THE TERRESTRIAL PLANETS

Astronomy

The Terrestrial Planets

Sections:

1. Mercury
2. Venus
3. Mars

The Terrestrial Planets

Introduction

- These planets are structurally similar to Earth
- All four of these planets are terrestrial (land based)
- Too small and too warm to have captured massive hydrogen pockets (atmospheres)
- Even though they are similar in size and composition, their surface conditions differ on a really big scale
- Size and distance from the Sun play big roles in the atmospheric development and retention
  - Mercury = too small and too close to the Sun
  - Earth and Mars = larger, much further away, cooler, and therefore can hold an atmosphere

Mercury

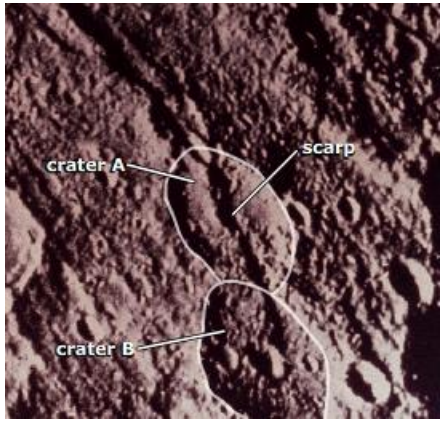
Introduction

- Smallest terrestrial planet
- Changes its position in the sky faster than any other planet
- Resembles our Moon in both size and appearance
- Known as the “dead” planet
- Its radius is about 1/3rd Earth’s and its mass is about 1/20th Earth’s
  - Determined by angular size and distance
- Its mass was calculated through gravitational attraction to the *Mariner 10* space craft in 1974

Mercury

Introduction

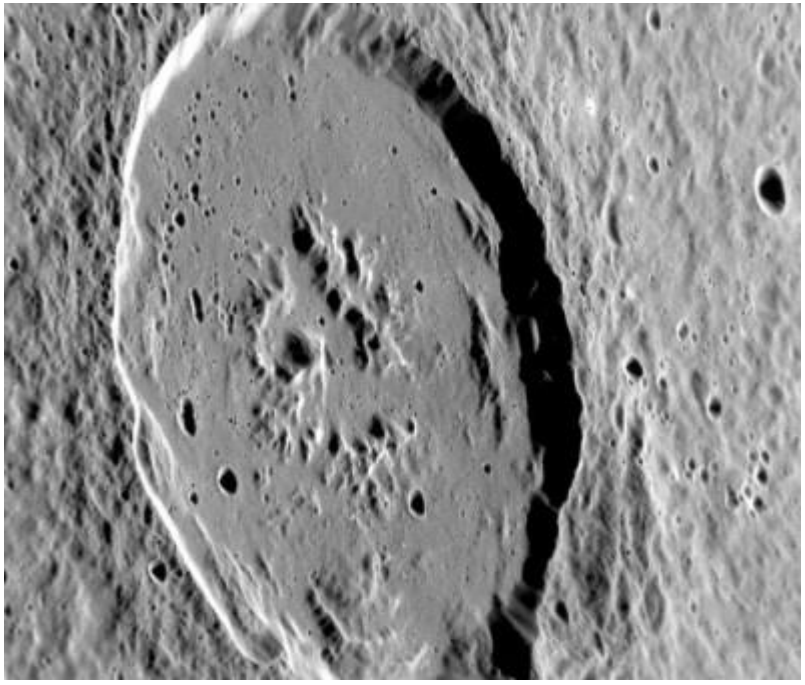
- Surface is covered in craters and congealed (solidified) lava pools
- Scarps – cliffs formed where the crust has shifted
  - These run for hundreds of km across the surface
  - Likely formed as the planet shrank and cooled
- Largest crater is the Caloris Basin
  - Diameter of about 1,300 km (800 mi)
  - Formed from impact
  - The impact triggered volcanoes around the edge of the basin
  - Estimated to have happened about 3.8 billion years ago

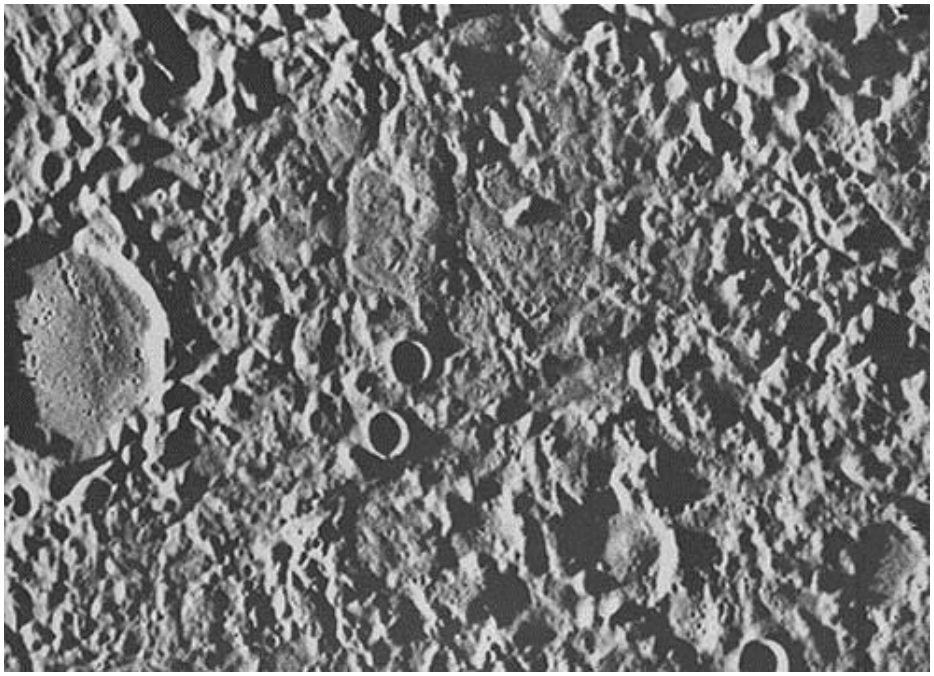


Mercury

Introduction

- Opposite of the Caloris Basin is the *hummocky*
  - A jumbled surface also known as a “chaotic terrain”
  - Thought to be churned up by earthquake waves generated by the impact that created Caloris

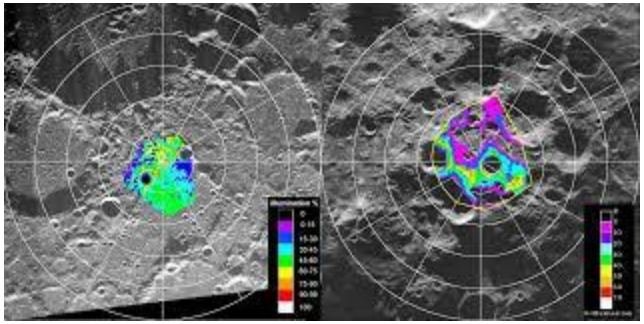




Mercury

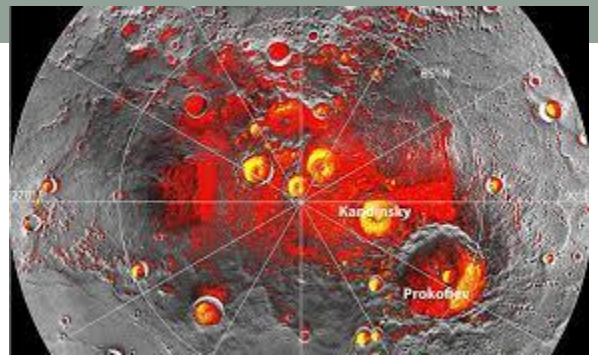
Temperature and Atmosphere

- One of the hottest surfaces in the solar system
  - (rightfully so…)
- Noon temperatures at the equator reach 820˚ F
- Night temperatures can fall as low as -320˚ F
- Caused by:
  - lack of atmosphere
    - No moderation like ours
  - distance from the Sun
    - Closest planet
  - slow rotation
    - Allows the surface to heat up completely and cool completely



- Even though its so close to the Sun, its poles are really cold to the point of possible ice caps

Mercury



Temperature and Atmosphere

- There are gases that have been detected around Mercury, but the attraction to maintain them isn't there
  - no atmosphere
- Big question: So if there's no atmosphere and all of this heat, where did the polar caps come from?
  - Theory: comets striking the poles
  - The comets can occasionally crash into the Sun, so Mercury wouldn't be far off
  - With them striking the poles, it's cold enough to maintain that frozen status

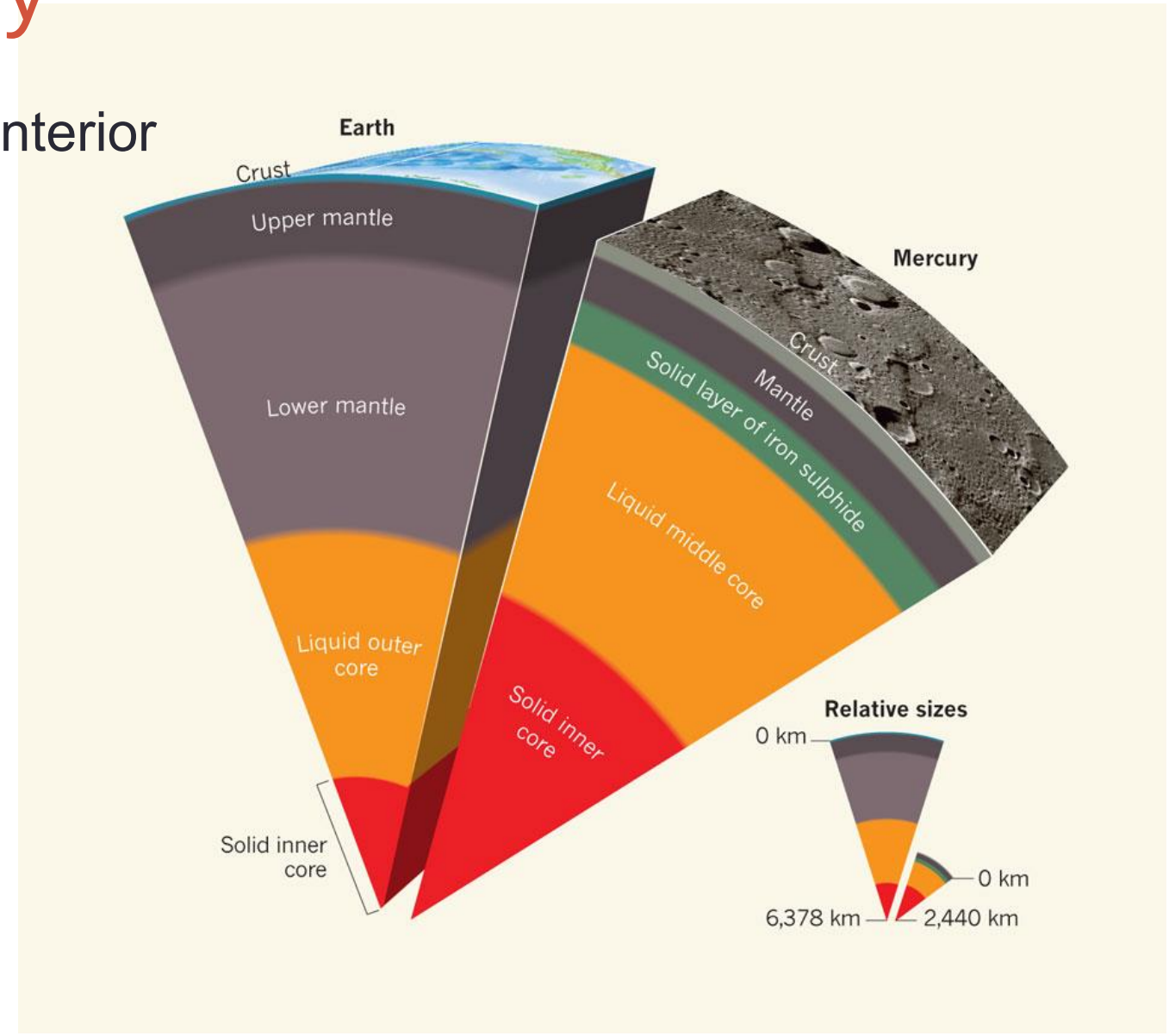
Mercury

Mercury's Interior

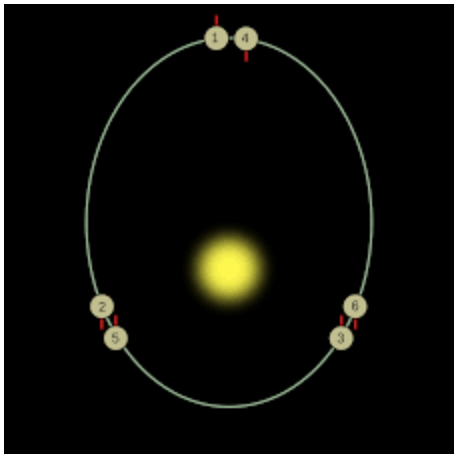
- *Most likely* has an iron core beneath the silicon crust
  - Just like Earth
- Astronomers have little evidence because we can't land there to investigate its seismic (earthquake) activity
- They have based it off of the gravity field and density
- With a density of 5.4 g/cm^3, this structure is the only setup that makes sense
- Much more richer in iron than silicon
- Possible semi-liquid core like Earth
  - Figured this out from the planet wobbling
- Magnetic field is present, but weaker because of a slow rotation

Mercury

Mercury's Interior



Mercury



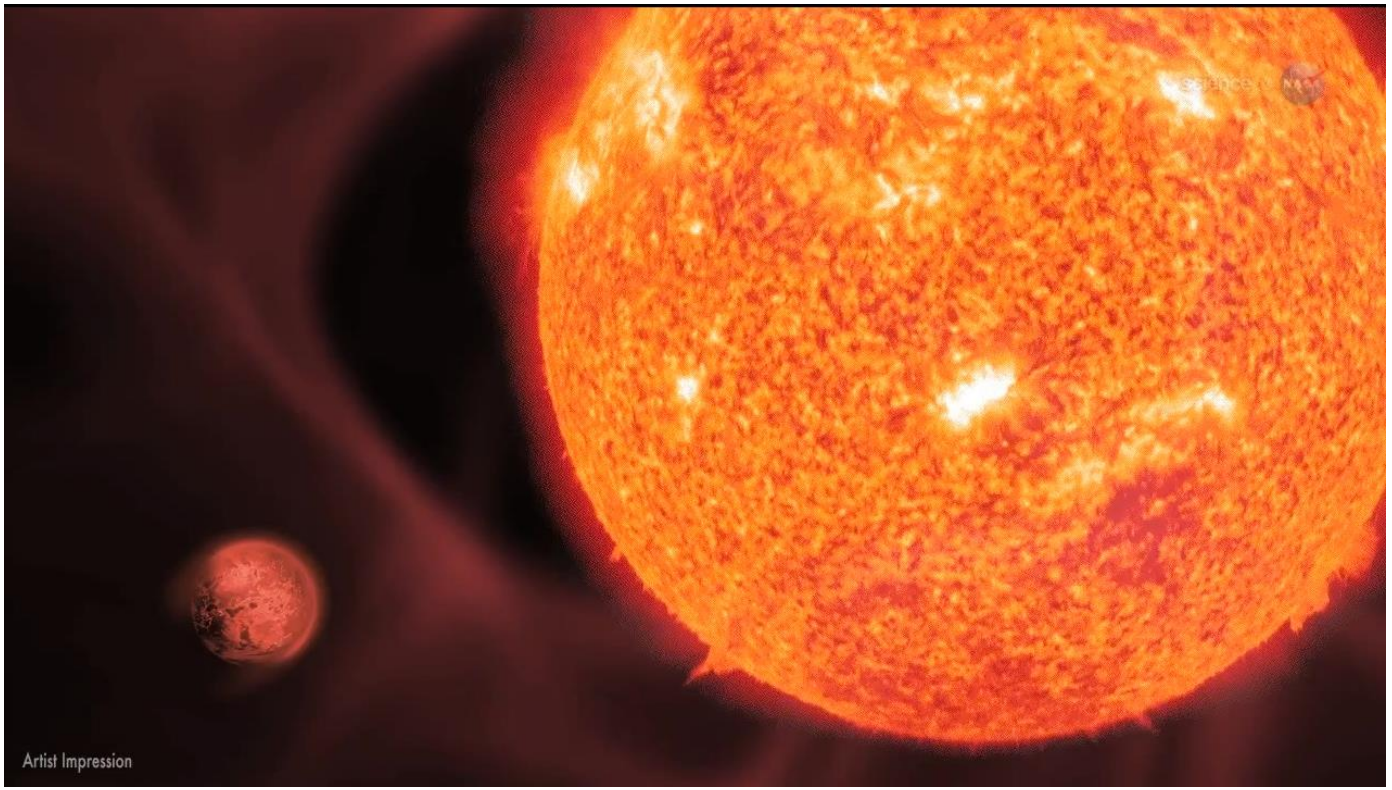
Mercury's Rotation

- Rotates very slowly
- Rotation period: 58.646 Earth days
- Orbital period: 87.969 Earth days
  - This means it rotates three times for every two trips around the Sun
- Mercury's speed changes as it moves around the Sun due to an elliptical orbit
- Resonance – when a force that acts repeatedly on a body causes its motion to grow even larger
  - Ex: pushing someone on a swing
  - The Sun does this to Mercury and causes the 2:3 ratio

Mercury

Mercury's Rotation

- This rotation pattern gives Mercury a long solar day
- Solar day: 176 Earth days



Venus

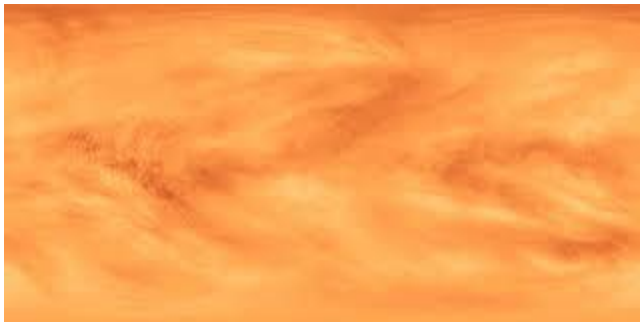
Introduction

- Most like Earth in regards to diameter and mass
- Named for the Roman goddess *Venus* for beauty and love, but it's pretty far from that
- Even though it's similar in mass and diameter, its significantly different on the surface and in atmospheric structure/composition
- Really rough surface terrain with a very dense and hot atmosphere covering it

Venus

Atmosphere

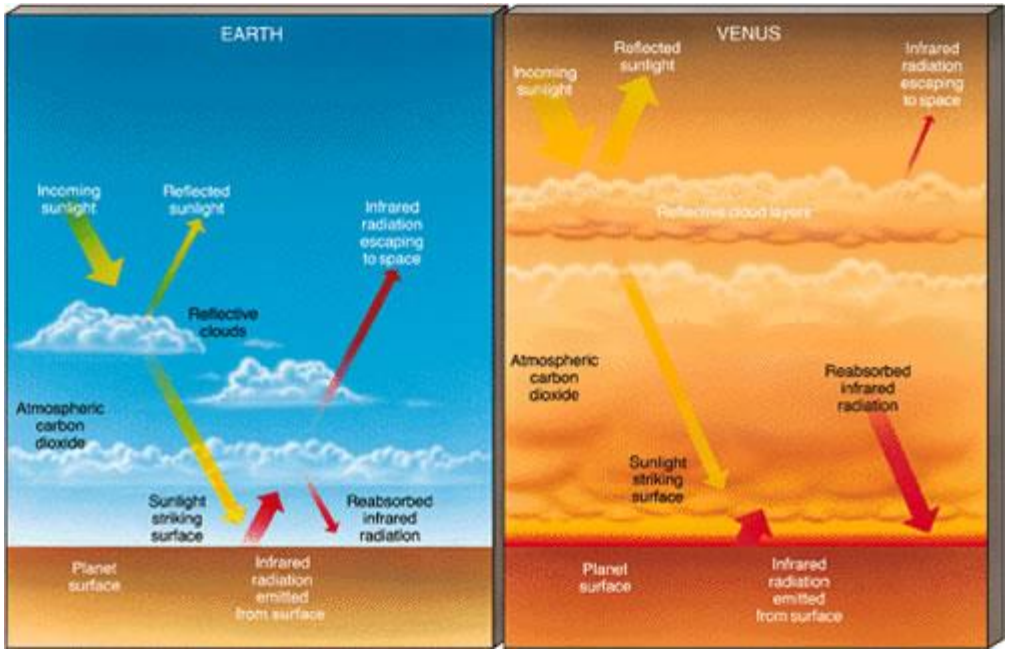
- Venusian Clouds – clouds found on Venus that are composed of sulfuric acid droplets from volcanic sulfur compounds combined with water
- These permanently cover the planet
- Very high and very thick to where astronomers can't see through them to analyze the surface with telescopes
- Reflects a lot of sunlight so it looks really bright from Earth
- It's tinted orange because the blue wavelengths get absorbed by the clouds



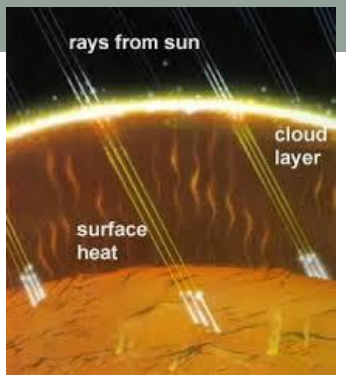
Venus

Atmosphere

- Atmosphere is really dense
- 100x stronger pressure than Earth
  - The same that you would feel 1000 meters (about 3000 ft) under water



Venus



Runaway Greenhouse Effect

- The atmosphere causes the surface to exceed 900˚ F!
- Runaway Greenhouse Effect – gases in the atmosphere trap heat and radiation from the Sun and continuously heat the planet
- Due to high levels of CO_2
- 300,000x more CO_2 than Earth
- Any water that could have once been there has been boiled away
- This causes Venus to be hotter than Mercury even though it's further from the Sun

Venus

The Surface of Venus

- Some Russian crafts did make it through the atmosphere in the 70s and was able to transmit pictures and rock data
- The rocks showed that they were volcanic
- With the conditions the way they are, probes orbiting Venus can use radar to scan the surface and map the ground
- These maps show that Venus contains less land formations like mountains and rugged terrain
- Most of the surface is low, gentle rolling plains

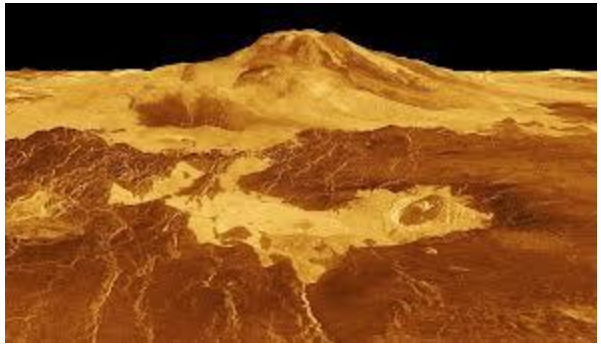
Venus

The Surface of Venus

- *Magellan* spacecraft was able to detect features as small as about 100 meters in size
- Brighter regions reflected radon more strongly meaning the surface was rougher than the dark regions
- Doesn't show signs of plate tectonics like many astronomers assumed it would
  - Ex: continental blocks, crustal rifts, trenches at plate boundaries, etc.
- Does have some craters and crumpled mountains, volcanoes dominate

Venus

The Surface of Venus



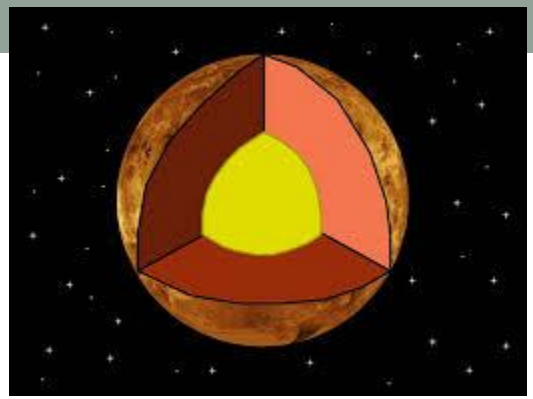
- Common volcanic land formations:
  - Uplifted rock
  - Peaks with heavy lava flows
  - Long narrow faults (cracks)
  - Peculiar lumpy terrain
- Evidence of a young and active surface
- Astronomers believe that Venus's original surface has been completely destroyed by these volcanoes
- The surface we can see is 500 million years old, much younger than Earth's

Venus

The Surface of Venus

- Volcanic eruptions can cause electrical charges (lightning) and we're still detecting that on Venus along with increases in sulfur in the atmosphere
- Heat flows are less uniform than what they are on Earth
- Lava plumes are common and that might tell us how our own crust was formed

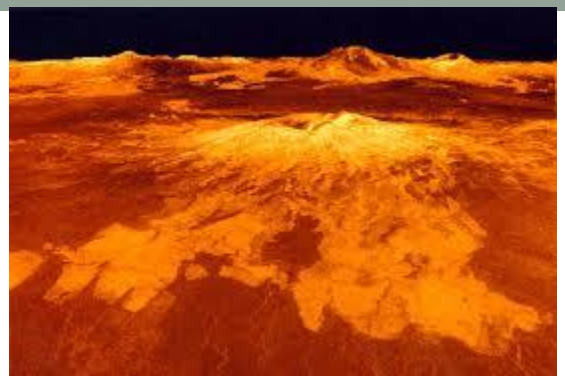
Venus



The Interior of Venus

- Interior is similar to Earth's with the iron core and rock mantle
- Extraterrestrial geologists don't have any concrete seismic information so they rely on density and gravity
  - Same as Mercury
- Even though internally similar, geologists believe the amount of water in the rocks is why the surface conditions are so different
  - Earth: "runnier" magma where the melting temperature is lower, creating a thinner crust
  - Venus: drier, so the rocks can become much hotter and much less stable or consistent in the cooling process

Venus



The Interior of Venus

- A thin crust (Earth): allows steady loss of heat, but still causes that thin layer to break into plates and allow that pressure to be released more consistently
- A thick crust (Venus): holds heat in and convection continues to build without it being able to escape through the surface (building pressure)
- 2 theories on the surface land formation development:

    1. rising, hot material causes the surface to bulge into a closed volcano and as it cools, it settles back down to form the continent

Venus

The Interior of Venus

- 2 theories on the surface land formation development:

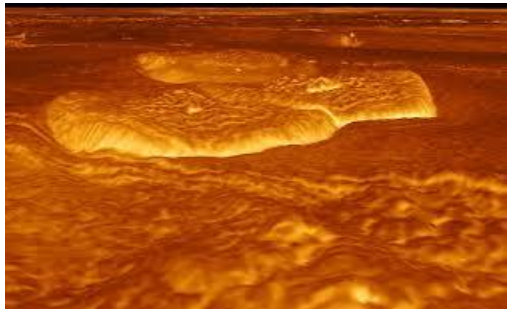
    2. the trapped heat gradually melts the bottom of the thick crust, thinning it, and allowing it to break up and flooding it with lava

- Both theories are plausible and have the ability to repeat themselves every hundred million years or so

Venus

Rotation of Venus

- Venus rotates on its axis (in retrograde) slower than any other planet in our solar system
- Sidereal day: 243 Earth days
- Theory for this: it was struck right after it developed which knocked it off of its original axis and caused it to begin rotating backwards
  - To add to it… thoughts are circulating that it could have also shifted in axis degree slightly over time thanks to the Sun and even Earth pulling on it for so long
- Very weak magnetic field
- Long solar day: 117 ED



Mars

Introduction

- Mars is named for the Roman god of war because of its red color
- Its diameter is only about half of Earth's and its mass is 1/10th of Earth's
- Its axis tilt is very similar to Earth's and its day turn is only 39 minutes longer, causing it to experience similar seasons
- Around the equator, the temperature can get up to 50˚F
- Atmosphere is generally clear, allowing astronomers to check out the surface easily

Mars

Introduction

- Contains polar caps that are clearly visible against the red terrain
- Astronomers have sent many different probes to analyze Mars, including the Rover that is currently there surveying the surface

Mars

The Surface

- Has dramatic surface features
- Along the equator, there is a rift called the *Valles Marineris*
- It stretches 4000 km (2500 miles) long, 100 km (60 mi) wide, and 7 km (4 mi) deep
- Named after the *Mariner* spacecraft that discovered it
- It would span the entire length of the US if here on Earth

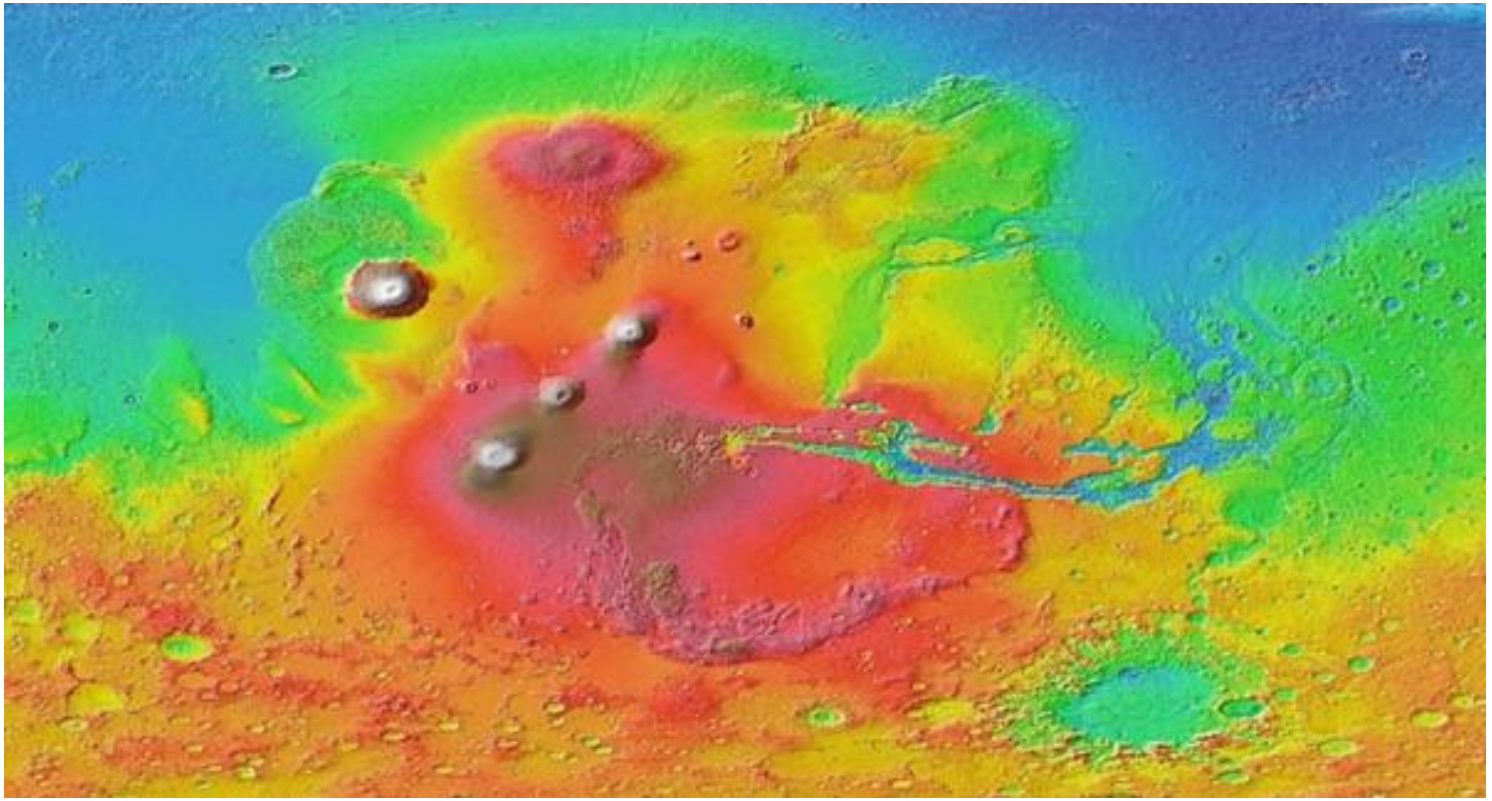
Mars

The Surface

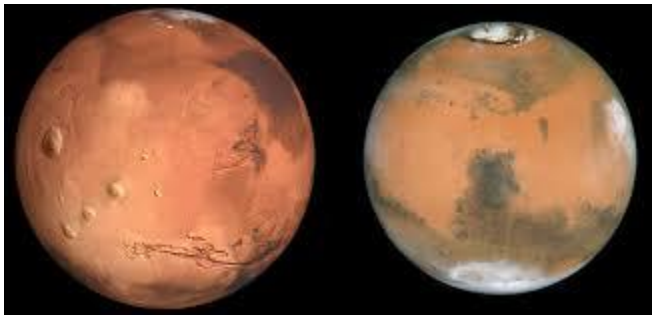
- The *Tharsis Bulge* is a large land formation that is dotted with volcanoes
- *Olympus Mons* rises about 25 km (16 mi) above its surroundings
  - 3x the height of Earth's highest peaks
- Planetary geologists think that the Tharsis region formed as hot material rose from the deep interior of the planet and forced the surface upward as it reached the crust
- The hot matter erupted through the crust to form the volcanoes

Mars

The Surface



Mars



The Surface

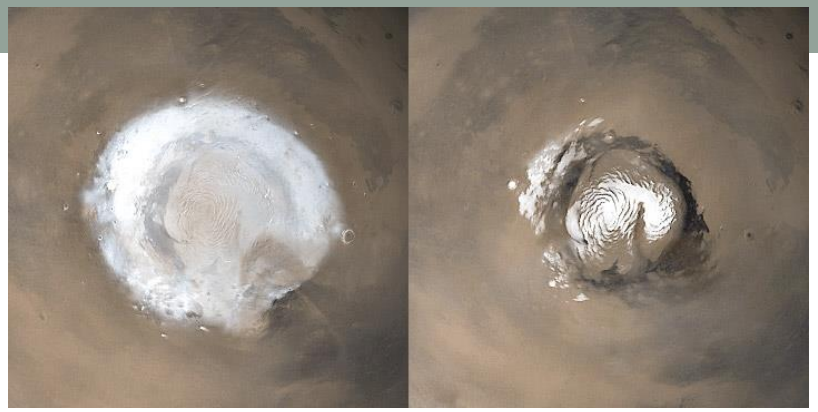
- The small number of impact craters in its slopes shows that Olympus Mons is no older than 250 million years
- Some planetary geologists think that the Tharsis bulge may have also created the gigantic Valles Marineris
  - Valles Marineris formed as the Tharsis region swelled, stretching and cracking the crust
  - Others think this could be evidence for tectonics, but that it isn't active now that the planet has aged and cooled

Mars

The Surface

- Easily found on Mars are the Martian polar caps
- Frozen regions change in size during the cycle of the seasons
  - Martian seasons are more extreme than Earth's because the atmosphere is much less dense and doesn't retain heat as well
- Most of the visible caps are frozen carbon dioxide (dry ice)
- In the winter, the southern cap can extend to be about 5900 km (3700 mi) in diameter from the south pole to 40˚ latitude
- In the summer, the southern cap shrinks down to about 350 km (220 mi) and the northern one to about 1000 km (600 mi)

Mars



The Surface

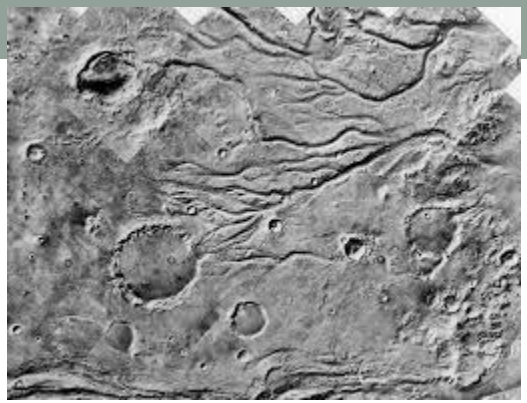
- There is a carbon dioxide layer on the surface, but underneath is all standard frozen water
  - Determined by temperature and radar studies
- The depth of the caps measures out to be able to cover the entire planet in about 10 m (30 ft) of water if thawed
- The northern cap has layers showing that Mars may have had ice ages in a similar to fashion to Earth
- With the southern pole being much higher in elevation than the northern one, this explains their dramatic differences in size
- The northern cap is larger on average throughout the seasons

Mars

The Surface

- The poles are bordered by immense deserts with dunes blown into parallel ridges by the winds
- Huge dust storms blow the fine red dust over the entire surface of the planet
- The color comes from the iron minerals in the surface rocks
  - Iron usually reacts with oxygen to create this look, but on Mars it reacts with other gasses and creates the same effect

Mars



Water on Mars

- Liquid water is the “secret ingredient” that astronomers believe to be the key to life forms on other planets
- Scientists have sent dozens of space crafts to Mars which have sent back photos of landscapes, measurements, and close ups of the rocks
- Two intriguing features that were found by the *Viking* spacecraft in the 70s were:
  - Dry riverbeds
  - Huge channels
- This is evidence of water flowing on Mars in the past even though there is no evidence of liquid water today thus far

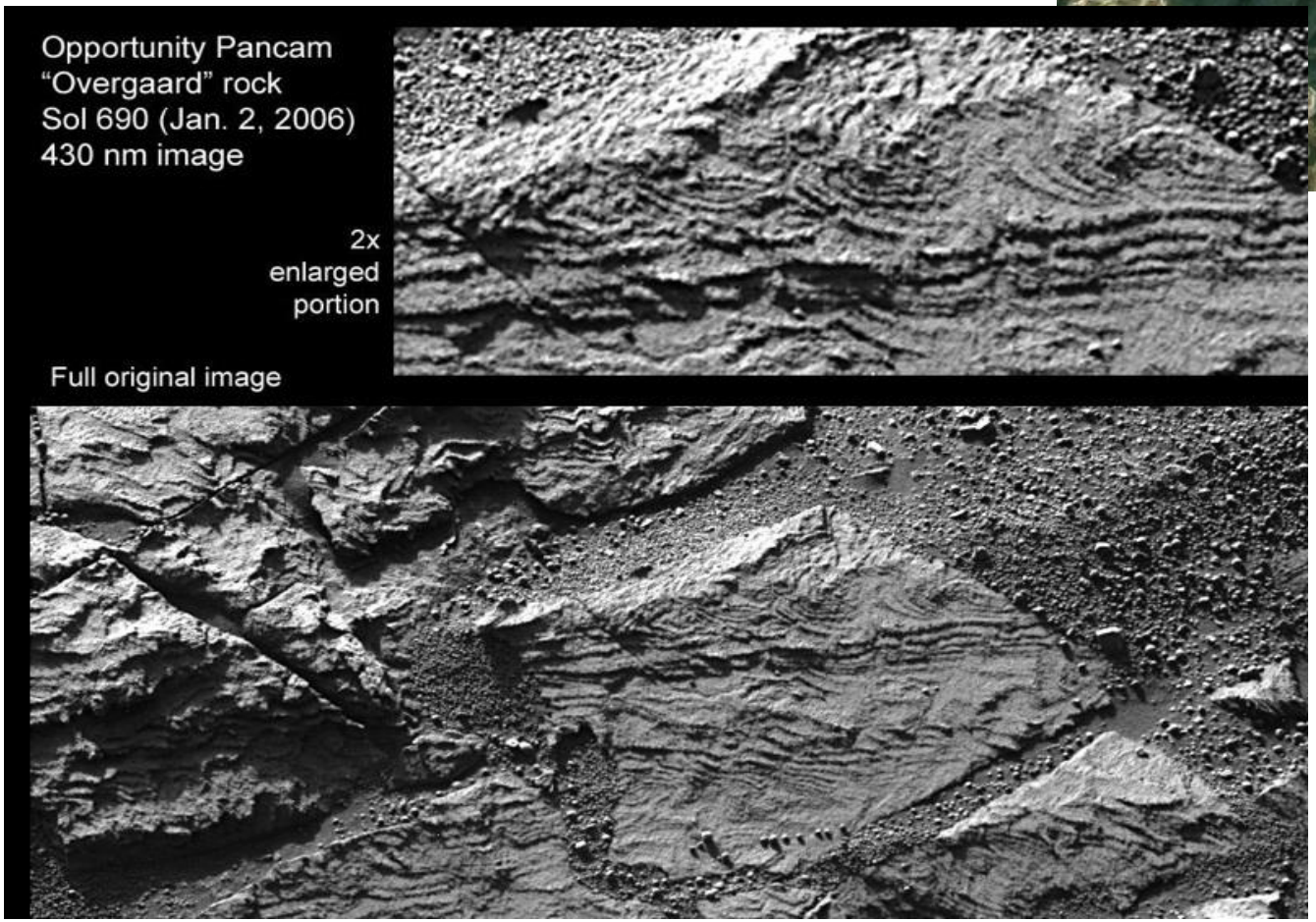
Mars

Water on Mars

- Many astronomers think there may have been large lakes or even small oceans at one point
  - How do we know? - There are smooth terraces that look like old beaches around the inner edges of craters and basins
  - Narrow canyons breach the craters' rims showing where water flowed in and drained out into lowland areas
- Photos of these areas triggered rovers to explore their basics and brought back many great pictures and details of these dried up basins
- Many of the detailed ripples that can be found on ocean coastlines from the ripples of the wave have mineralized and can be found on Mars in these basins

Mars

Water on Mars



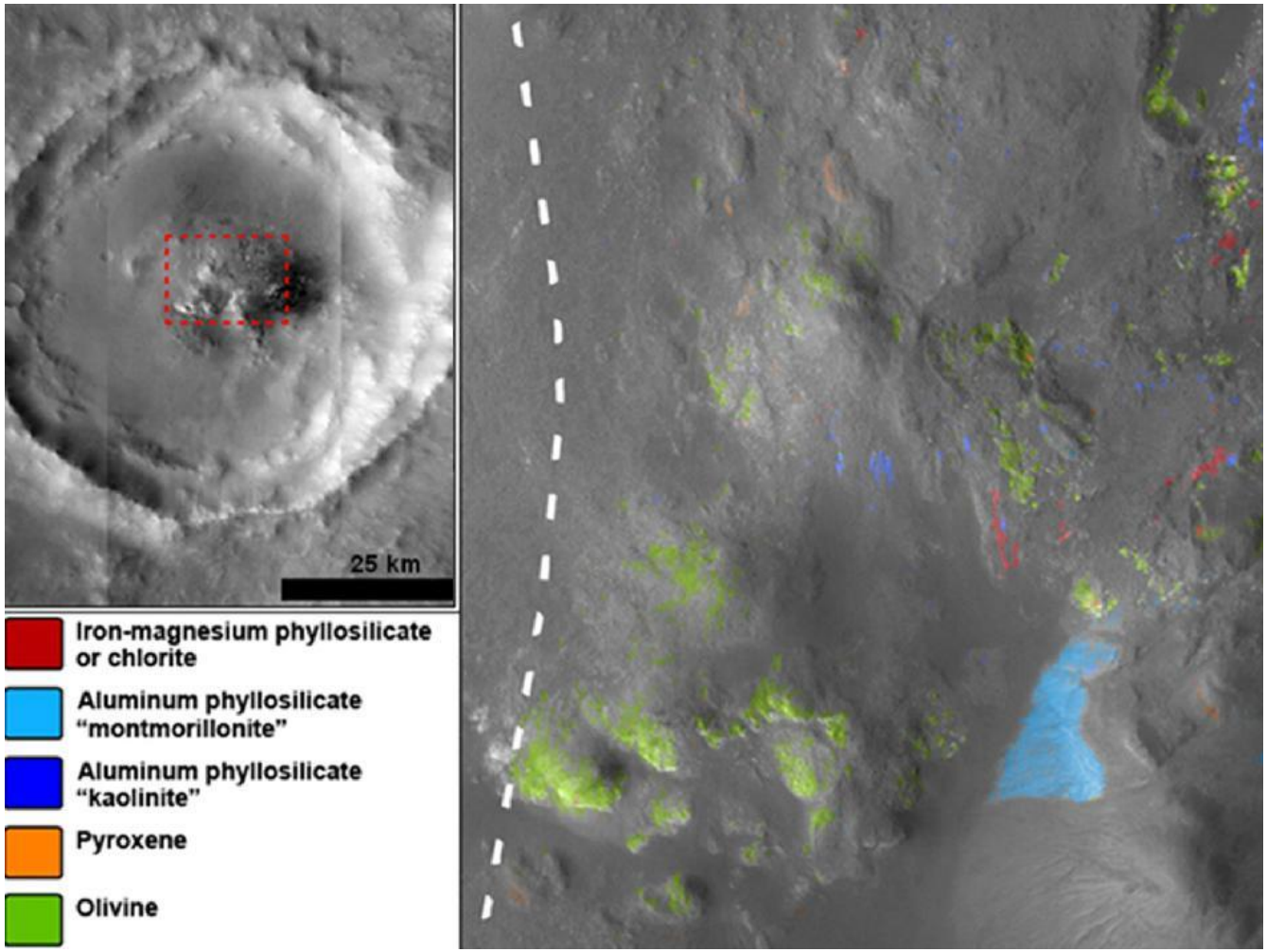
Mars

Water on Mars

- In these areas, ice was dug up by a third rover that explored the northern polar area in 2008
- It was found that after the soil testing was complete, the soil came back highly alkaline
  - … to the point of baking soda with high levels of oxidizing chemicals (not really suitable soil)
- The rovers that did the soil testing were equipped with spectra radars that read what the spectrum of light reflected from the surface
- Astronomers realized what minerals are there thanks to this process

Mars

Water on Mars



Mars

Water on Mars

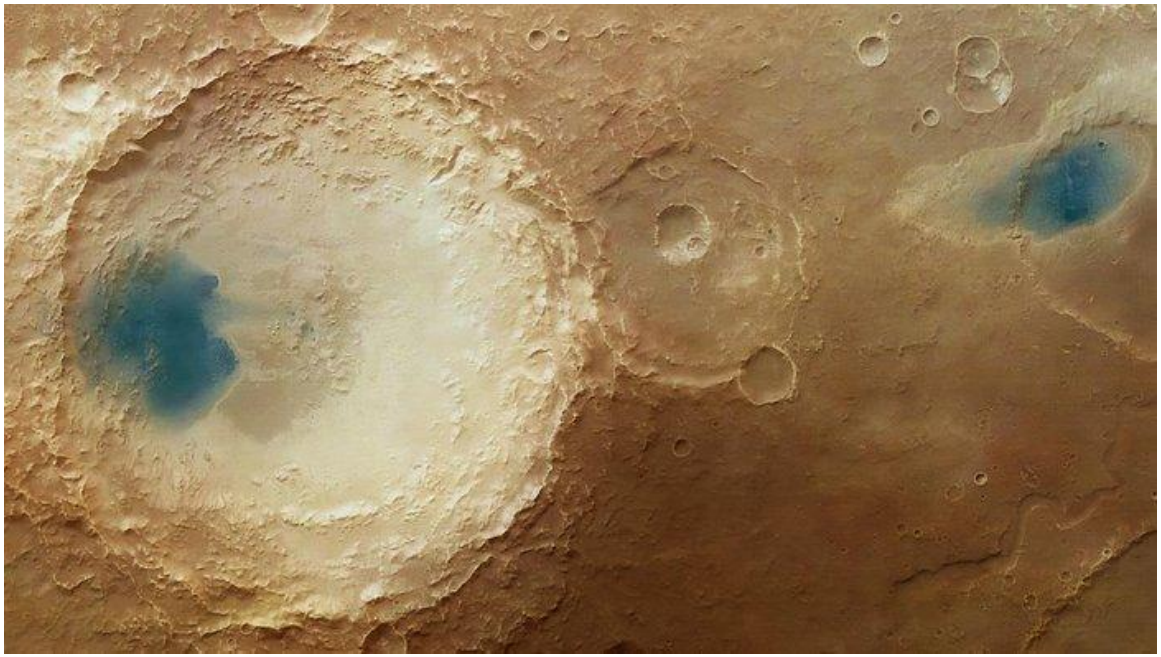
- Finding these types of minerals gives astronomers more evidence of liquid water in the history of Mars because these minerals would have needed it for development or developed from it
  - Ex: hematite has been found and in descent quantities
  - Hematite is an iron compound that needs water to form and is an indicator that that region (now dry) was once covered by a salty lake or sea of some sort

Mars

Water on Mars

- Data came in from the *Odyssey* that showed there are huge amounts of frozen water just under a dust layer
- The question remains… so why isn't it still there??

Or is it??

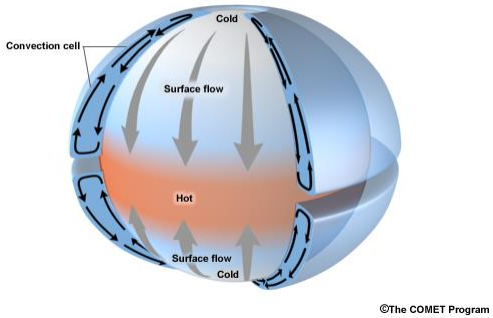


Mars

The Martian Atmosphere

- Clouds and windblown dust are both evidence that Mars has an atmosphere
- 95% CO_2 and 3% N_2 with only traces of O_2 and water vapor
- The density of the Martian atmosphere is only 1% what Earth's is
  - This low density creates a really weak greenhouse effect
  - This is why it is significantly different from Venus even though it has about the same amount of CO_2
- Because of the lack of heat withheld by these gases, the average temperature on Mars is only -67˚F!
  - Cold for us? YES! … however, it could be much worse

Mars



The Martian Atmosphere

- The clouds found in the atmosphere are frozen molecules of CO_2 and H_20
- The air that is warmed near the equator will migrate its way north, forcing it to rise, and creating some strong winds
- Because of the rotation of the planet, the Coriolis effect deflects them and forces them to move parallel with the equator
  - Similar to Earth's minus the ocean pull
- Dust storms can kick up from time to time and can cause the sky to turn pink from the iron heavy surface
- No rain falls even though it has clouds because it is too cold

Mars

The Martian Atmosphere

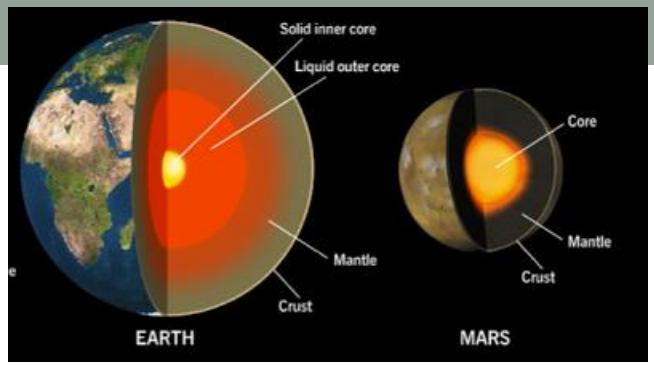
- Despite how dry it is, fog can sometimes form in valleys and frost condenses on the ground on cold nights
- Snow? That's frozen CO_2
- With the pressure on Mars, any liquid water would evaporate
  - Regardless of the temperature, if a pressure is low enough, the boiling point will drop significantly
  - This is why standing liquid water would be tough to find
- In order to have the standing water in the past, that means the atmosphere would have had to have been warmer and more dense

Mars

The Martian Atmosphere

- The higher pressure would've created a decent greenhouse effect and really warmed the planet
- It obviously cooled almost to the point of a permanent ice age
- Could have happened two ways:
  - Repeated asteroid impacts on Mars when it was young may have blasted its original atmosphere off into space
  - Mar's low gravity may have let the gases slowly escape over the first 1-2 billion years of its history
- The low levels of tectonics and volcanic work wouldn't have been able to replenish it

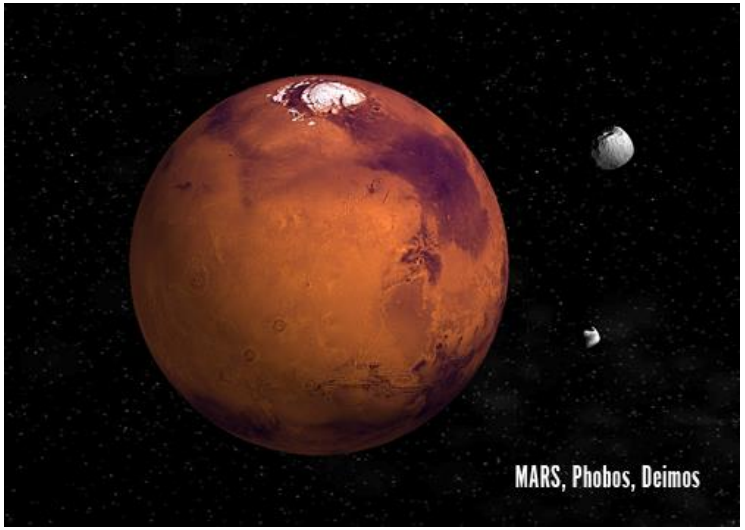
Mars



The Martian Interior

- Contains a crust, mantle, and iron core
- The interior is cooler than Earth's
- With it being smaller, it lets go of the heat easier
- Has a metal core whose radius is between 1200 km and 2400 km, but has no magnetic field, so the core probably isn't molten anymore
- Because Mars doesn't have any folded mountains, it doesn't show signs of any thin crust tectonics and is assumed to have a crust twice the thickness of Earth's
  - This is why Earth has a lot of small volcanoes and Mars has a few very large ones

Mars



The Martian Moons

- Two of them:
  - Phobos
  - Deimos
- Named for demigods of fear and panic
- Only about 20 km in diameter and are possibly asteroids that were caught by the gravity pull
- Both are cratered and were probably hit by smaller asteroids
- These were discovered in 1877 through assumption
  - Earth has one and Jupiter had four (so they thought at the time) which means Mars should have two… bad logic but correct!

Mars

Life on Mars?

- No concrete evidence, yet
- The current *Curiosity* rover is seeking out organic compounds to try to find links to life forms
- NASA's plan: