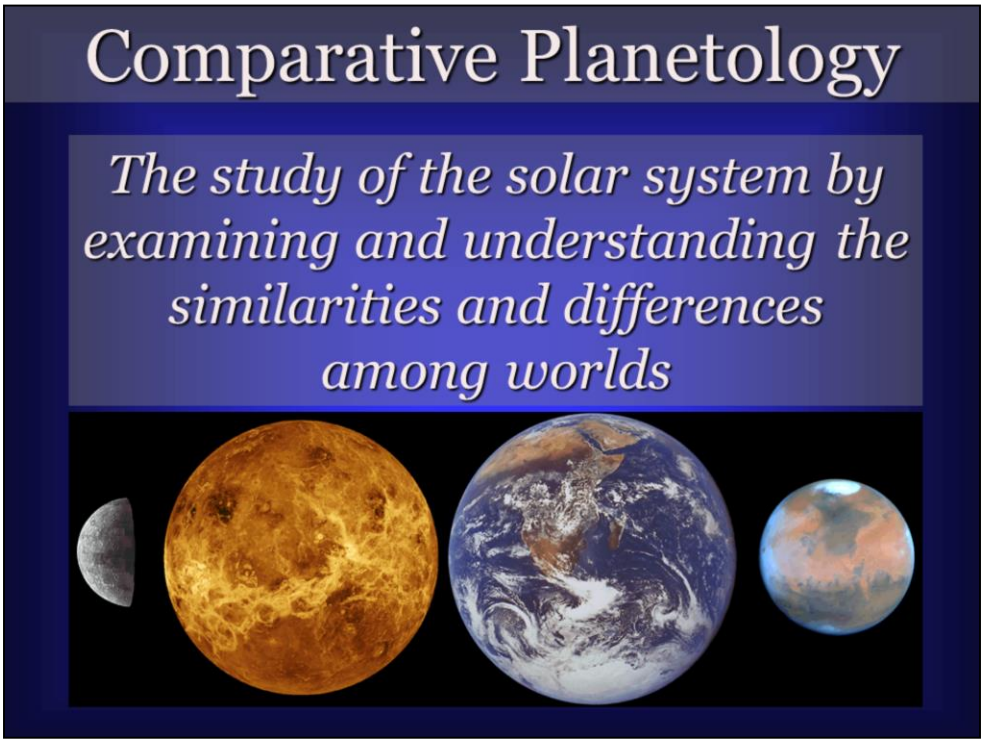
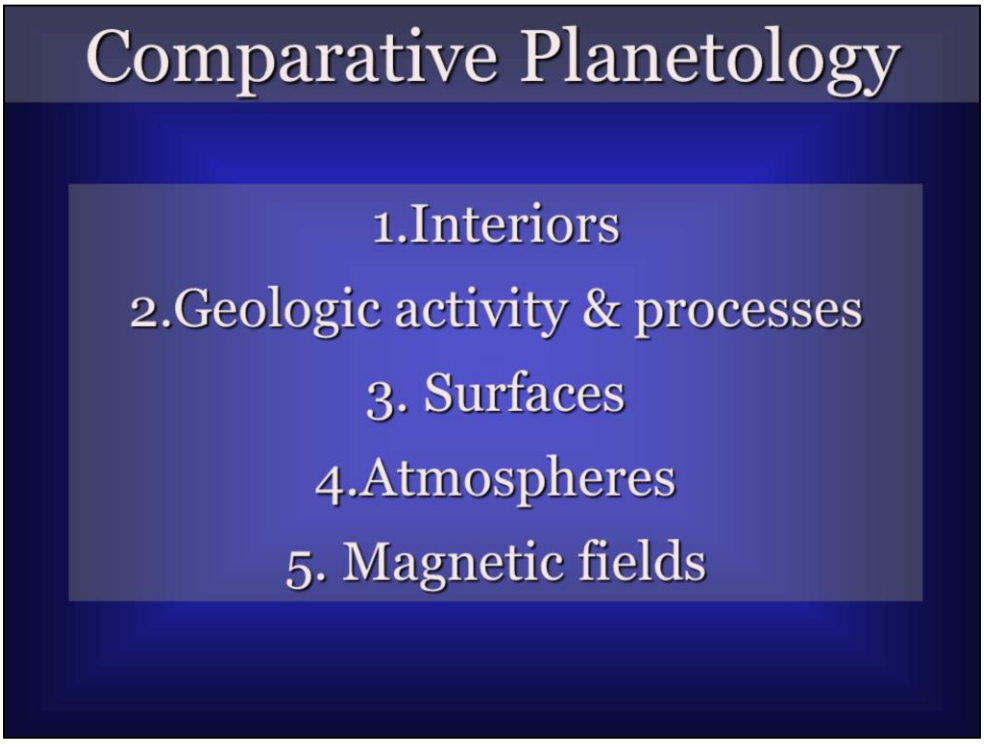


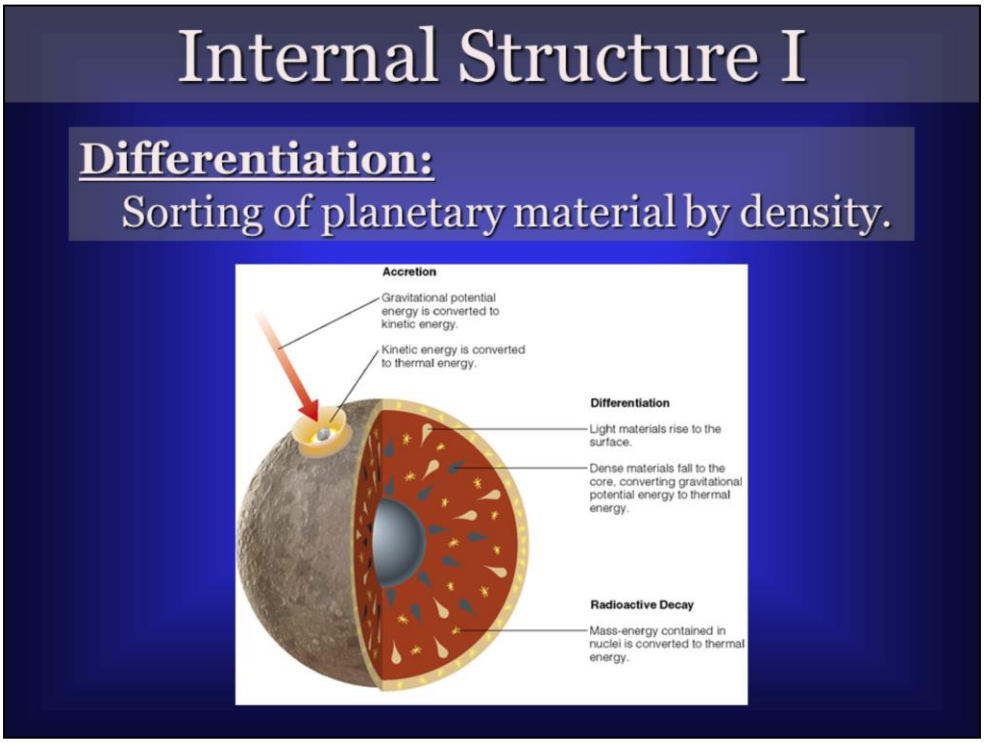
We'll start with the terrestrial planets



These are the things we need to look at to understand how (terrestrial) planets form. We'll start with the Earth, and compare from there.

We'll start with the terrestrial planets

The amount of water and other light molecules/elements that we have here on Earth, Venus and Mars all came from comet impacts during the heavy bombardment. A small amount probably came from outgassing as it may have been trapped inside some rocks (we do see ice on the asteroids: remember if the dust is thick enough we can "shield" *some* ice so that it sticks around in the inner solar system, just not a lot).



Liquids differentiate by density as well. Oil floats on water.

The interiors of the terrestrial planets are hot.

accretion, released gravitational potential, radioactive decay.

Rocks are viscous (meaning that they can flow).

Note that large bodies are spherical (lots of gravity eventually causes the rock to flow into a spherical shape)

Smaller bodies (asteroids) are misshapen because there isn't enough gravity to deform them.

Hot rocks flow better than cold rocks

Heavy stuff tends to sink to the center of the planet (ie iron and heavy metals)

Lighter stuff (silicates, rocks) rises to the top.

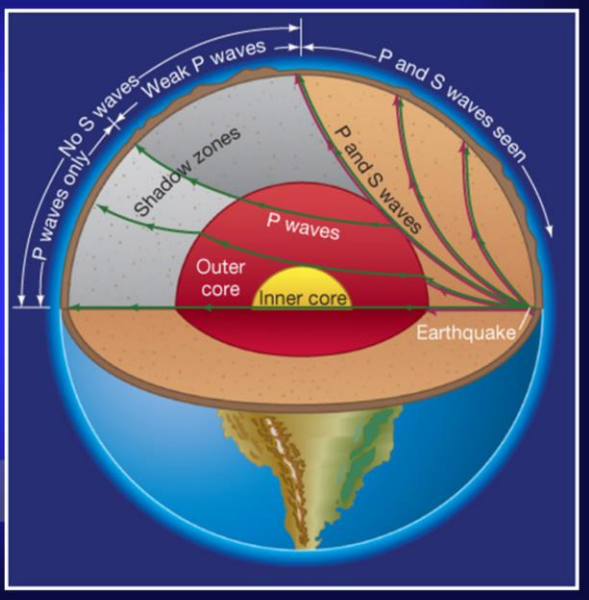
Internal Structure I

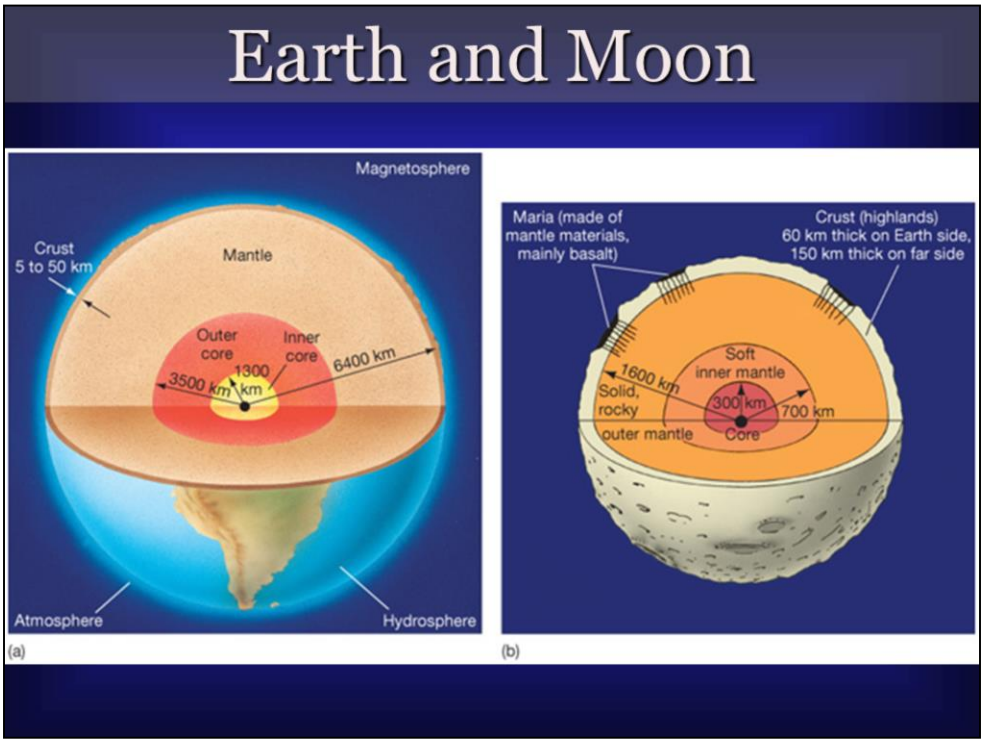
How do we know?

Earthquakes!

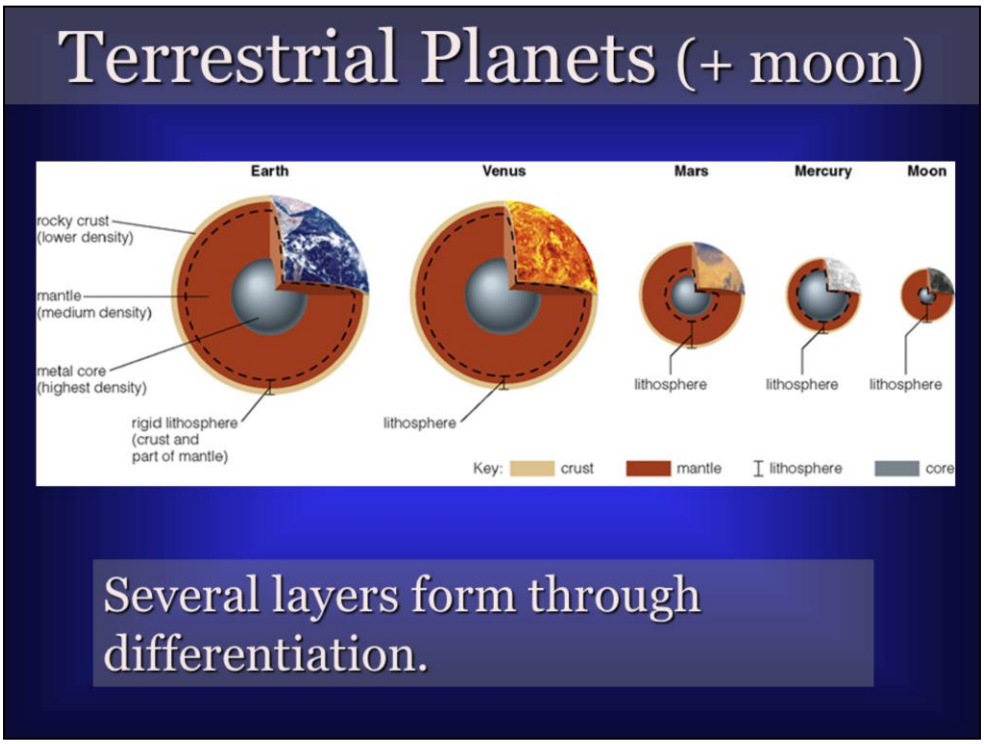
Gravity + Size!

(& theory too)





Here is an example of the kinds of things we will be doing: looking at both the Earth and the moon to figure out similarities and differences.



The lithosphere contains the crust and part of the mantle.

Higher temperatures deeper in the planet allow the rock there to be more fluid and the lithosphere essentially 'floats' on top of the mantle.

Large planets have more internal heat and thus a thinner lithosphere.

Small planets lose their heat more quickly and have a thicker lithosphere.

Mercury has a GIANT core. Was it made from more metal rich planetesimals?

The leading hypothesis is that it suffered some large impact in the past that blasted away part of its mantle. (So where did it go??)

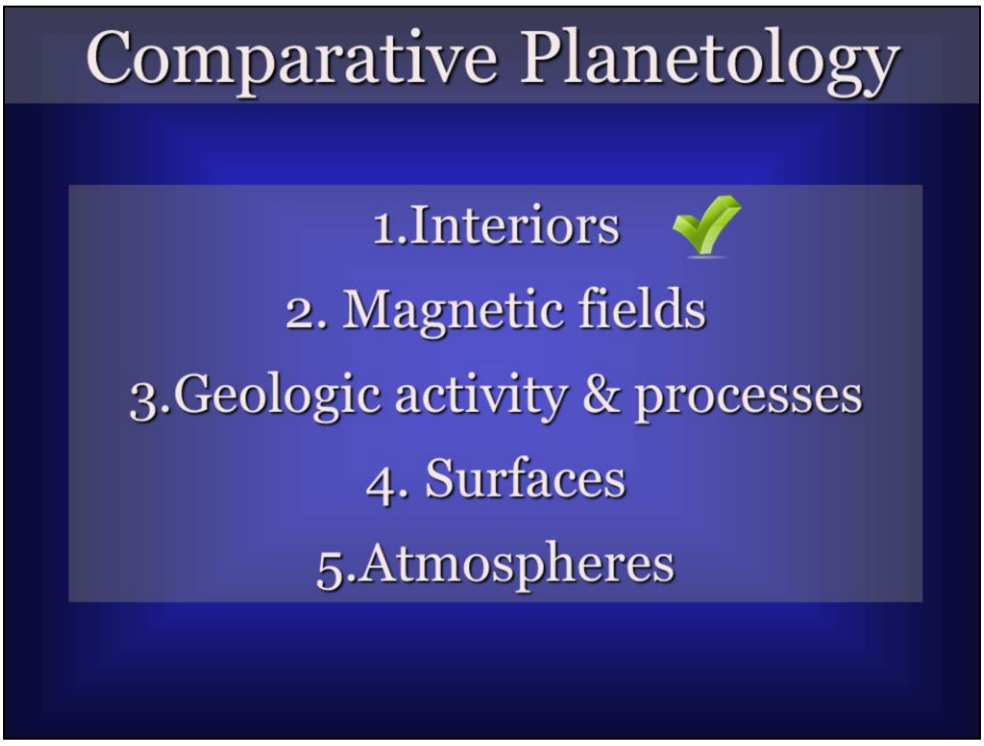
Earth and Venus have very similar interiors.

Mars has a very thick lithosphere, because it is small. It may have a very small amount of semi-plastic mantle, however the lithosphere is so thick that there is no current tectonic activity. Its core is also fairly frozen: we can tell because there is not a global magnetic field any more (though there used to be one).

The moon is all lithosphere and frozen core. Notice that it has a higher

lithosphere to core ratio than Earth/Venus/Mars, which is probably due to the big impact that smacked off part of the Earth, which then coalesced into the moon. (the impact would have knocked off more lithosphere/mantle than core material: what core is there may be part of the original impactor, though it's hard to say for certain)

NOTE: This differentiation is not the same as differentiation in the solar nebula!



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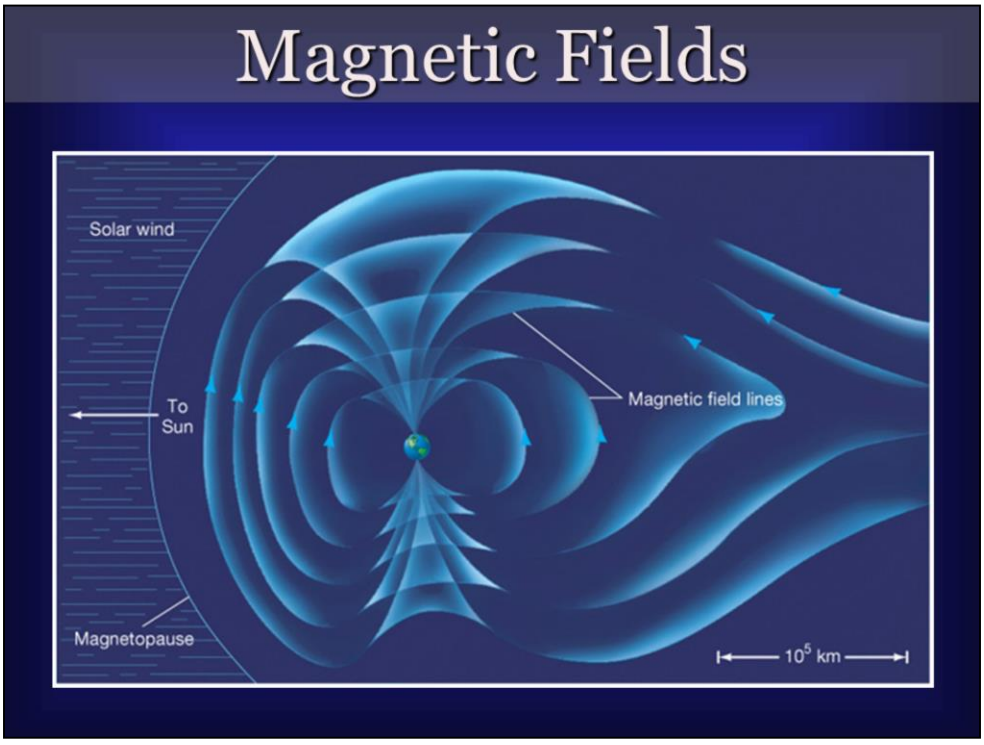
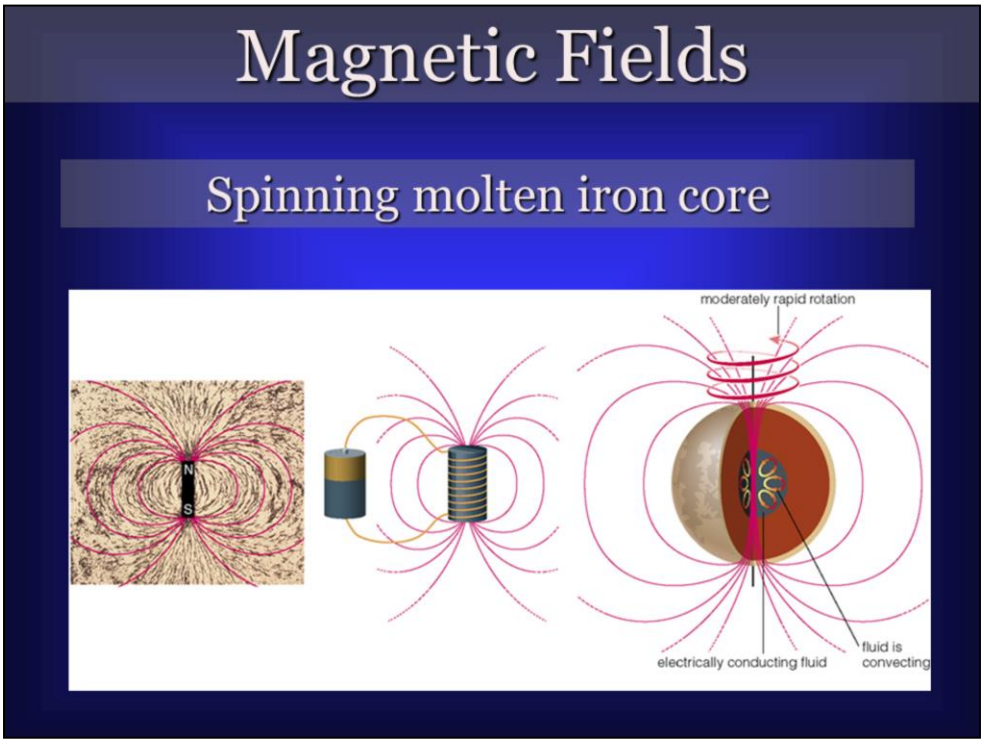


You can see the shape of the magnetosphere in this picture. It's asymmetric because of the solar wind hitting it. Inside our magnetosphere we are shielded from lots of high energy protons from the solar wind. This also helps satellites, except those that go far enough out that they are outside the magnetopause.



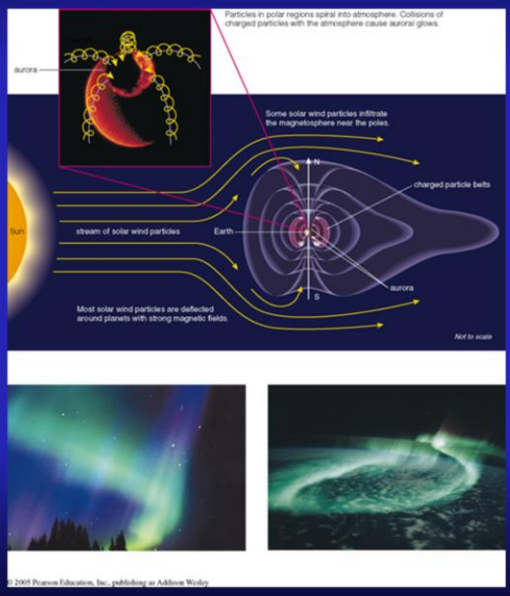
Free electrons in the molten core are dragged around by the rotating earth giving rise to magnetic fields.

Of the terrestrial planets, *only the Earth* has a strong magnetic field.

It protects us from harmful cosmic rays and diverts the solar wind around us. Also partially responsible for aurora

In mars and mercury the core is likely solid or mostly solid. Venus rotates too slowly to have a magnetic field, even though its core is most likely molten.

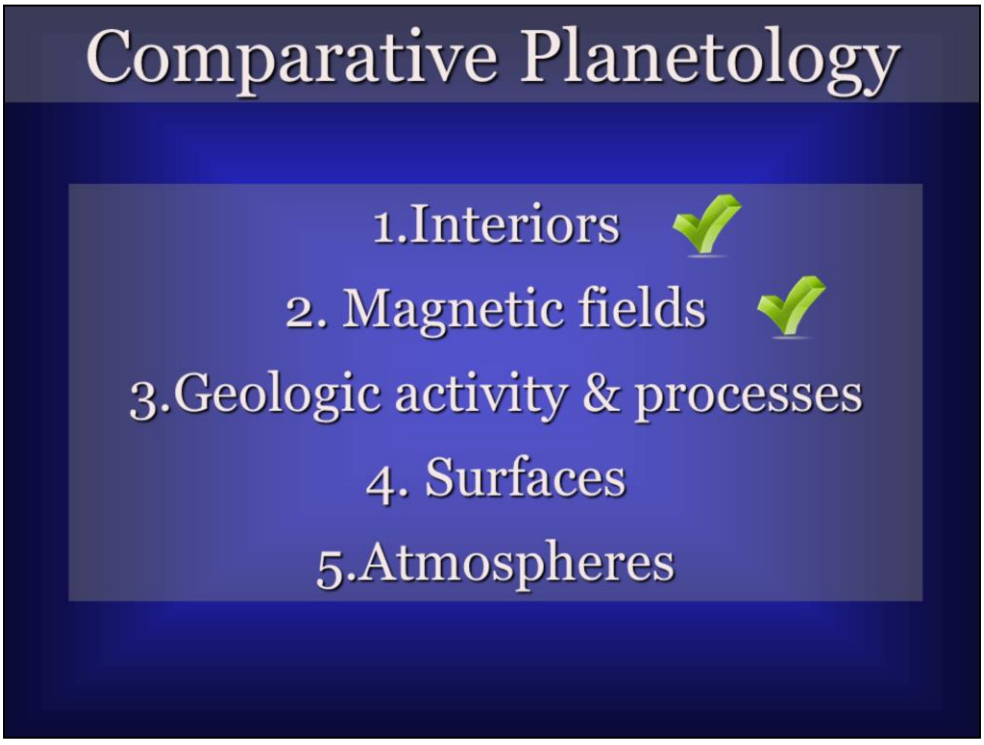
Aurora



Magnetic Fields

Mercury	Venus	Earth	Mars
Strong, Asymmetric	No	Strong	Remnant
Large dense solid core	Molten core Slow rotation	Molten core Fast rotation	(Mostly) solid core

Mercury: what's up with that? We don't know; we only just found out about it!



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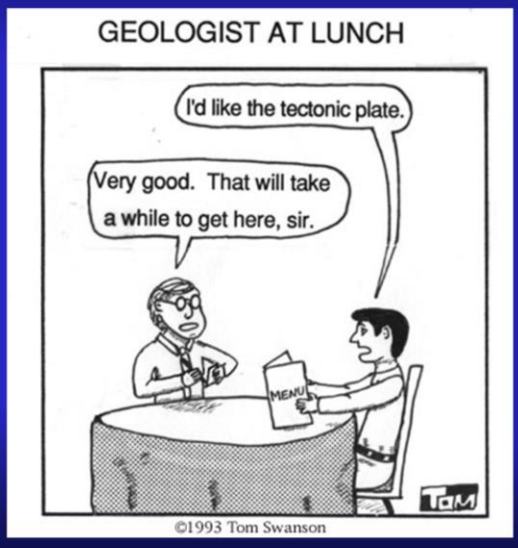
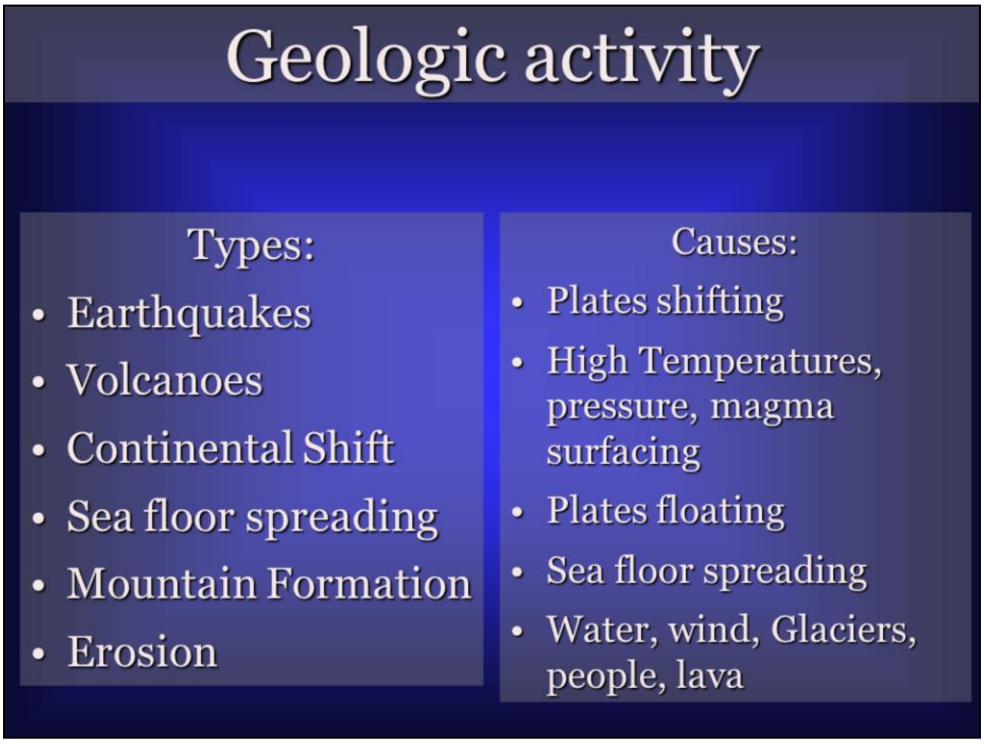
Geology



What kinds of geologic activity can we think of?

Earth

Lots of evidence for ongoing geologic activity

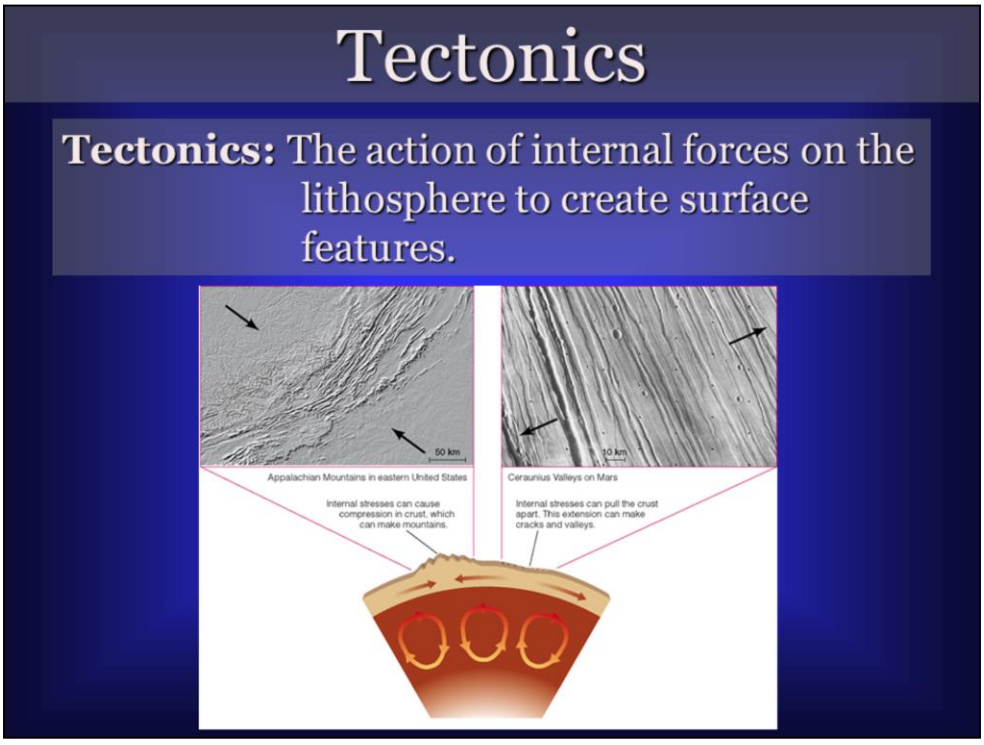


Not all of these happen on all planets!

What causes geologic activity?

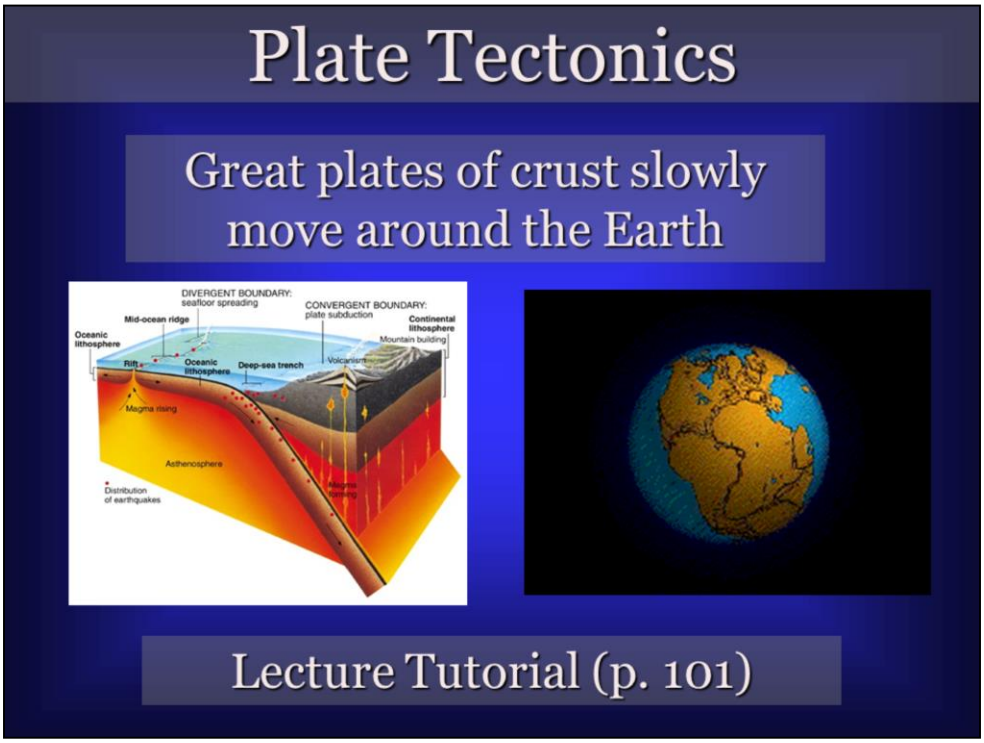
Heating	Cooling
• Accretion	• Convection
• Differentiation	• Conduction
• Radioactive decay	• Radiation

The amount of heat a planet currently has drives its geologic activity. These all (roughly) relate to the planet's SIZE.



Earth and Venus have ongoing tectonic activity.

Mars had such activity in the past

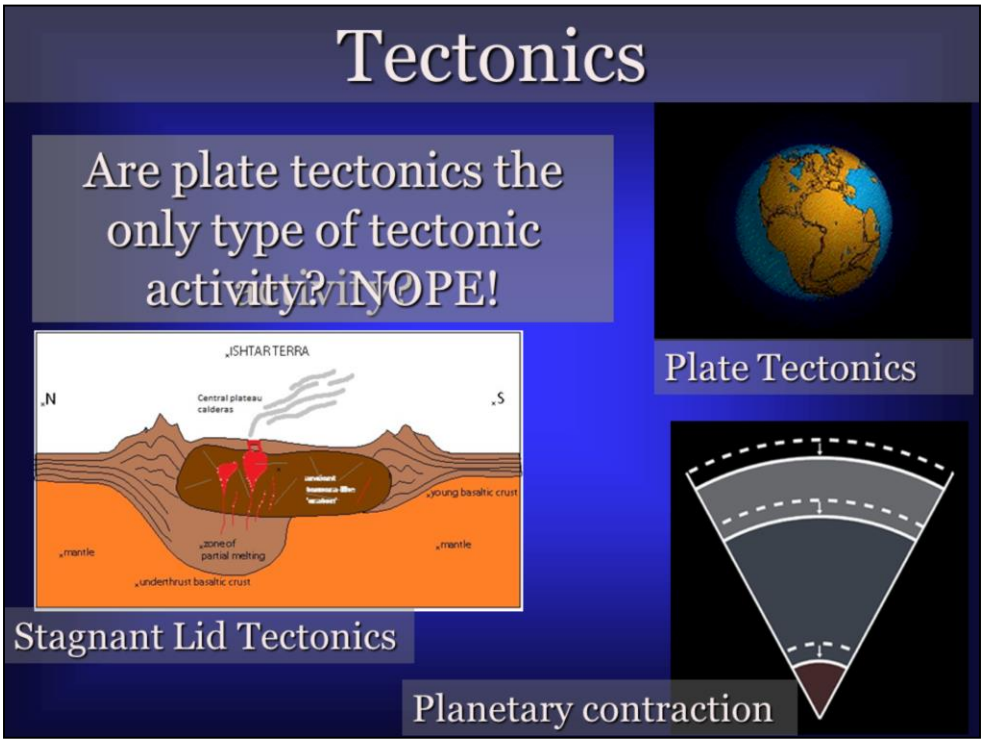


Subduction is Where one plate dives under another.

Where plates are moving apart rifts form. Lava often wells up to fill in the rift.

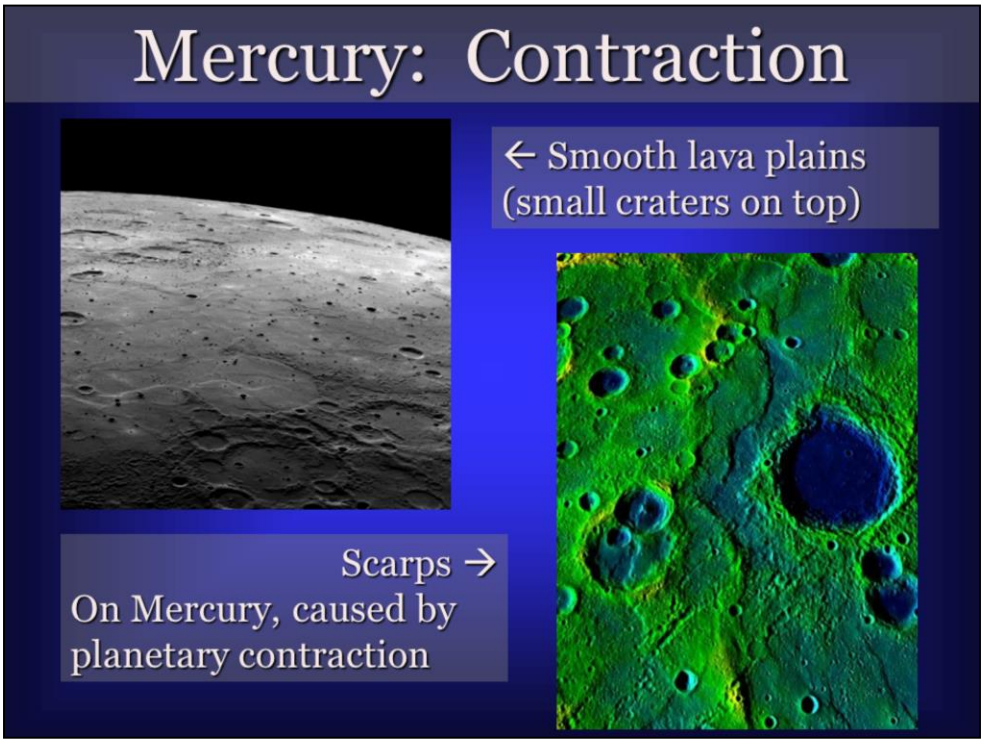
Mountains form where the plates meet.

Earthquakes happen when plates stick and snap loose suddenly

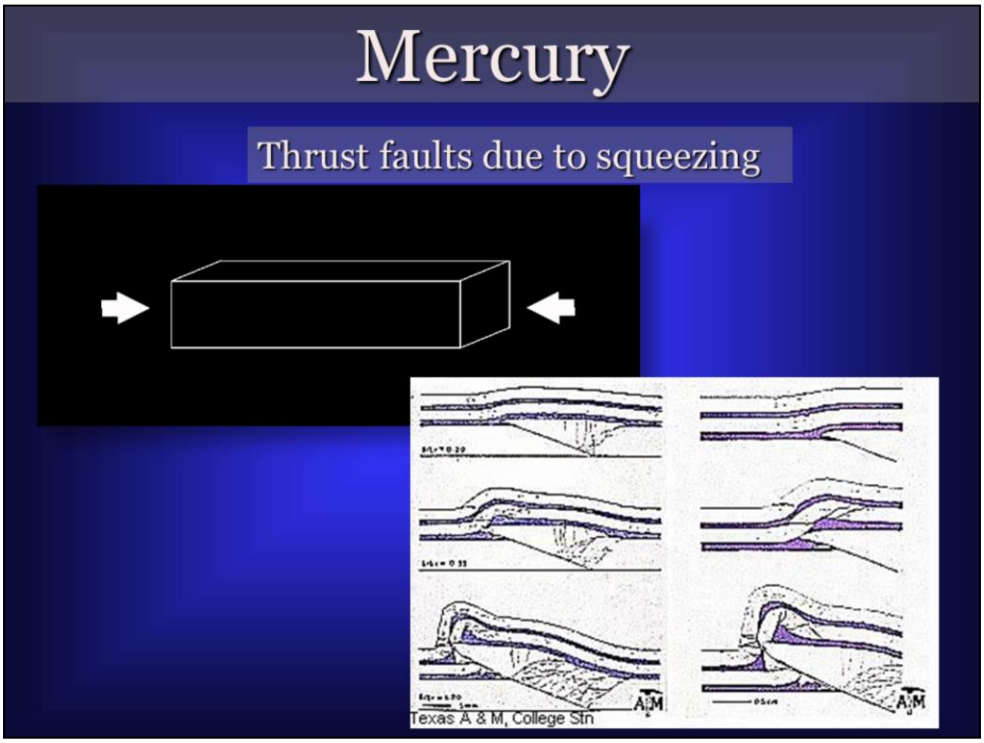


NOPE! Earth is the only planet with plate tectonics but not the only planet with tectonics!

****Why is Earth the only planet with plate tectonics?** (question to be answered later, but pose it here)**



Some impact craters do show lava in-fill (much like the lunar maria), and as that cooled, we see cracks. The lava plains are the largest volcanic features on Mercury and likely have thicknesses of several kilometers thick. Mercury doesn't currently have any tectonic activity.



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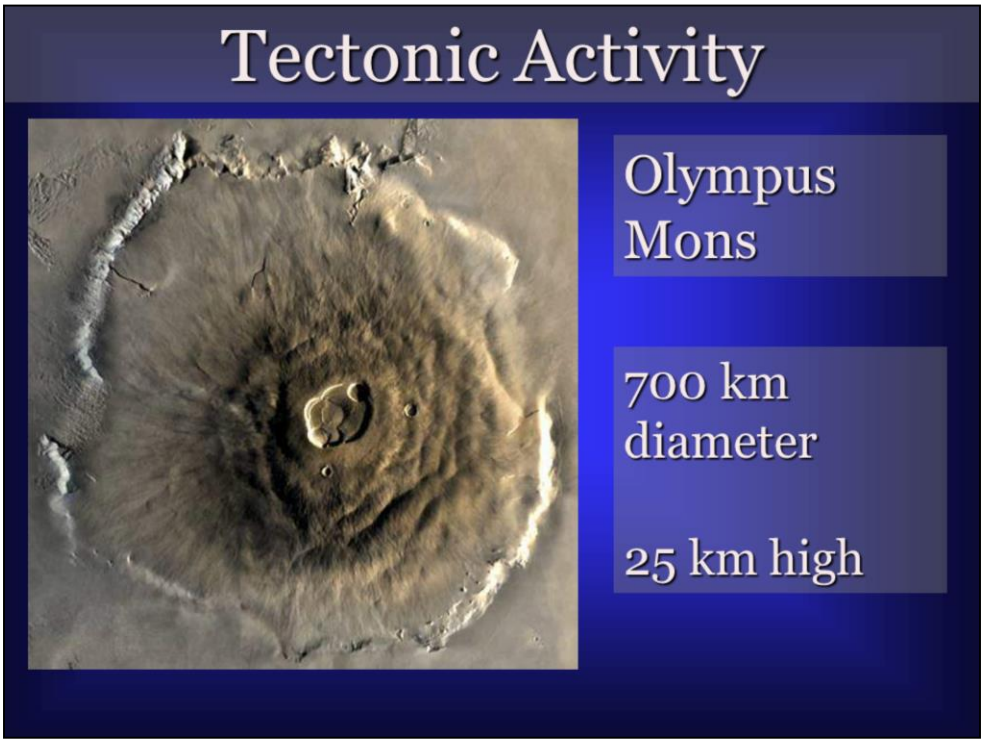
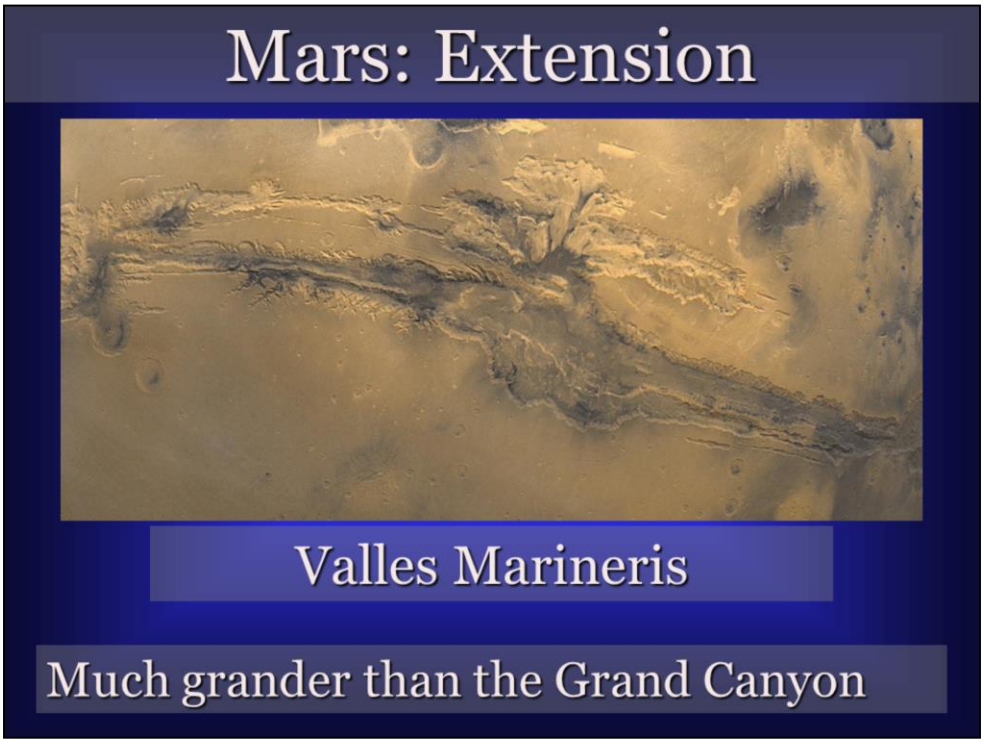


Volcanoes on Mars can grow very tall because of the low surface gravity… Olympus Mons is the tallest, and is more than 2.5 times higher than Mount Everest (8.8km high)! There are three other large volcanoes in the Tharsis region. There are lots of other volcanoes too, but these four are the largest. Because of the huge weight on the crust, we have…



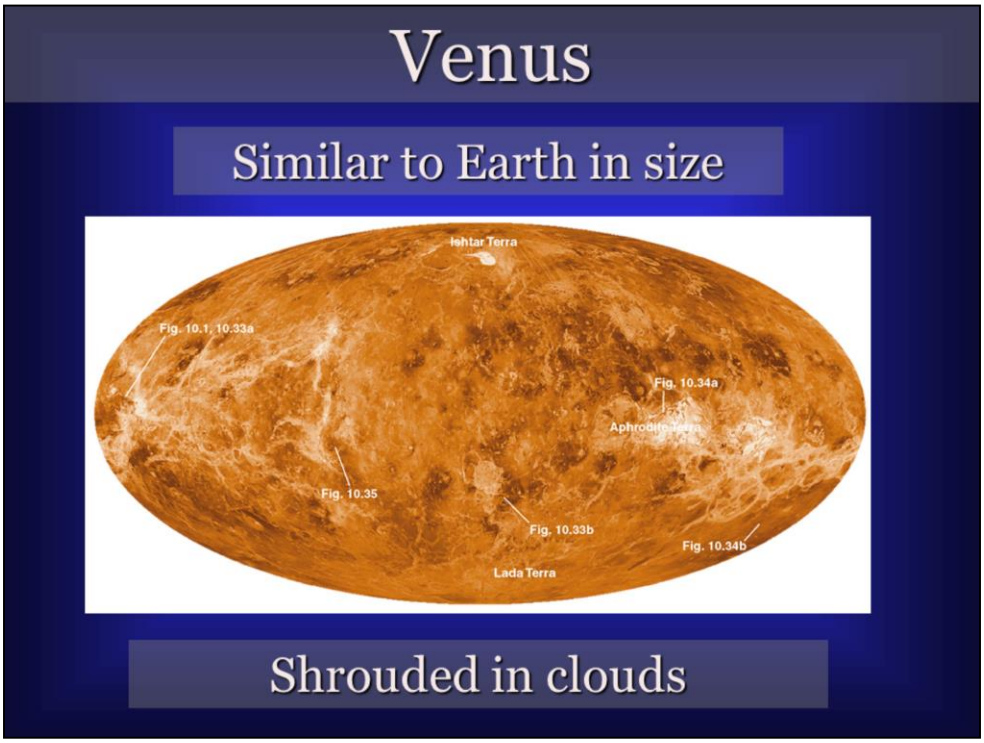
4000 Kilometers long (the continental US is about 3,000km long)

50 to 100 Kilometers wide

10 km deep (7 times deeper than the grand canyon)

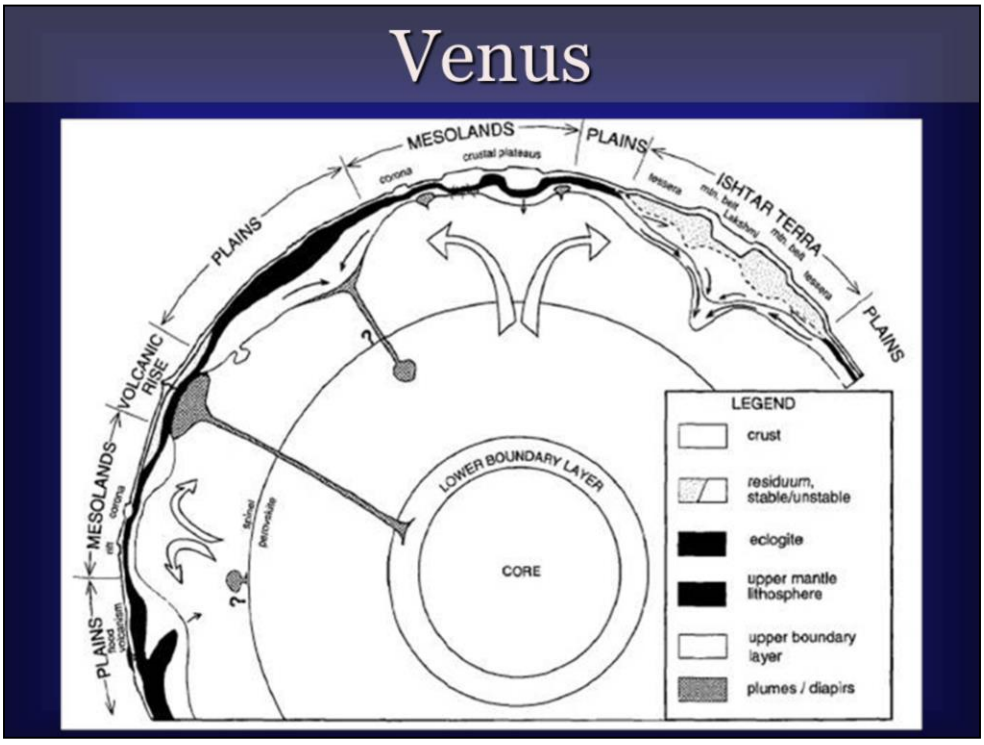
Likely formed by tectonic stresses – due to Olympus Mons and three other large volcanoes to the west of the crack. Also note the giant outflow region to the north side… probably a catastrophic outflow caused this.

There used to be volcanic activity in the distant past… Mars is cool now

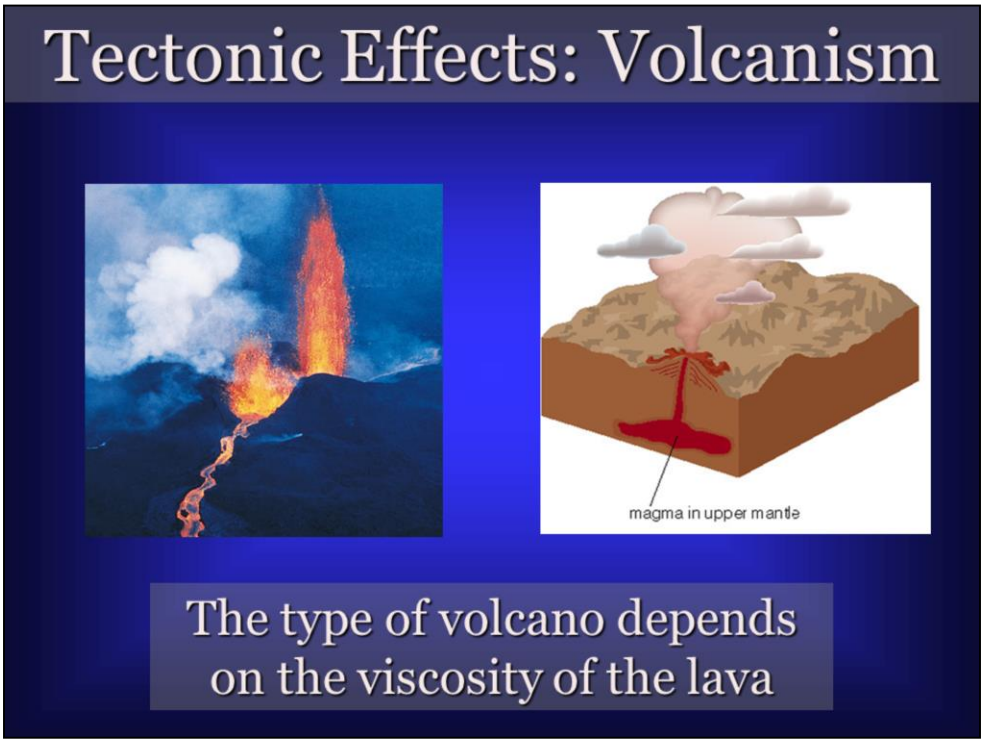


These images are created with radar.

Radio waves penetrate the clouds. Time the echo of the emitted radio pulse to determine the topology of the landscape.



But, we don't actually have plate tectonics. Why not? Because they're no water – which makes it much harder for rocks to "flow" like they do here on Earth. So what do we have going on instead? As the lava covers the surface, it gets heavy and sinks down into the mantle. Other areas upwell… so plains are sinking and areas of uplift are rising. This causes long linear features (*fossae*) due to extension and compression as well.



The interior of the planet is <u>not</u> all molten lava. The lava is in hot pockets in the lithosphere.

Molten lava can erupt to the surface significantly changing the surface of a planet by erasing older features.

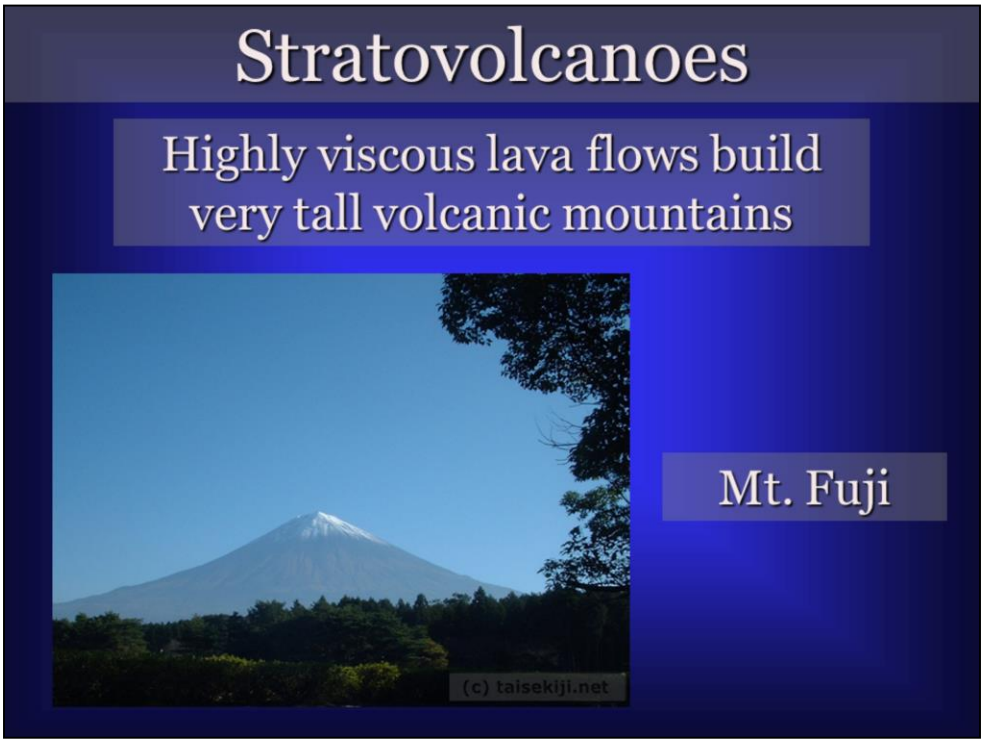
The planetary interior must be hot to have active volcanism. ****How do we heat the interior?** (one minute write/think pair share)**

Volcanism

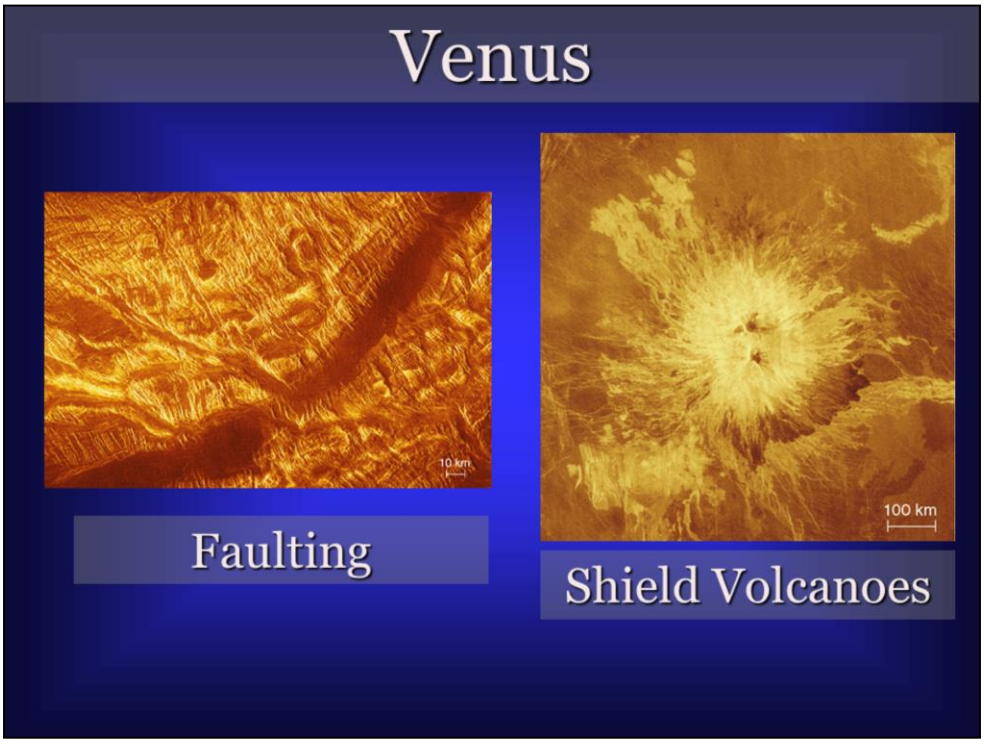
Shield volcanoes have moderately *viscous* flows and tend to spread out

Mauna Loa

Olympus Mons



Volcanic activity requires a hot planetary interior

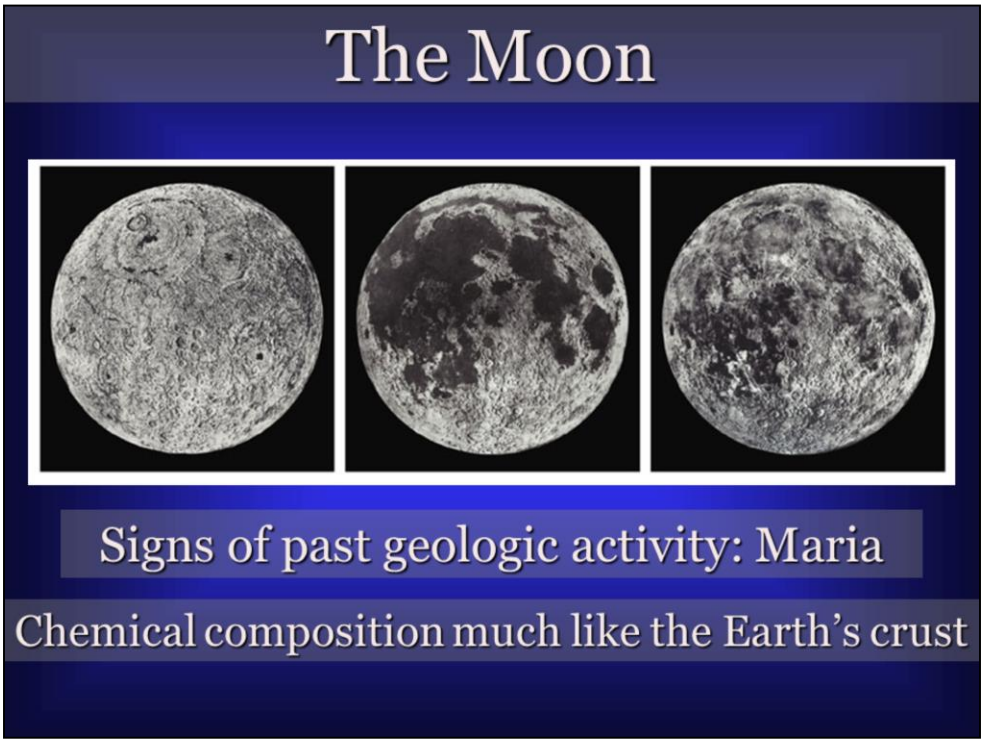


Low cratering.

It looks like the surface was completely recreated approximately a billion years ago.

Evidence of recent tectonic activity and volcanic activity, by the sulfuric acid in the atmosphere – if there were no current volcanoes, it would become locked up in the surface rocks.

There does not appear to be any erosion despite the thick atmosphere



Heavily cratered during heavy bombardment period.

Radioactive decay slowly heated the interior until it was hot enough for some volcanism

Volcanic eruptions created the maria

The dark color of the maria is due to iron rich rock from the interior.

The interior re-solidified.

Surface continued to crater

No atmosphere, so no erosion. No tectonic activity

The surface is powdery… impacts from micro-meteorites.

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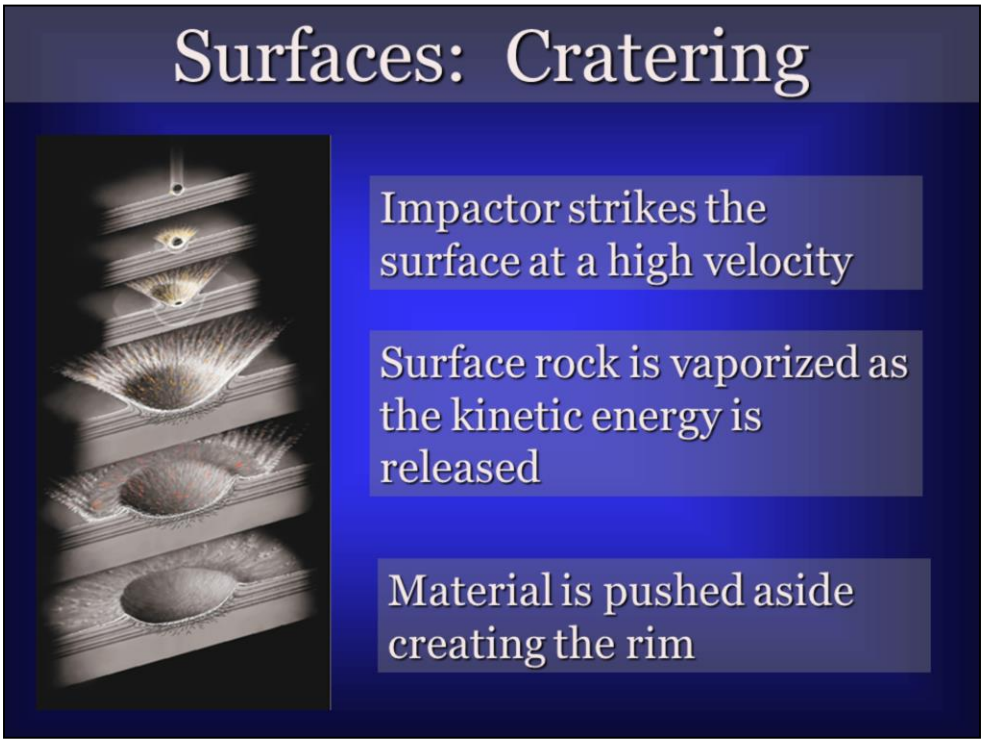
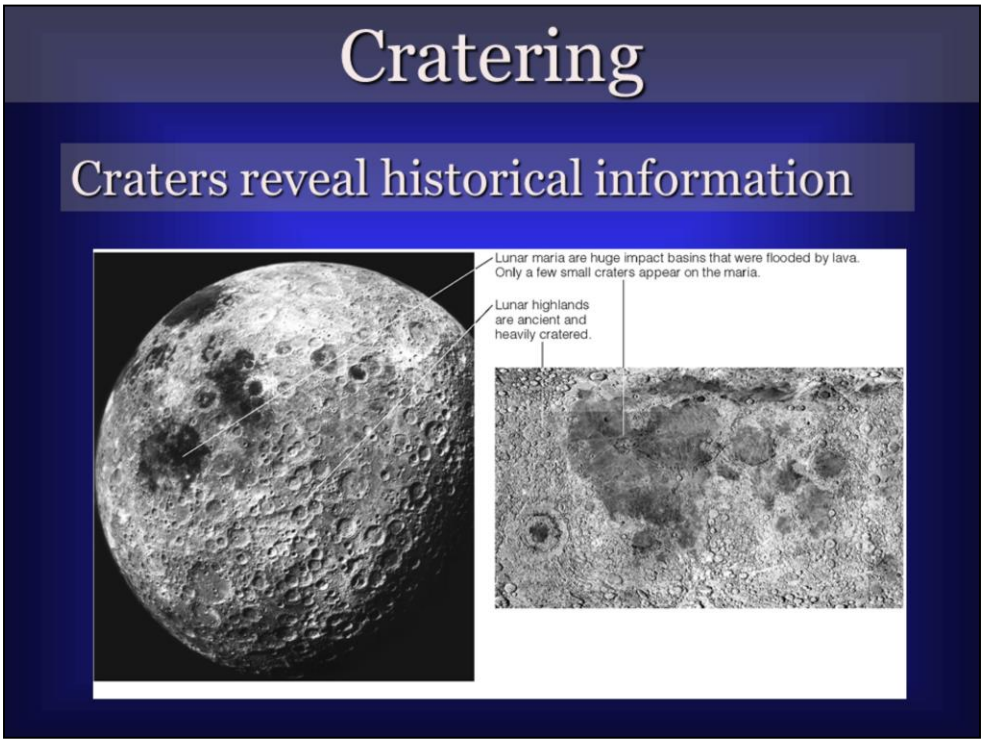


Typical impact velocities are between 10,000 and 100,000 km/hour

Craters are **much** wider than the impactor…

Material is thrown a large distance in a spray around the crater.

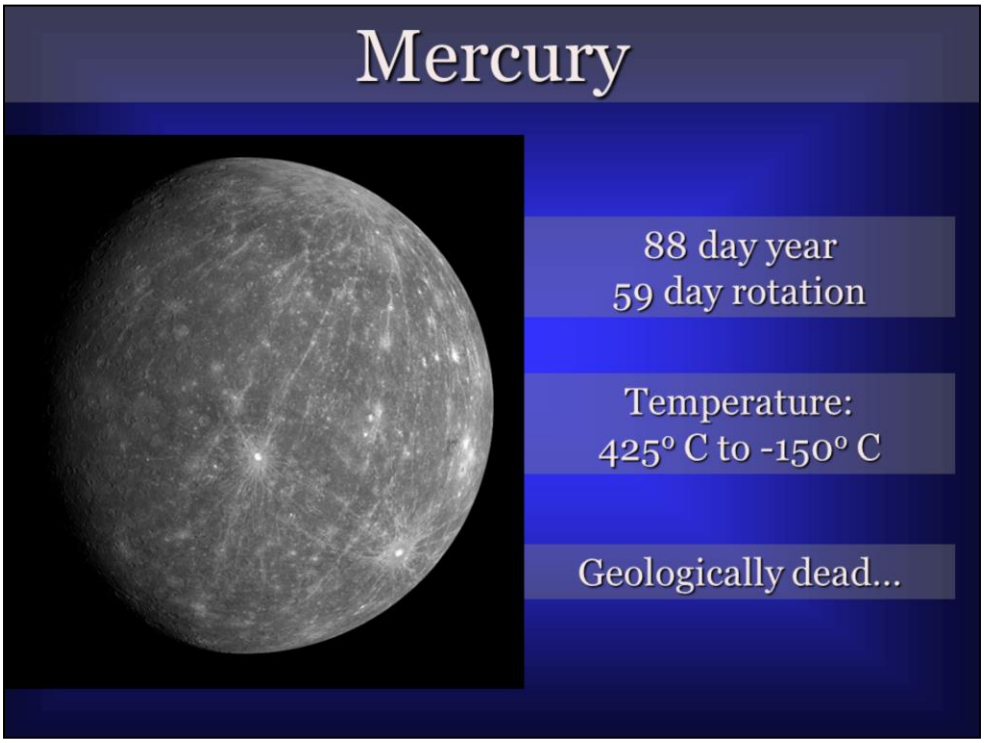


Small craters outnumber large craters.

Large craters are overlapped by smaller ones (the ones on top are newer)

There are few impacts in the Moon's Maria. (so they are newer)

Craters provide a way to figure out what features are older and what features are newer.



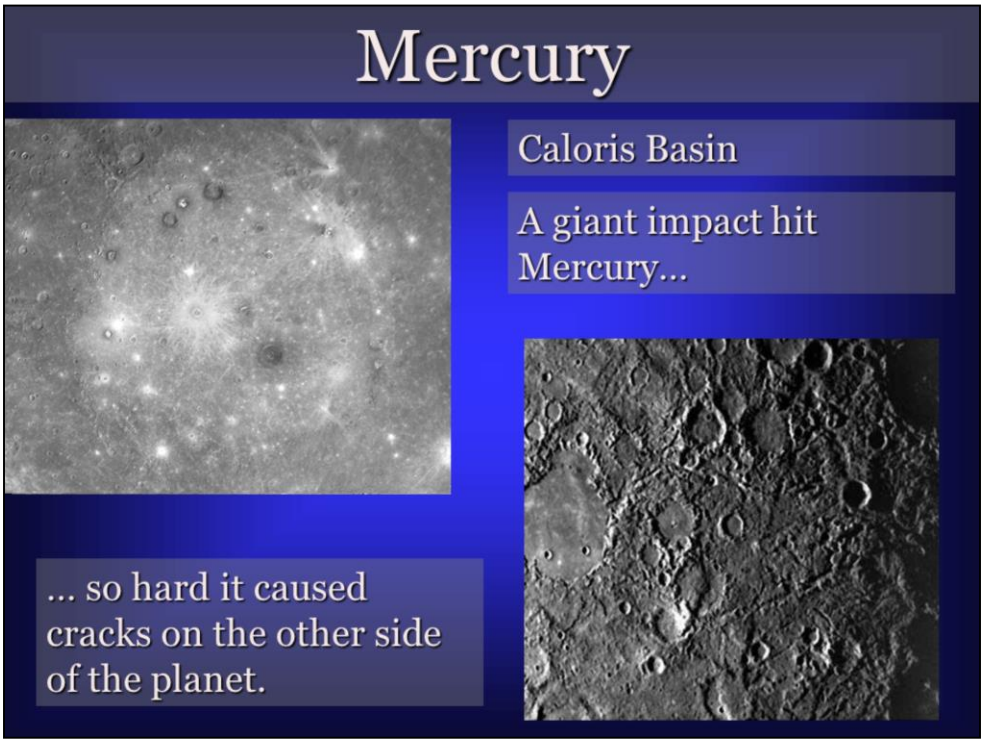
Heavily cratered

signs of tectonic activity in the distant past, smooth lava plains like the moons maria

Evidence for a very large solid iron core.

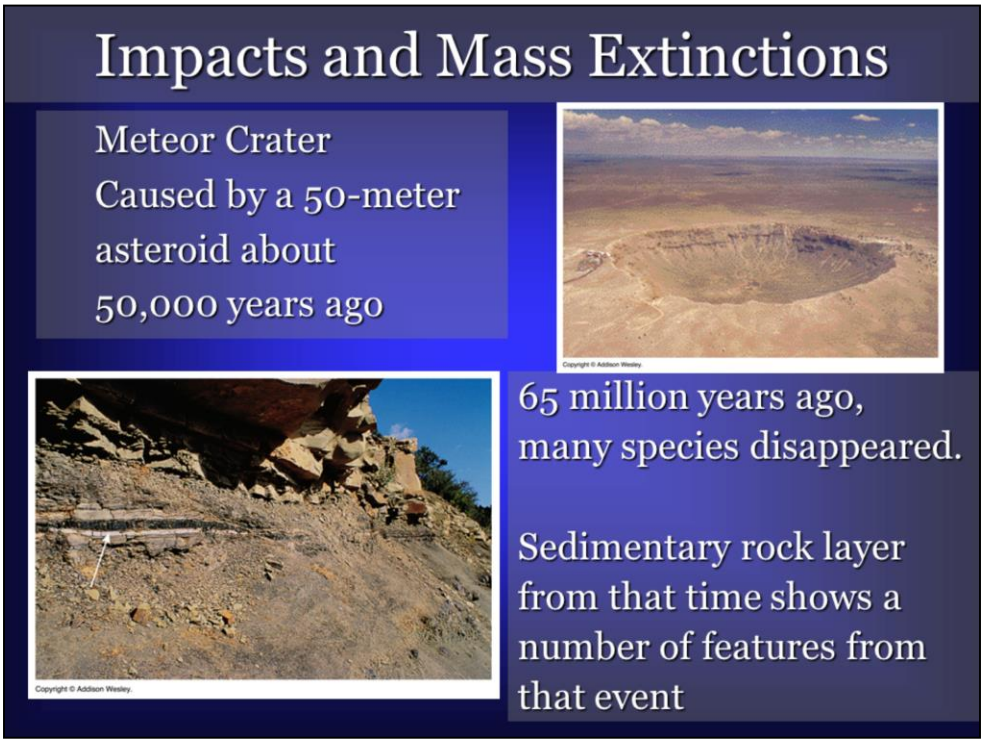
It is now geologically dead (no tectonic activity)

At the poles are very likely water ice deposits.



The crater is about 1550km across and the ringing mountains are about 2km high. The floor is filled with lava plains (like the Moon's maria). As with many big impacts there are concentric rings around it. There are some other weird things inside the crater, like what look like extension faults. MESSENGER should be able to sort out what some of these things are.

All of these planets have fewer craters than Mercury and the Moon. Why? Hint: Venus has a thick atmosphere, Earth is medium, and Mars has a very thin atmosphere.



We know large objects have hit the Earth.

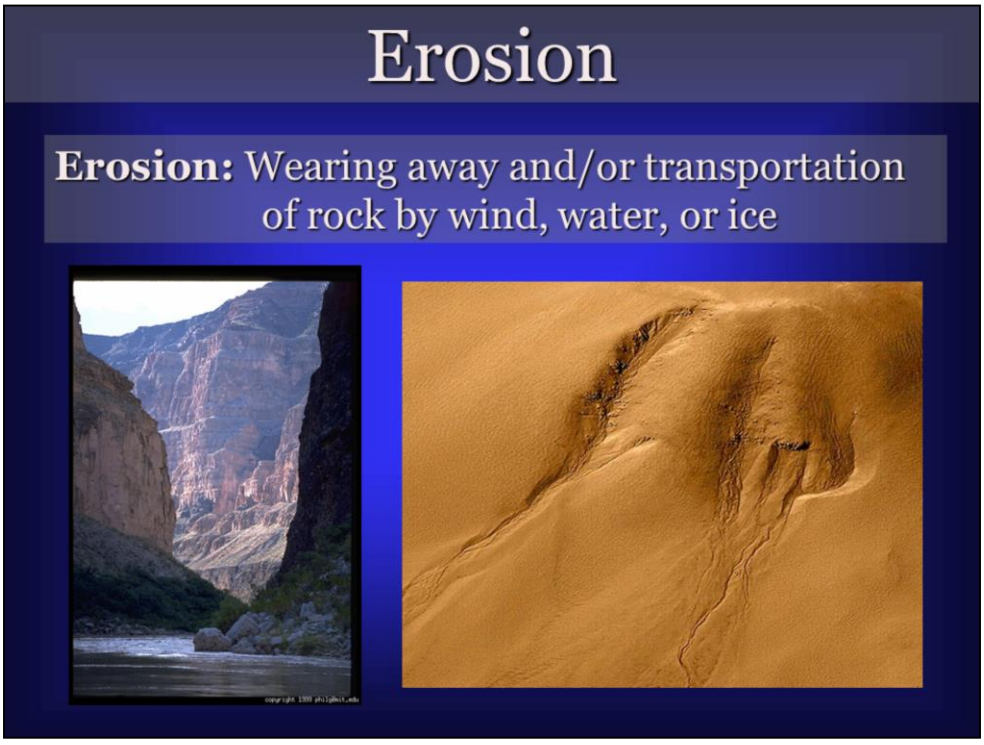
Iridium, Osmium, Platinum, grains of "shocked quartz", spherical rock droplets, soot from forest fires

In 1991, a 65 million year old impact crater was found on the coast of Mexico.

- 200 km in diameter
- implies an asteroid size of about 10 km across
- called the *Chicxulub* crater
- Coincides with the mass extinction of the dinosaurs

An impact of this size would have caused:

- debris in atmosphere blocks sunlight; plant die…animals starve
- poisonous gases form in atmosphere



On a planet with a significant atmosphere, erosion is an ongoing process.

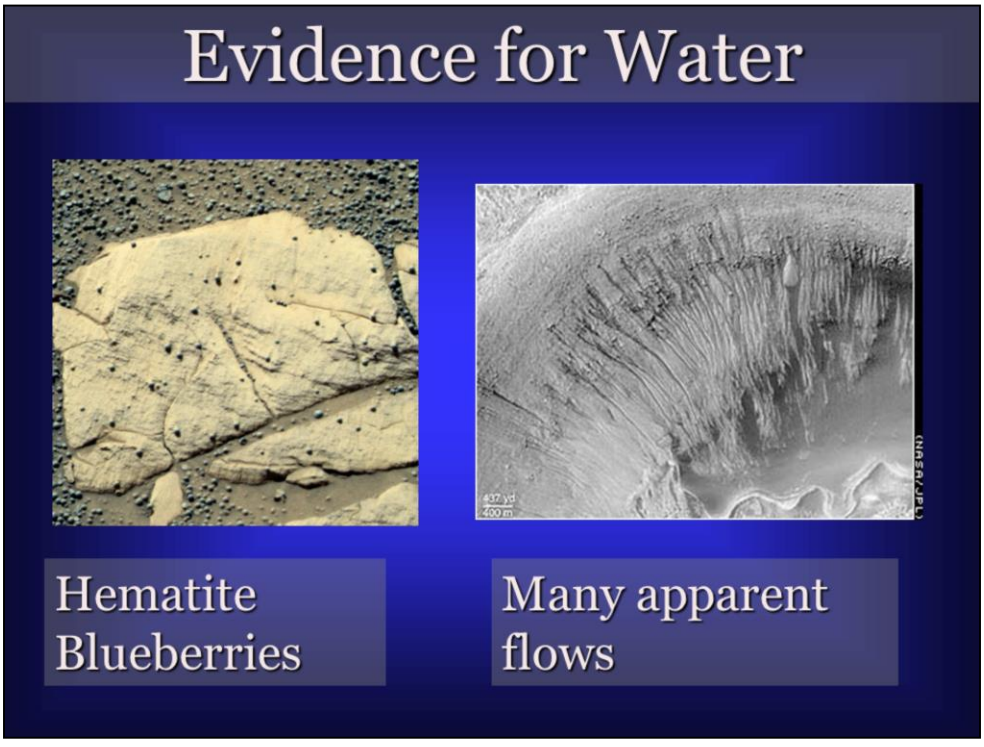
****Which planets have a "significant" atmosphere?****

Nearly 24 hour day, tilt very similar to the Earth

Light cratering

Half the radius of the Earth

Plenty of evidence of past geologic processes but no active volcanism (other, smaller, processes are happening though)

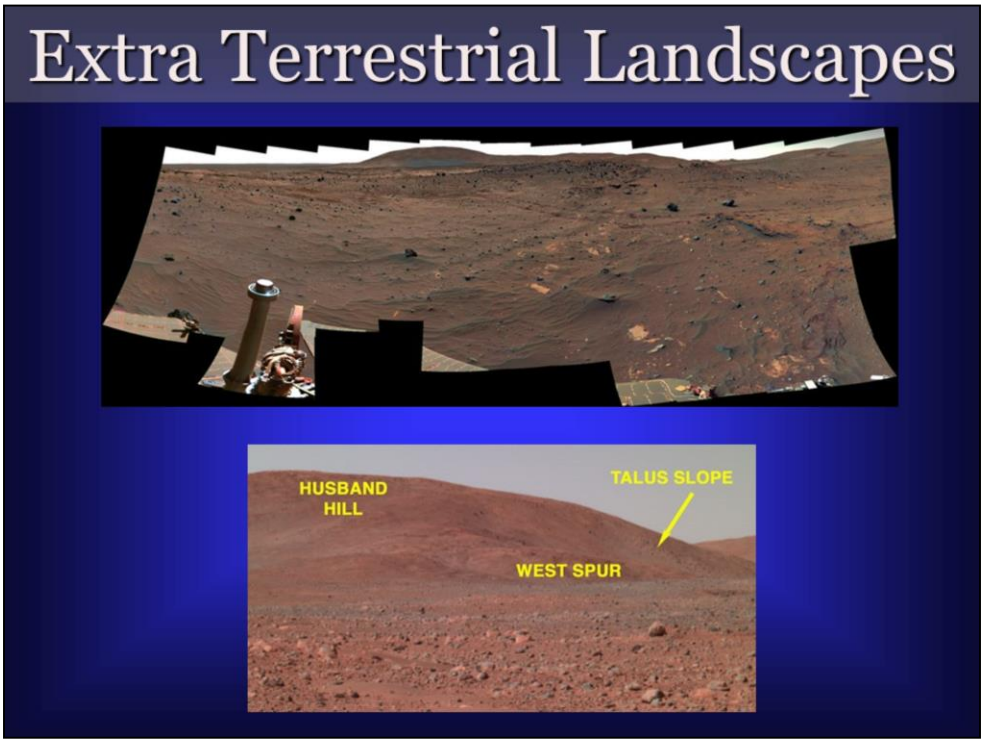


Blueberries and other salt deposits suggest that the surface was once bathed in water.

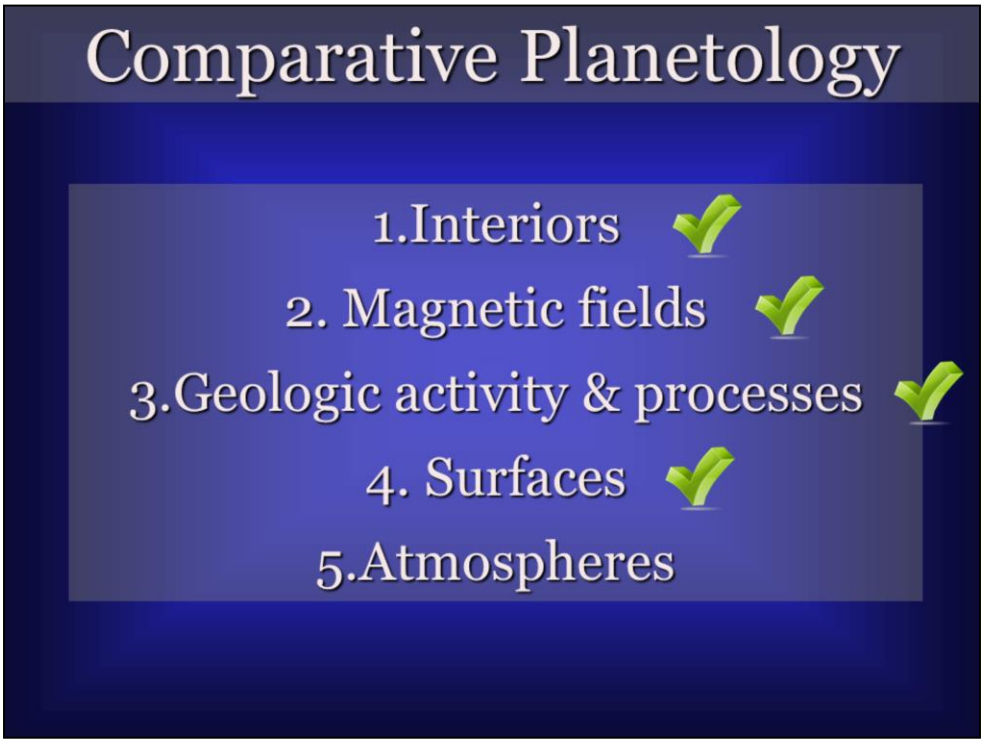
Many surface features are strongly suggestive of liquid flows – we definitely see flows *currently happening* but whether or not it's liquid or slush/slurry is unclear

Where is the water now?

At this point we're certain there was once liquid water on Mars – this finding is *extremely recent*!!



Go to the mars rovers page and see LOTS of pretty pictures and read lots of stuff about mars.



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