Astr 2310 Tues. April 28, 2016

Today’s Topics

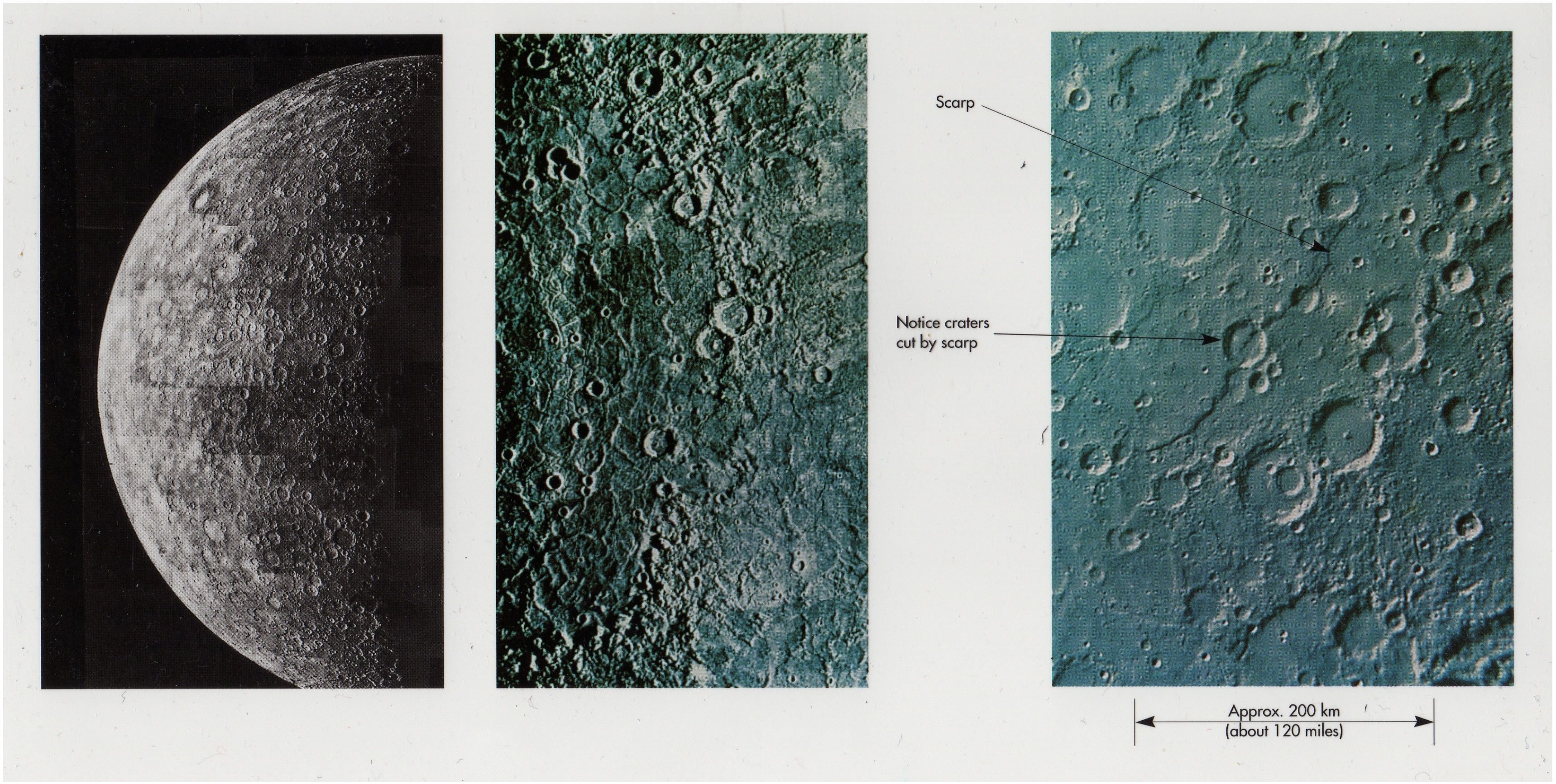
- Chapter 10: The Terrestrial Planets
  - Mercury
    - Physical Properties
    - Surface Features
    - Interior
    - Origin
  - Venus
    - Physical Properties
    - Surface Features and Atmosphere
    - Interior
    - Origin
  - Mars
    - Physical Properties
    - Surface Features and Atmosphere
    - Interior
    - Origin

Mercury

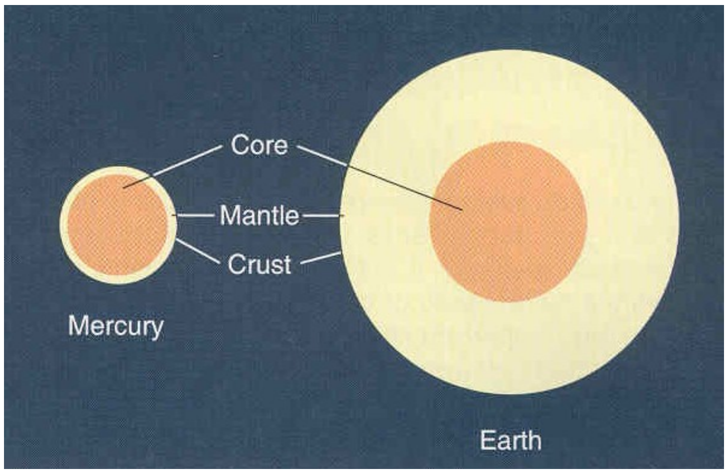
- **Exploration:**
  - Close proximity ot the Sun makes telescope observations very difficult
  - Mariner 10 flyby (1980)
- **Physical Properties:**
  - Mass: 1/18 of Earth's
  - Diameter: 4880 km (less than ½ Earth's)
  - Avg. Density: 5.4 gm/cc (Massive Iron core)
  - Rotation: siderial period of 59 days is 2/3 orbital period of 88 days
    (2:3 resonance with Sun)
- **Interior**
  - Composition: Models suggest Iron-Nickel core 3500 km in diameter with a 700 km thick silicate crust
  - Magnetic Field: weak, about 1% of Earth's but suggestive of liquid core
- **Surface Features**
  - Heavily cratered like the Moon but no Maria (lava planes). Wrinkling of crust suggestive of crustal shrinkage.
  - Noon temp. ~ 700 ^{o}K, but only 100 ^{o}K just before dawn (no atmosphere)
  - Obliquity ~ 0^{o} so polar craters in perpetual shadow, radar suggests ice!
- **Origin**
  - Massive Iron core somewhat opposite of the Moon
    - Model: Collision with massive body stripped most of crust??

Surface Features

Heavily cratered surface like the Moon.
Evidence for large impact basins.
Scarps or “wrinkles” suggestive of crustal shrinkage.



Relative size of Mercury's core



From: Horizons by Seeds

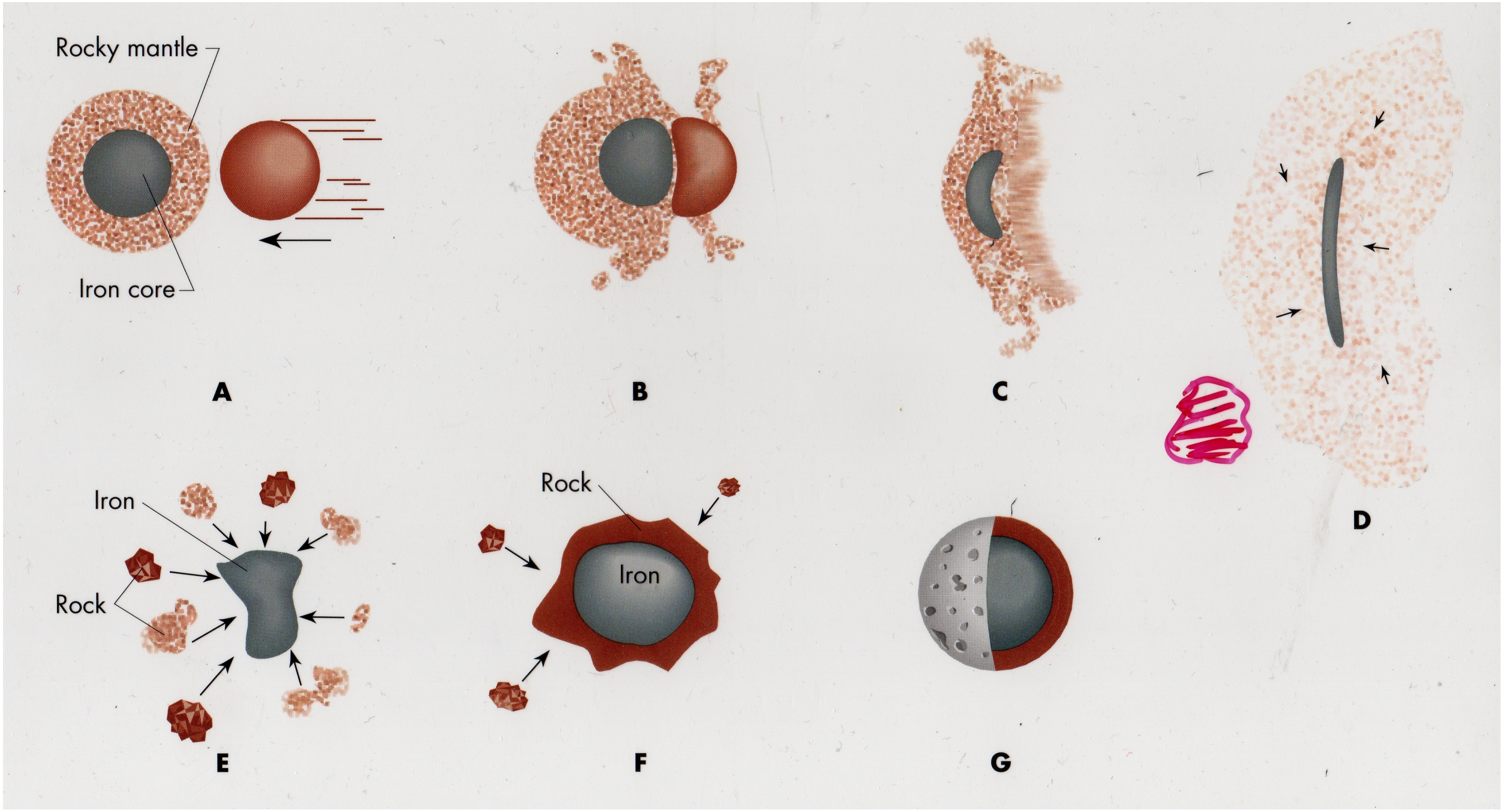
- **Mercury is very dense, with a large metallic core. Magnetic field consistent with liquid core.**

- **Not enough gravity to retain an atmosphere (and so too hot during its formation to retain much volatiles).**

- **Mercury may have suffered a massive impact late in its formation.**

Model of Formation of Mercury

Collision with a massive body after core differentiation strips much of original crust.



Venus

- **Exploration:**
  - Dense clould cover means surface has never been seen
  - Radar imaging of surface by Pioneer Venus (1970s) and Magellan (1990s)
- **Physical Properties:**
  - Mass: 0.82 of Earth's
  - Diameter: 12104 km (close to Earth's)
  - Avg. Density: 4.3 gm/cc (Iron core similar to Earth's)
  - Surface gravity 0.91 Earth's
  - Rotation: 243 days retrograde!

    (Sun rises in west every 116 days)
- **Interior**
  - Composition: Models suggest similar interior to Earth's Iron-Nickel core 4800 km in diameter with a mantle and a silicate crust
  - No Magnetic Field but a liquid core is likely
- **Surface Features**
  - Radar indicates 80% of surface covered in lava plains (Maria).
  - Mountains and Mountain Ranges + Continents similar to Africa or Australia

    (no rift zones so continential drift is unlikely)
  - Crater counts indicates young age, about 15% that of Moon's maria (~ 500 Million years old)
  - Many volcanoes and lava flows both large and small (active?)
  - Massive Atmosphere is 96% CO_2, 3.5% N_2, no water vapor

    (surface pressure is 90X Earth's, SO_2 and H_2SO_4 clouds but clear below 30 km)
  - Surface Temperature: 800 ^oK
- **Origin**
  - No satellite
  - Low rotational angular momentum is a mystery.

Expect Venus to be similar to Earth (but it isn't!)

- Venus only slightly closer to sun, so expect about same initial composition
- Venus only slightly smaller than Earth, so expect about same heat flow

- Venus atmosphere is dramatically different
  - Very thick CO_2 atmosphere
  - Virtually no water in atmosphere or on surface
- Venus shows relatively recent volcanic activity, but no plate tectonics

- Both probably related to its slightly closer position to the sun which caused loss of its critical water

- Thick atmosphere and clouds block direct view so information from:
  - Orbiting radar missions (Magellan in early 90's)

Venus' Atmosphere & Clouds

Dense atmosphere of CO2 (96%) and N2 (3.5%)

Clouds of SO_2 and H_2SO_4 (sulpheric acid!)

No water vapor is present

Very little wind at surface due to very high surface pressure.

Venus' Surface

Radar imaging reveals:

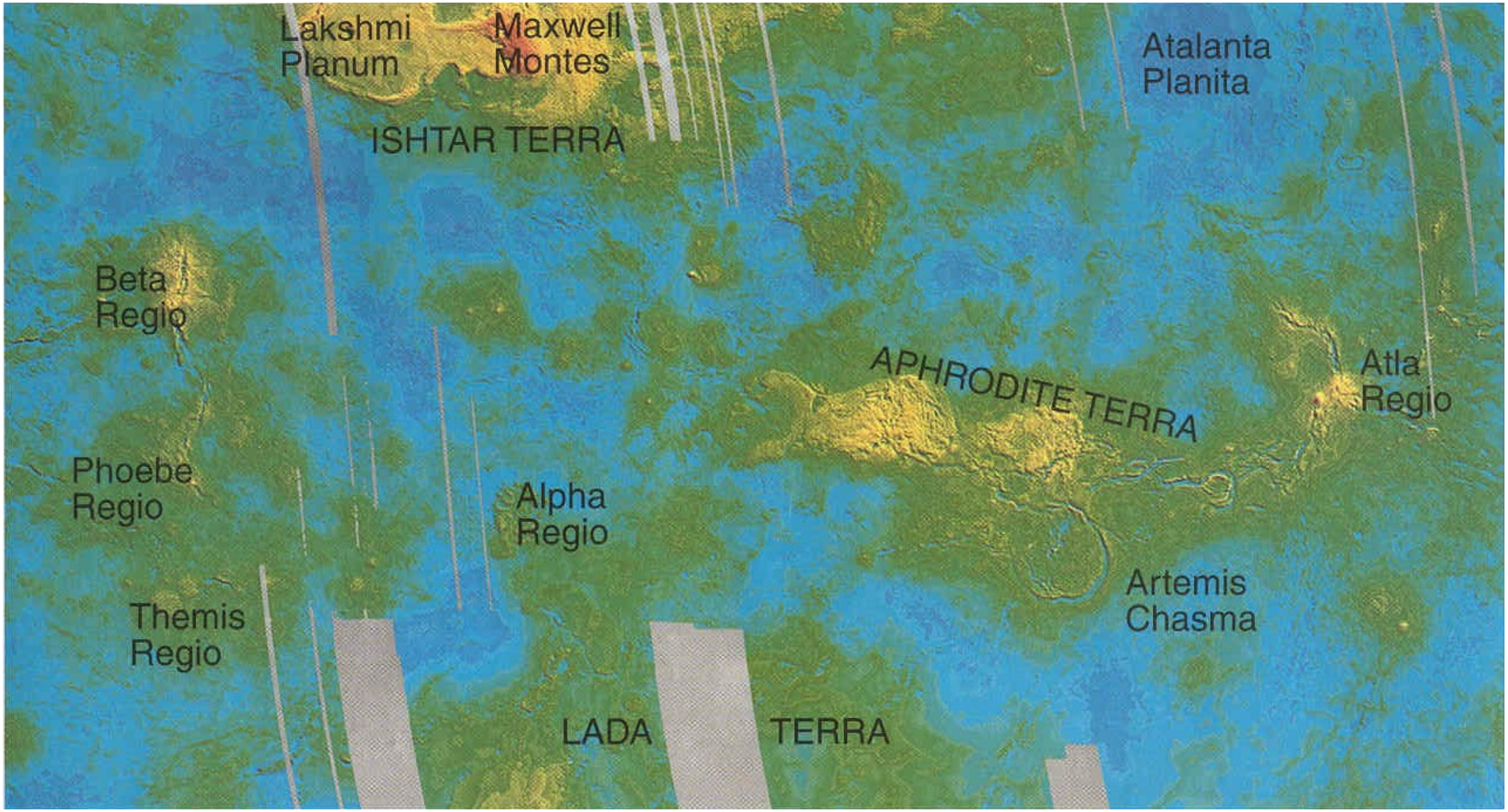
Continential sized regions

Huge volcanoes and lava flows

Lava domes

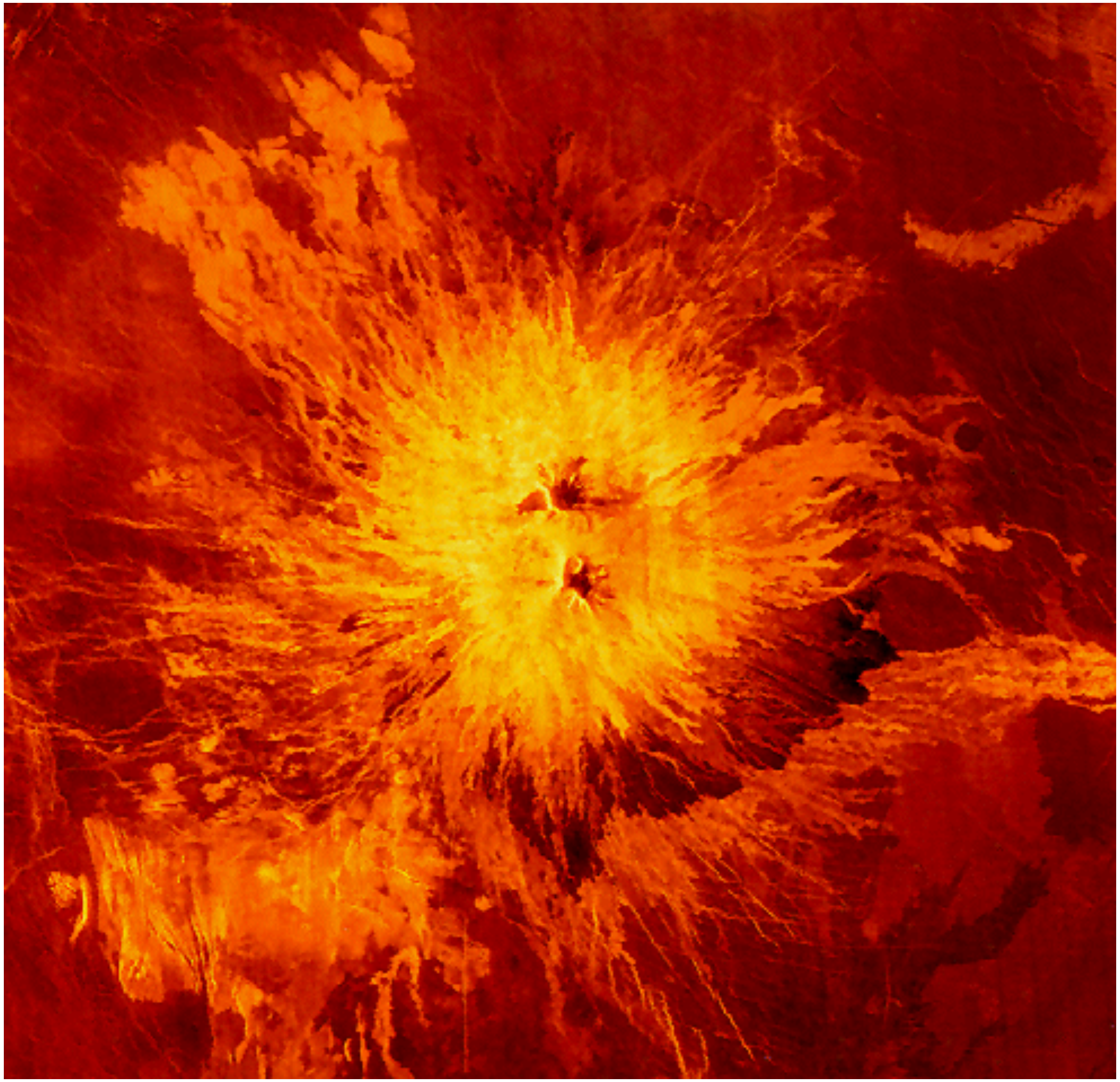
Large impact craters

Surface Relief of Venus from Radar



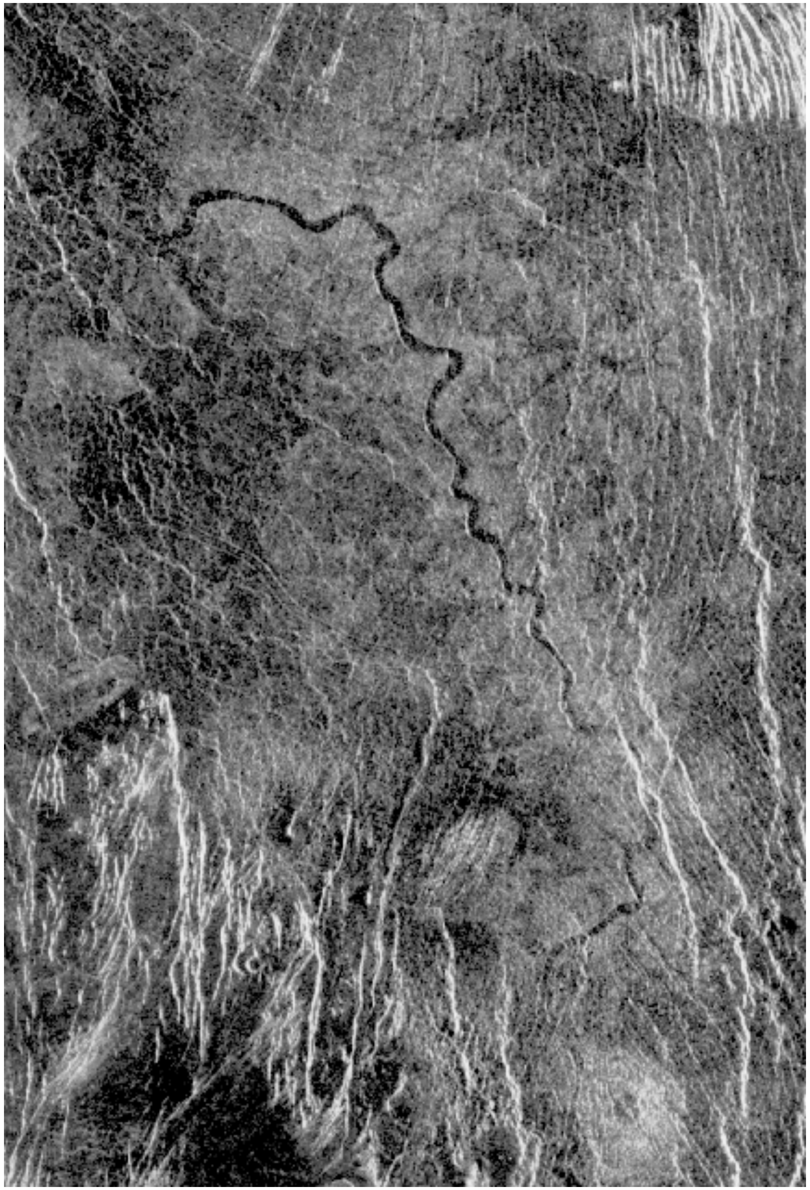
- **Venus does show evidence of “recent” volcanism**
- **It does not show linear ridges, trenches, or rigid plates**
  - **In a few spots there are weak hints of this – but clearly different**

Volcanoes



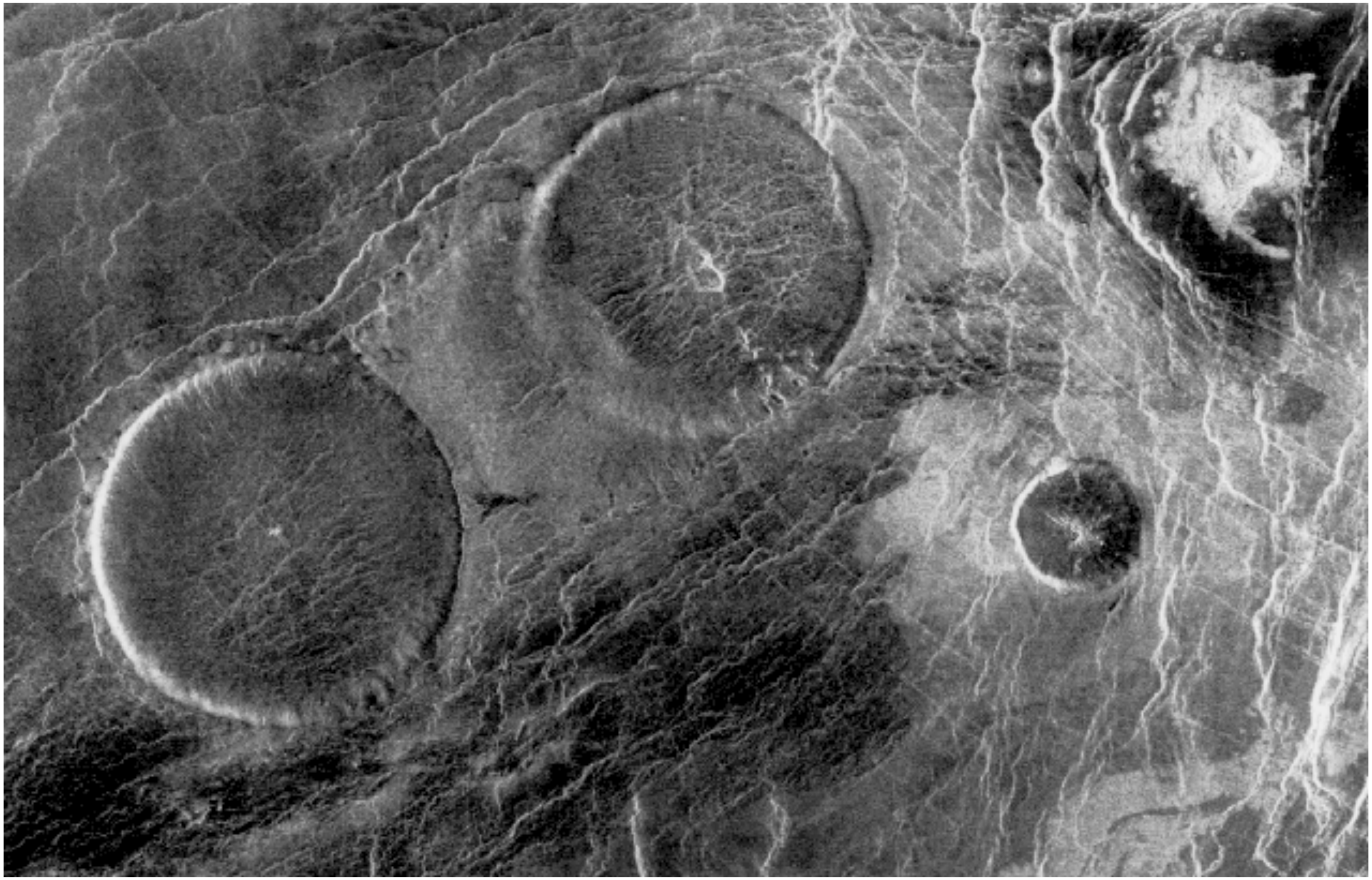
- **Sapas Mons**
  - Lava flows from central vents
  - Flank eruptions
  - Summit caldera
- **Size:**
  - 250 miles diameter
  - 1 mile high

Lava Channels



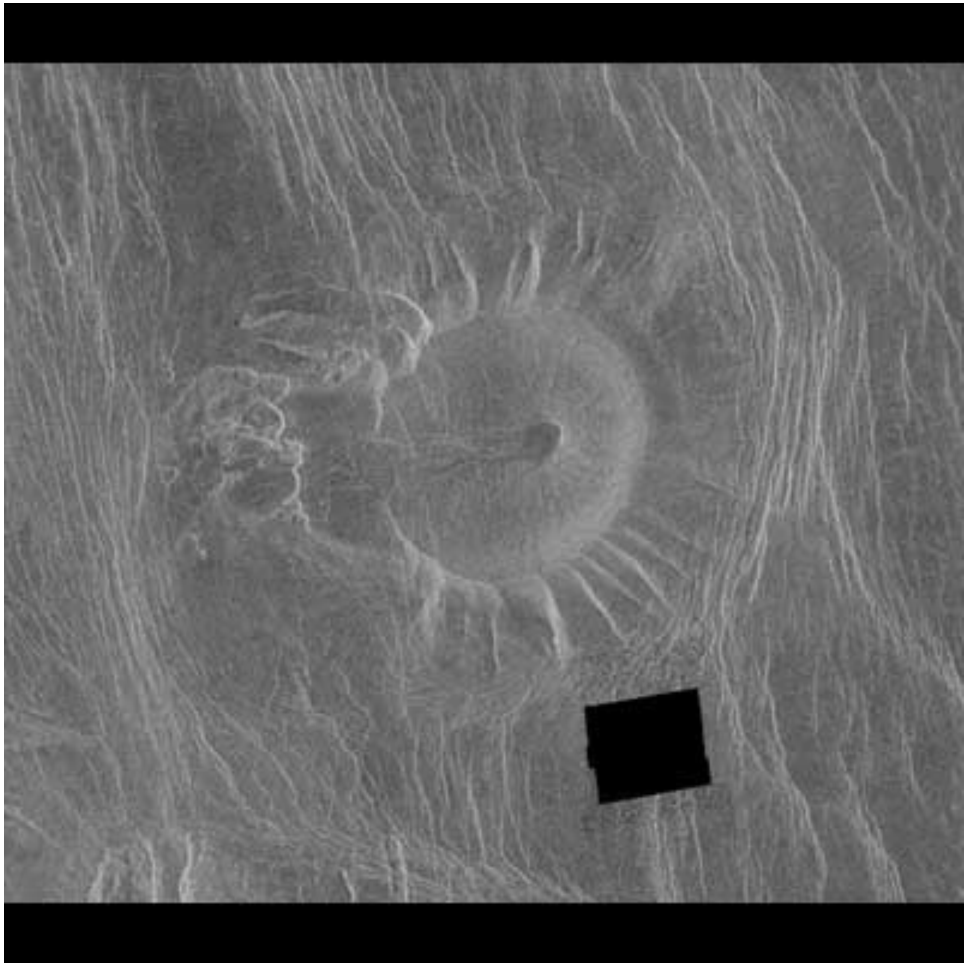
- **Large!**
  - 100's of miles long
  - 1.2 miles wide
- **High Venus temperatures may allow very long flows**
- **Composition could also be different**

Pancake Domes



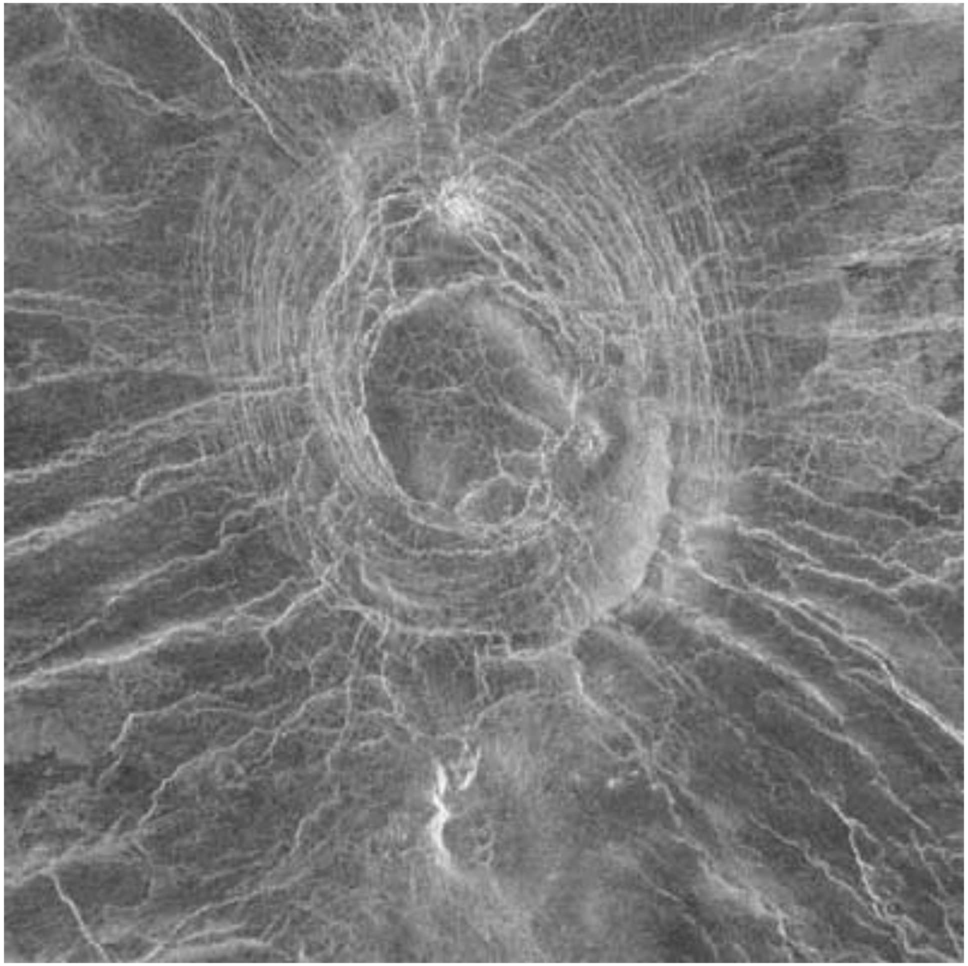
- **Pancake domes formed from very viscous lava**

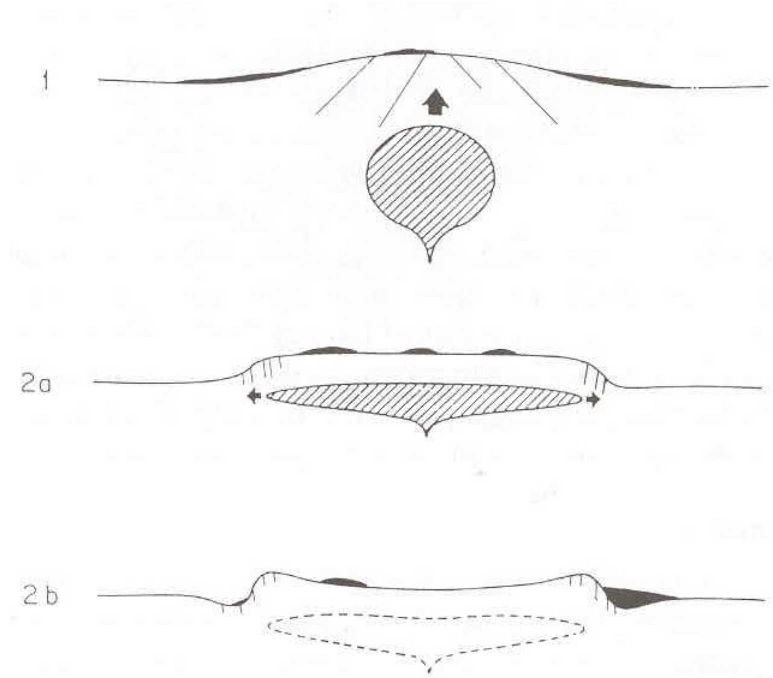
“Ticks”



- **Domes which have partially collapsed?**

Corona and a possible model





From Stofan et al. 1997 in Venus II

- **Corona possibly due to upward moving plume of hot mantle which bow up surface, then spreads out and cools (as in a “lava lamp”)**

Venus' Surface - III

Two Venera landers imaged the surface before high temp. destroyed them.

Flat basaltic rocks imply lava flows

Why does Venus have much more CO_2 in atmosphere than Earth?

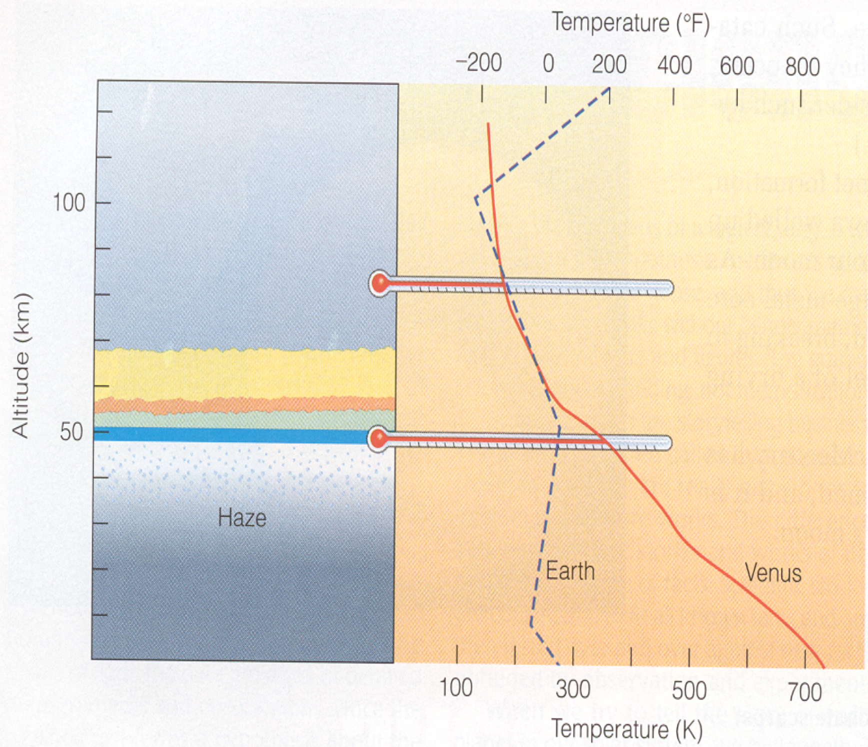


Figure 17-11

The four principal cloud layers in the atmosphere of Venus are shown at left. Thermometers inserted into the atmosphere at different levels would register the temperatures indicated by the red line in the graph at the right. The blue dashed line shows the temperatures in Earth's atmosphere for comparison. Note the difference in temperatures at the surfaces of the planets.

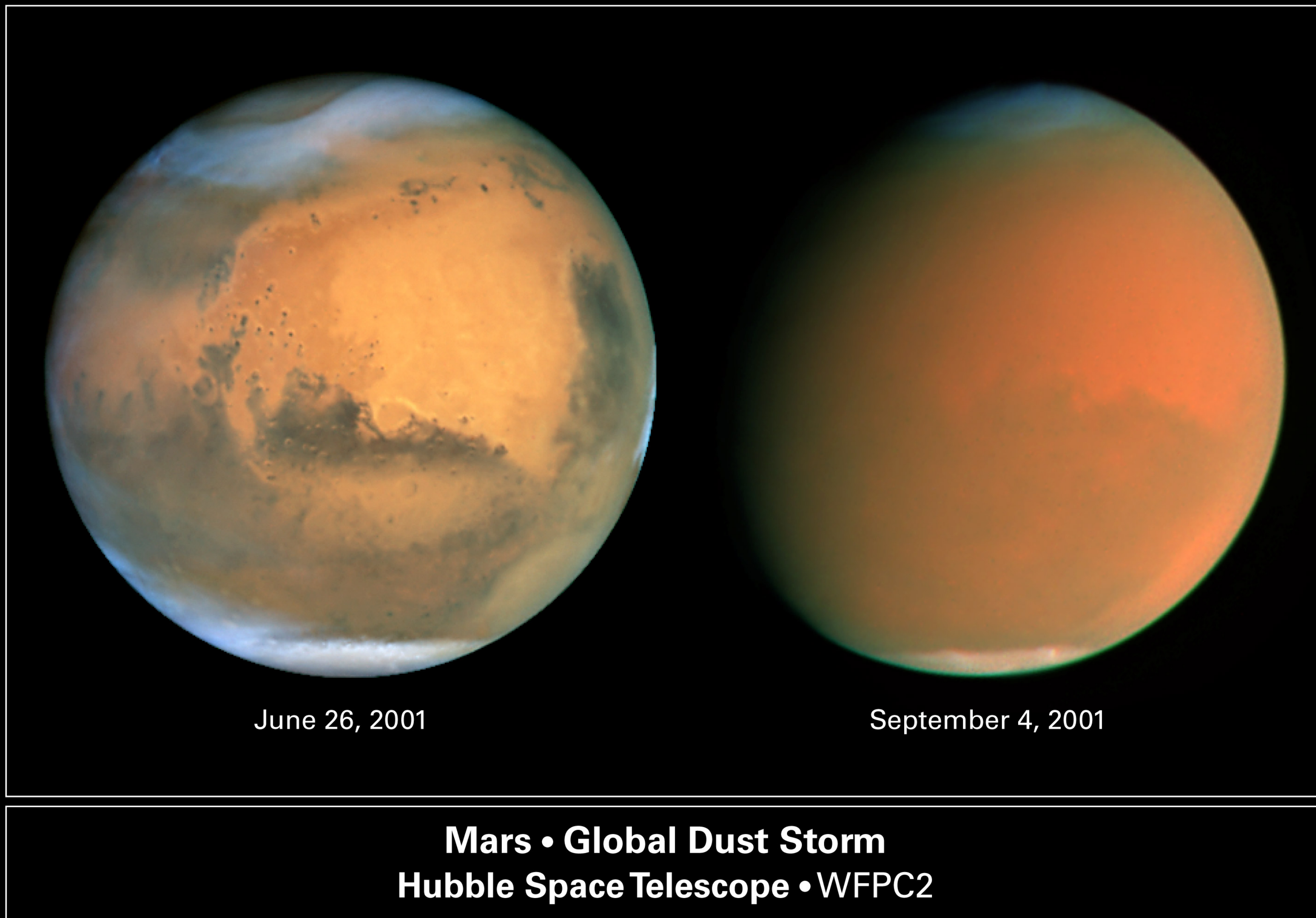
From our text Horizons, by Seeds

- **Amount of CO_2 in atmosphere on Venus roughly equal to amount of CO_2 in limestone on Earth**
- **With no oceans, don't have a way to get CO_2 out of atmosphere and back into rocks**
- **Runaway effect, because high T causes faster loss of water to space.**
  - If H_2O gets into upper atmosphere it is broken down into O, H by UV sunlight
  - H is so light it escapes to space
  - On Earth cooler T traps H_2O in lower atmosphere (it condenses if it gets to high)
- **Location closer to the sun pushed Venus "over the edge" compared to Earth**

Mars

- **Exploration:**
  - Early telescopic observations revealed polar caps and seasonal albedo patterns (early speculations of seasonal plant growth and "canals")
  - Mariner 4 flyby (1965), Viking landers and orbiters (1976)
- **Physical Properties:**
  - Mass: 11% of Earth's
  - Diameter: 6794 km (~ ½ Earth's)
  - Avg. Density: 3.8 gm/cc (Iron core but smaller than Earth's)
  - Surface gravity: 0.38 Earth's
  - Rotation: siderial period of 24 hours is almost exact match to Earth's
  - Obliquity: 25 degrees so Mars has seasons like the Earth
- **Interior**
  - Composition: Models suggest Iron-rich core 3500 km in diameter with a 700 km thick silicate crust
  - No Magnetic Field: implies solid core
- **Surface Features**
  - Some cratering but not like the Moon.
  - Huge extinct volcanoes
  - Large canyon systems some carved by running water
  - Noon temp. ~ 300 ^oK, so ice sublimes to form fog and clouds
  - Thin atmosphere: 95% CO_2, 2.7% N_2, 1.6% Ar (ancient atmosphere similar to Earth's)
- **Origin**
  - Iron-rich core implies partial melting
    - Model: Collision with massive body stripped most of crust??

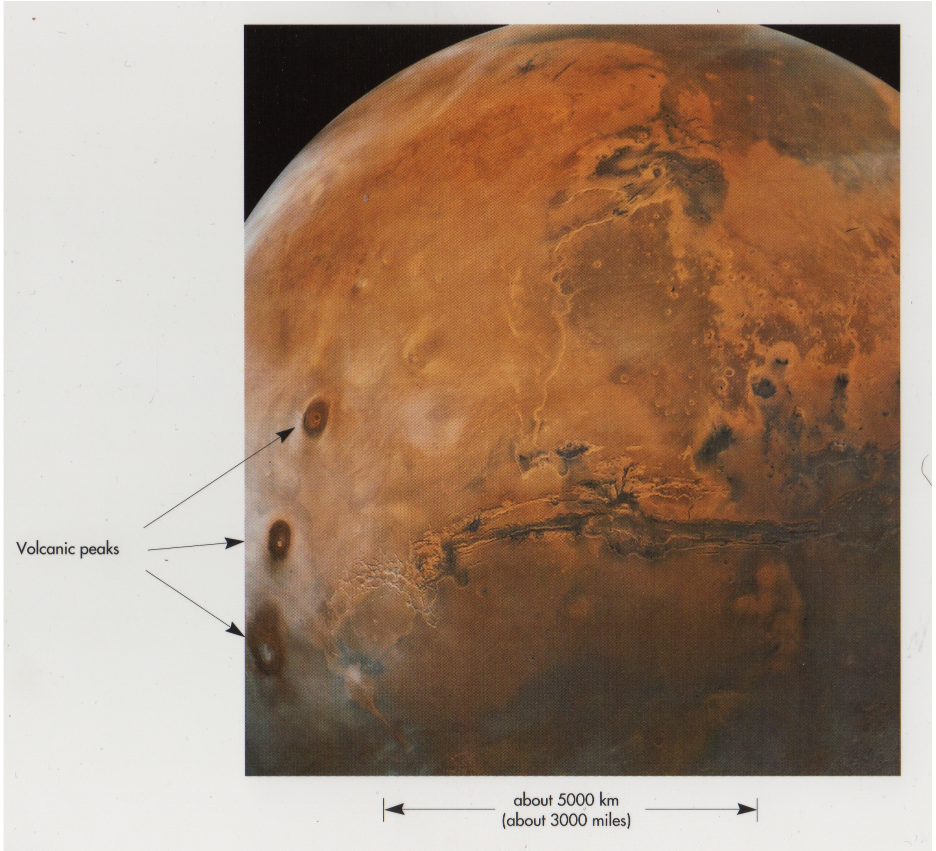
Mars

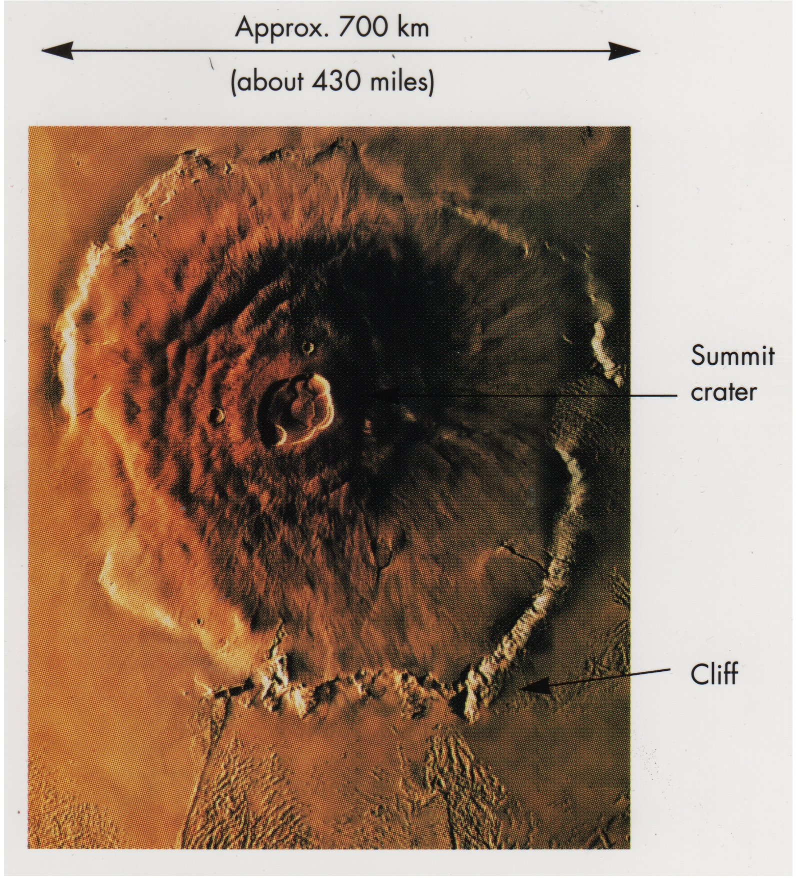


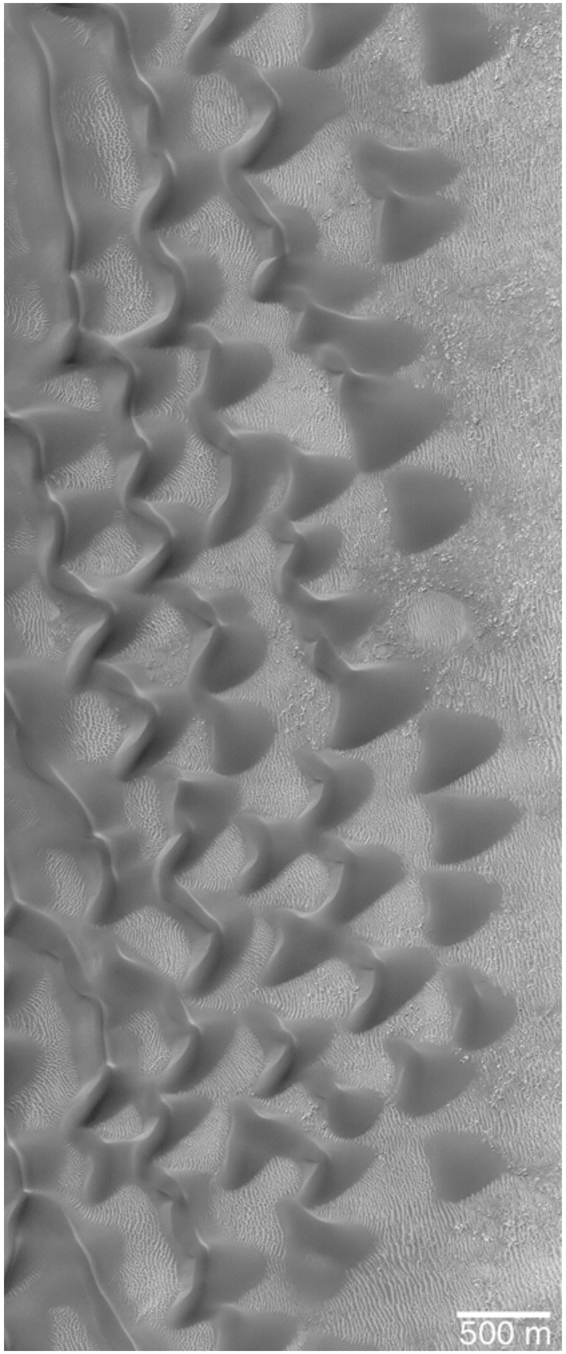
NASA, J. Bell (Cornell University), M. Wolff (SSI), and the Hubble Heritage Team (STScI/AURA) • STScI-PRC01-31

Mars’s Surface - I

Mars has enormous volcanoes but these have been extinct for ~ 1 Gyr



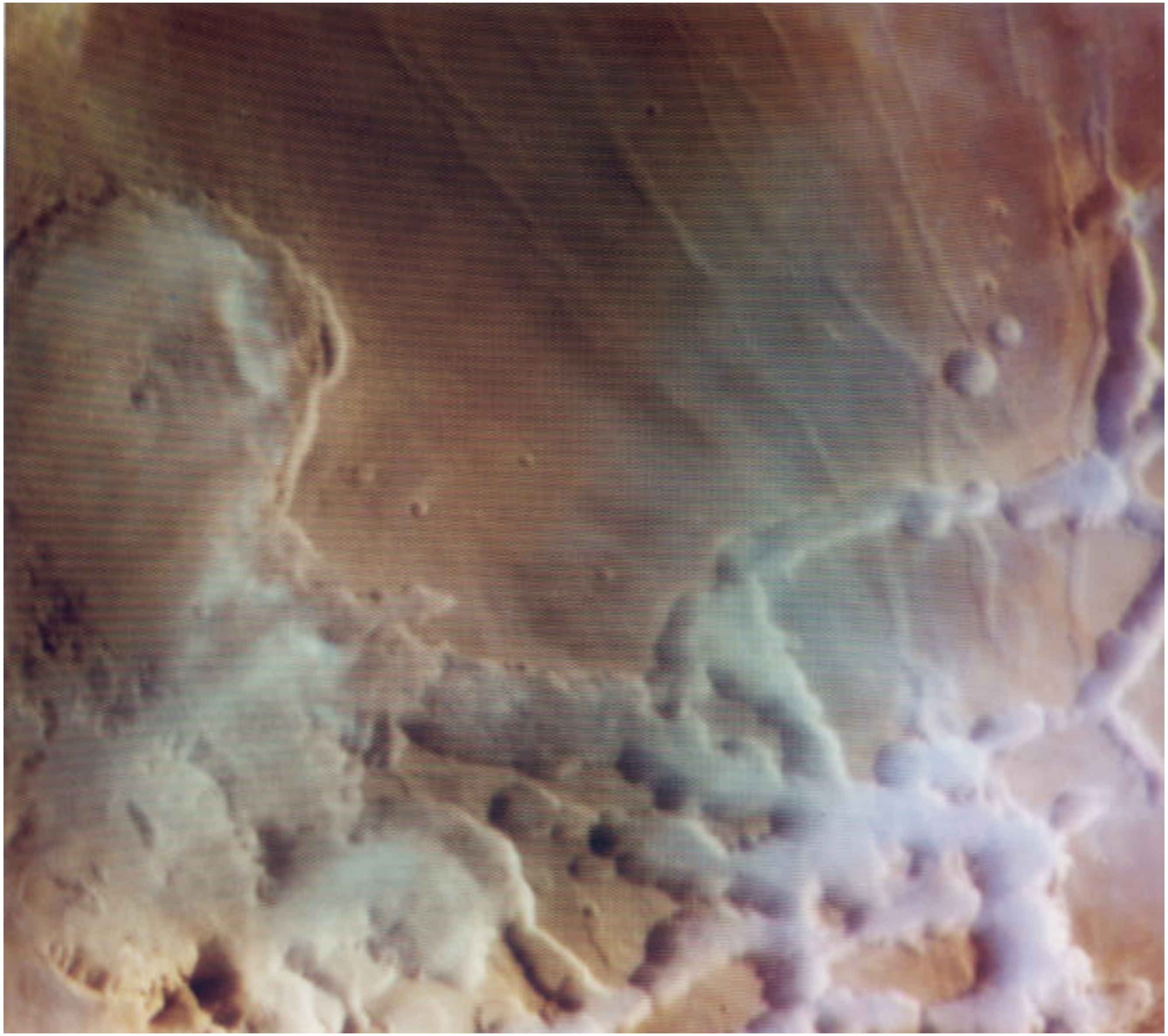




Sand Dunes on Mars

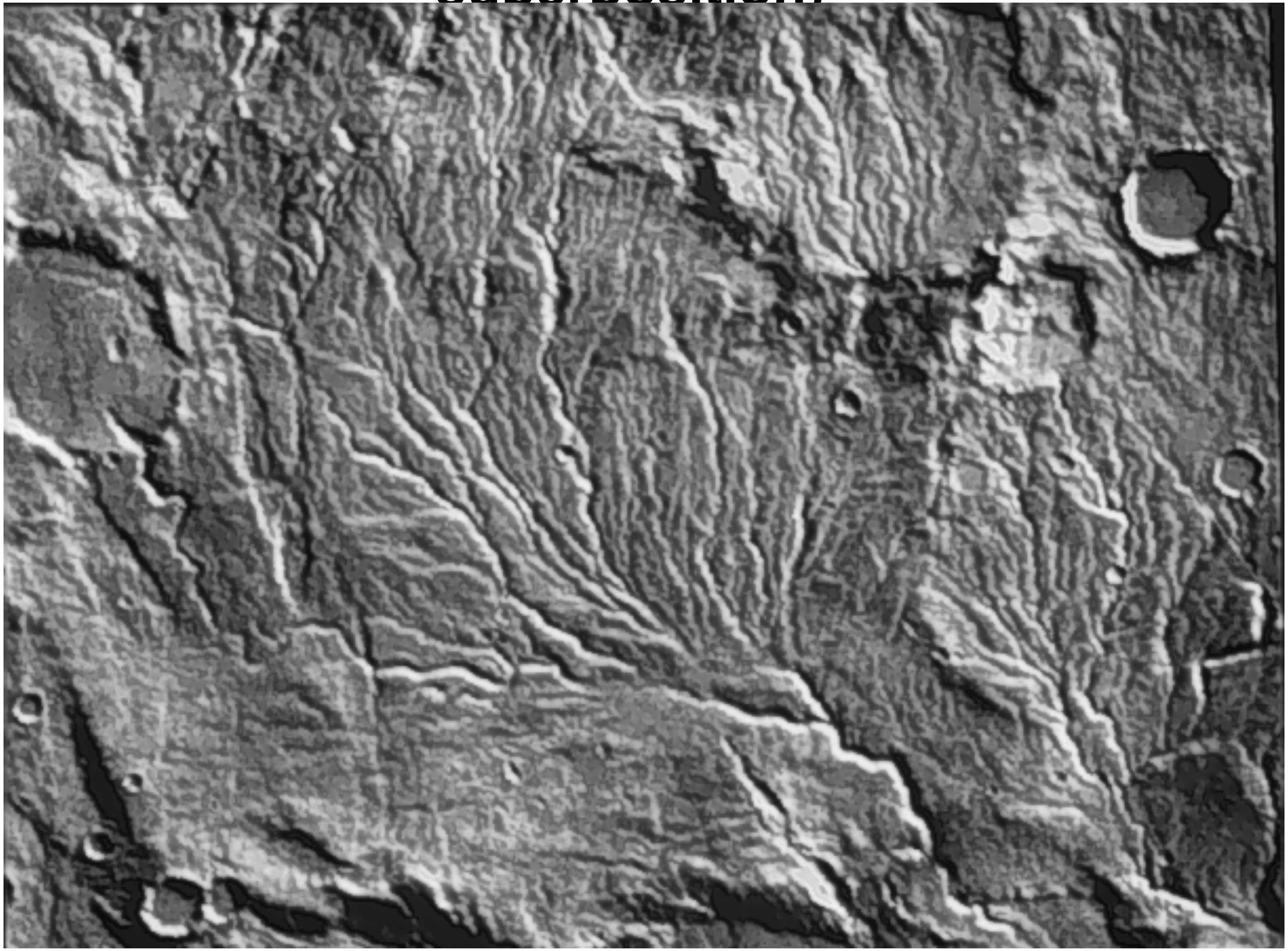
- Spacecraft in Mars orbit
  - Mars Global Explorer
  - Mars Odyssey
- Even though atmosphere is thin, high winds can create dust storms

Water ice clouds



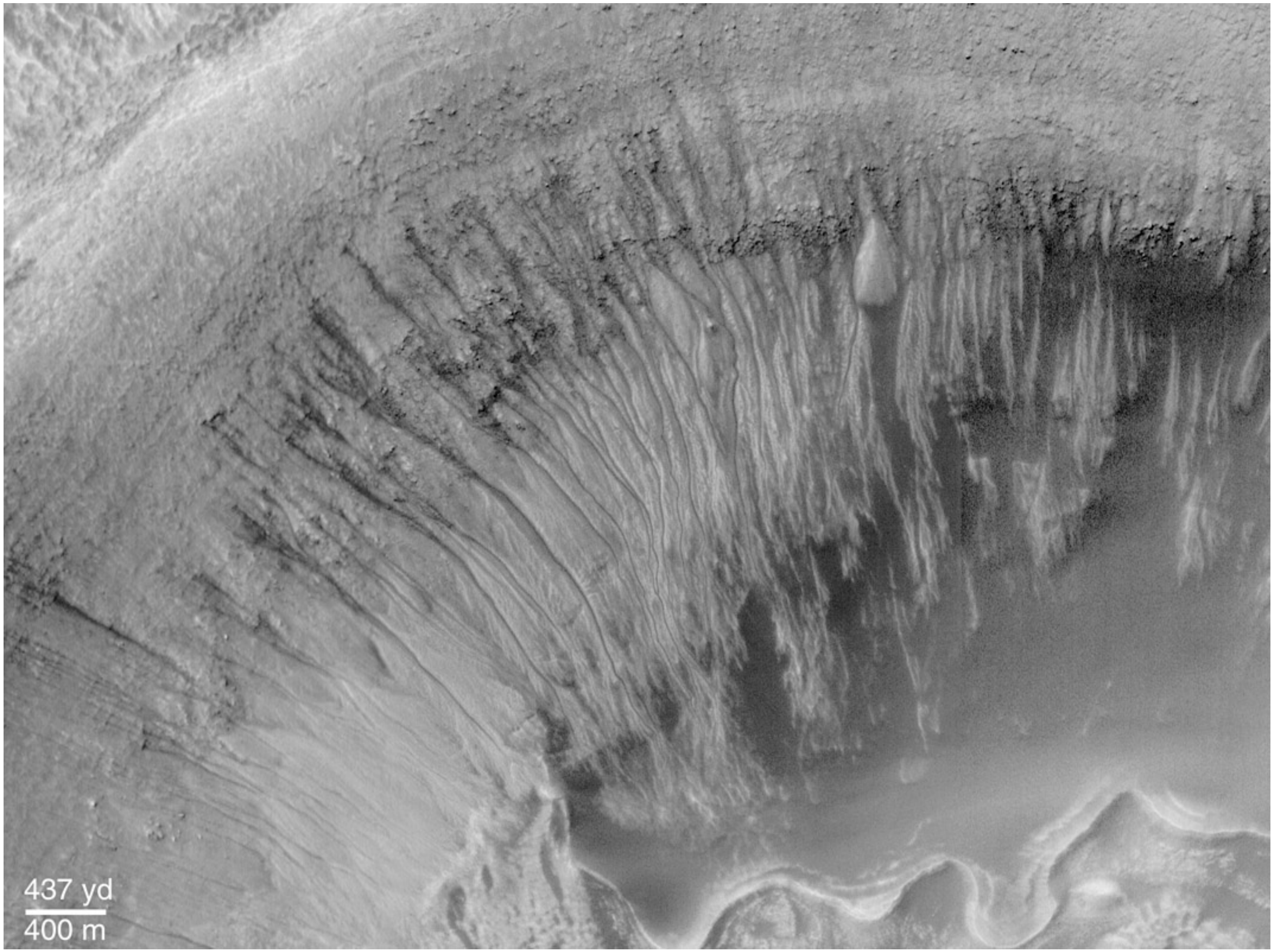
Ancient River Channels?

(note channels older than some craters – by superposition)

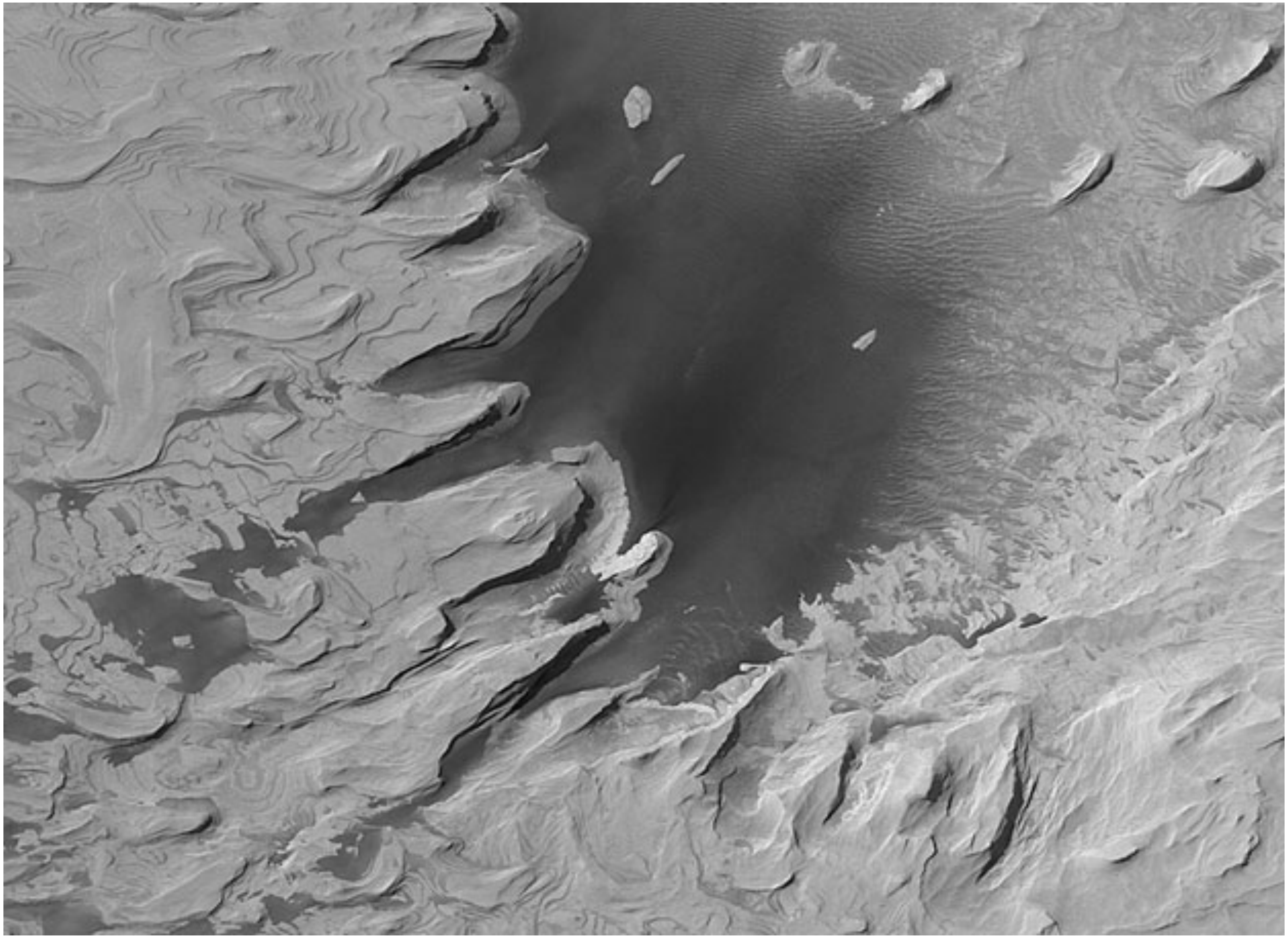


Recent liquid water?

(water seeping out of underground “aquifer” ?)



Layered Deposits



Mars atmosphere today

- **Pressure is only ~1% of Earth's**
- **Composition: <u>95% CO_2</u> 3% N_2 2% Ar**

- **Water:**
  - **Pressure too low for liquid water to exist**
    - **Water goes directly from solid phase to gas phase**
    - **CO_2 (dry ice) acts like this even at terrestrial atmospheric pressure**
  - **Water seen in atmosphere**
  - **Water seen in polar caps**
  - **Evidence of running water in past**

- **Carbon dioxide (CO_2)**
  - **Gets cold enough for even this to freeze at polar caps**
  - **Unusual meteorology, as atmosphere moves from one pole to other each "year"**

Where is the water today?

- Much may have escaped to space
- Some is locked up in N Polar Cap
- Much could be stored in subsurface ice (permafrost)

- Mars Missions making progress this semester:
    - http://www.nasa.gov/vision/universe/solarsystem/mer_main.html

- Location of water critical to knowing where to search for possible past life

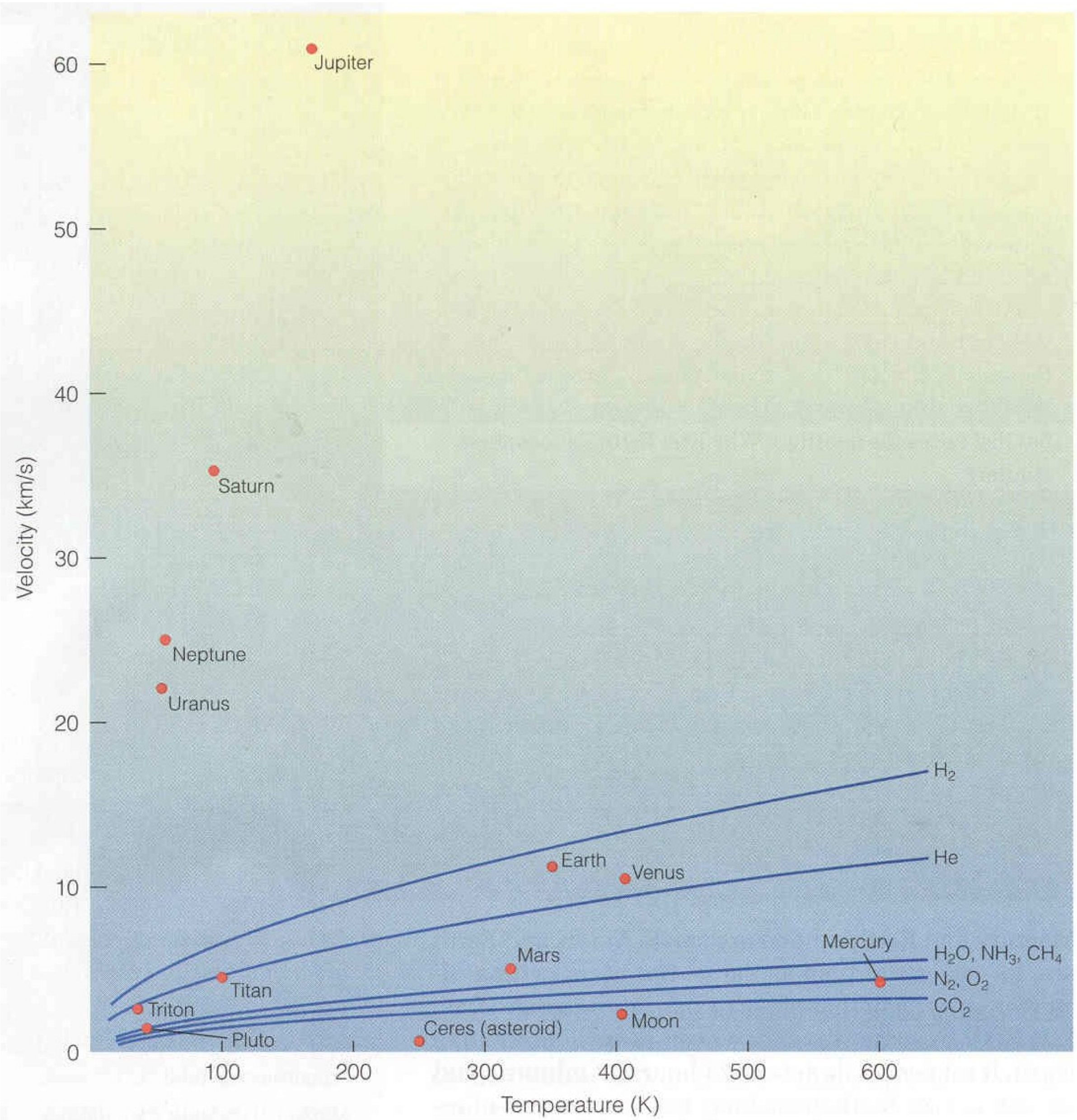
Why some atmospheres are lost

- **Compare velocity of gas atoms (V_{gas}) to planet's escape velocity V_{esc}**
  - If any significant # of atoms have escape speed atmosphere will eventually be lost
  - In a gas the atoms have a range of velocities,
    with a few atoms having up to about 10 × the average velocity,
    so we need 10 × $V_{avg\ gas} < V_{esc}$ to keep atmosphere for 4.5 billion years.

$$V_{\text{Avg Gas}} = \sqrt{\frac{3kT}{m}} \qquad V_{\text{Escape}} = \sqrt{\frac{2GM}{R}}$$

  - In above equations R = planet radius, M = planet mass, T = planet temperature,
    m = mass of atom or molecule, *k* and *G* are physical constants
- **Big planets have larger V_{esc} (i.e. larger $M/R \propto R^3/R$) so hold atmospheres better**
  - Earth would retain an atmosphere better than Mercury or the Moon
- **Cold planets have lower V_{gas} so hold atmospheres better**
  - Saturn's moon Titan will hold an atmosphere better than our moon
- **Heavier gasses have lower V_{gas} so are retained better than light ones**
  - CO_2 or O_2 retained better than He, H_2, or H
  - Even with "heavy" gasses like we H_2O we need to worry about loss of H if solar UV breaks H_2O apart. That is what happens on Venus

Which planets can retain which gasses?



From our text Horizons, by Seeds

- **Jovian Planets**
  - **can retain all gasses**
- **Earth and Venus**
  - **can retain all except H_2**
  - **Cold trap on Earth preserves our H**
- **Mars**
  - **can retain CO_2**
  - **barely retains H_2O**
- **Titan and Triton**
  - **only moons which can retain atmospheres**

Chapter 10: Homework

#1, 2, 6, 7, 9, 11

Thurs. May 5