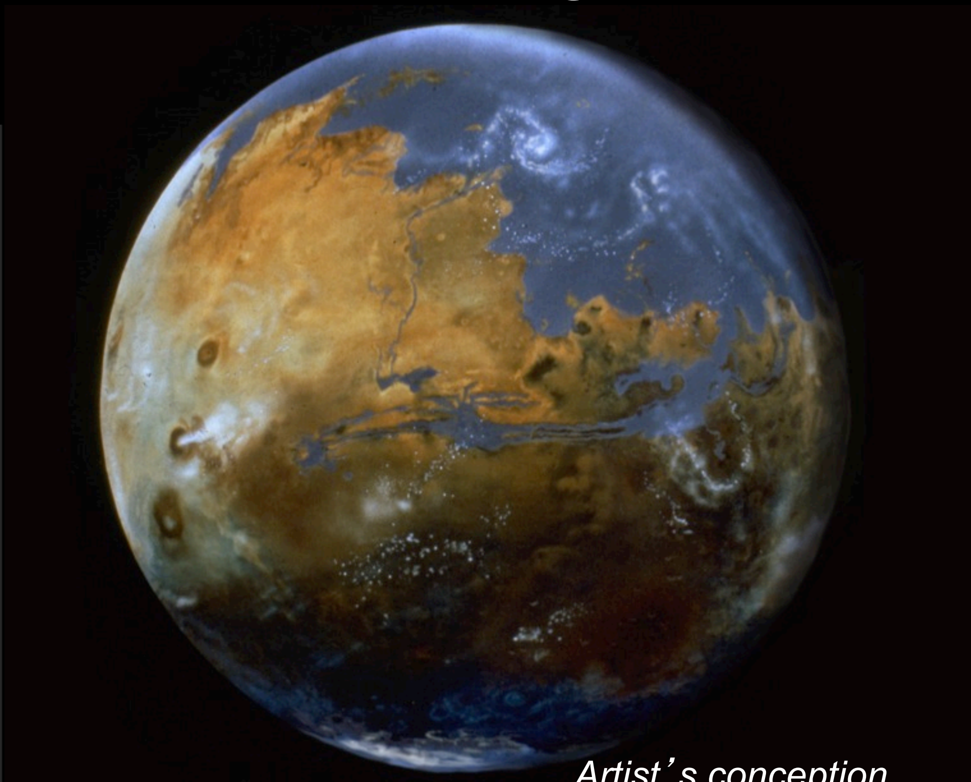
Mars: Once A Habitable World?

MAVEN Social Media Workshop, 24 Aug 2013



Artist's conception by Mike Carroll

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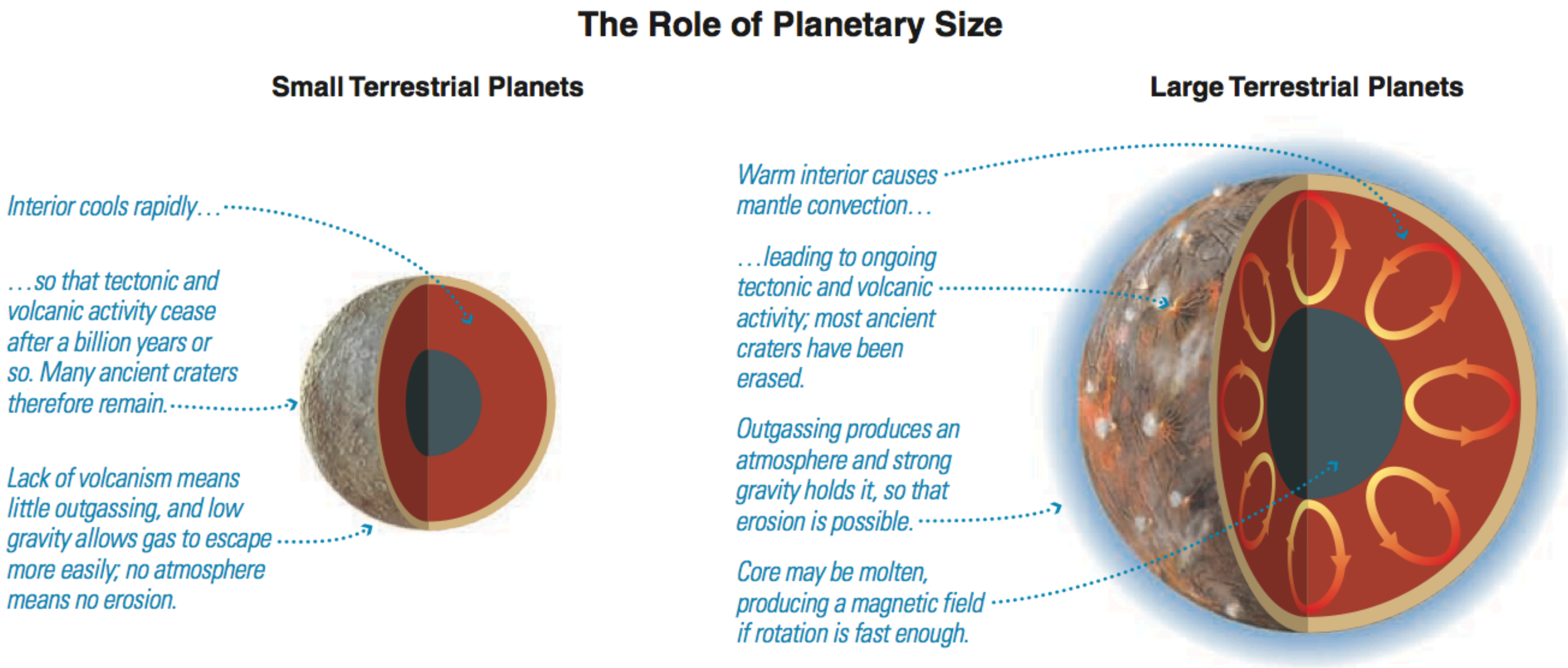
Mars: Once a Habitable Planet?

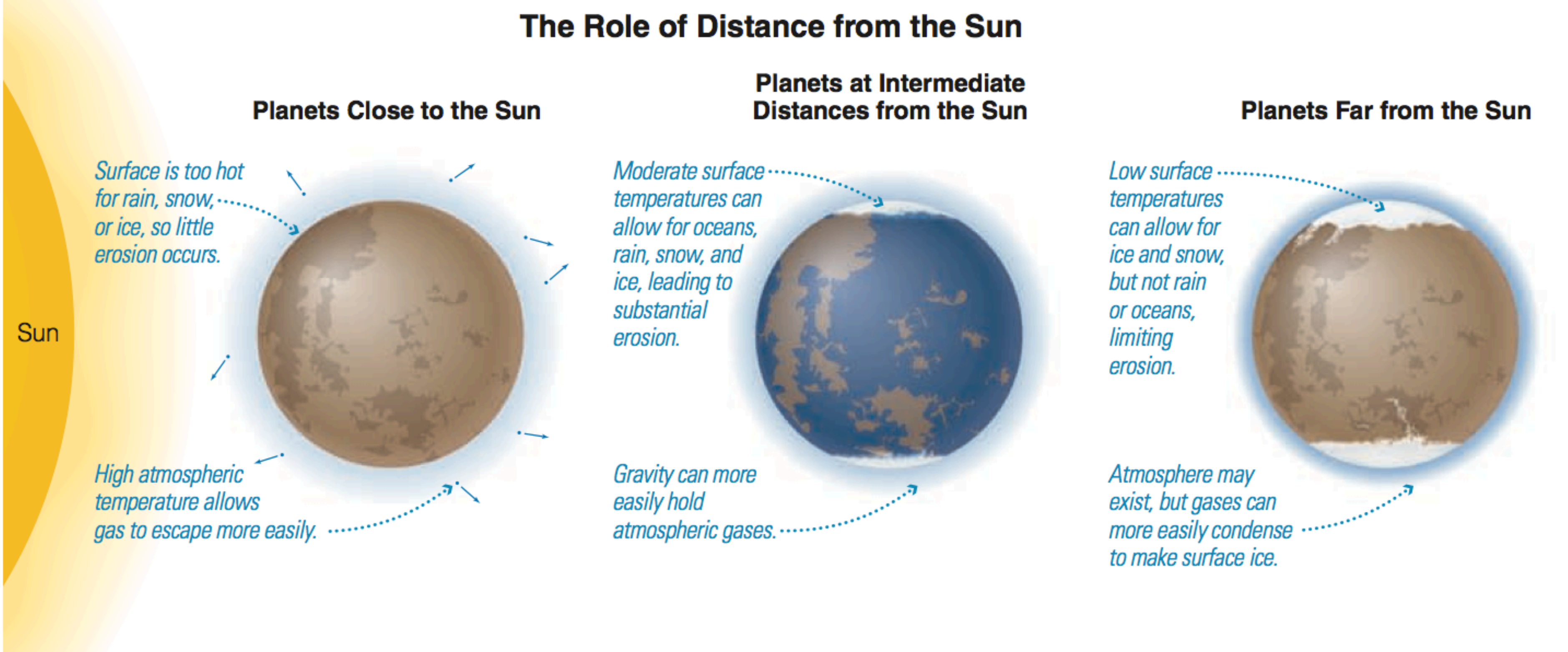
- What makes planets habitable?
- What’s the evidence for Mars’ past habitability?
- What made Mars habitable? What changed, and how?

Discussion: What are the requirements for a Habitable Planet?

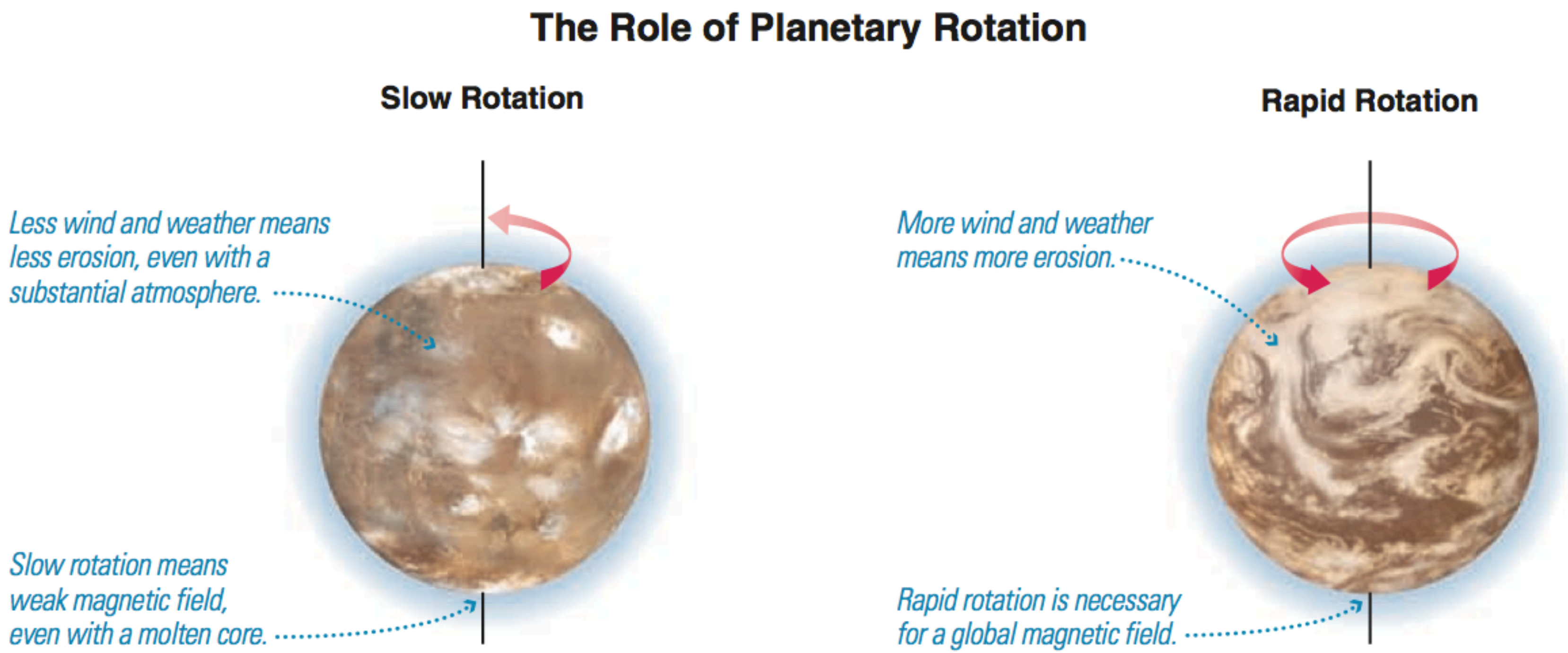
- Energy source
- Chemicals (nutrients)
- Liquid water



- Smaller worlds cool off faster and “harden” earlier
- Larger worlds stay warmer inside, leading to more volcanism and tectonics
- Larger worlds CAN have more erosion because they can create and hold an atmosphere



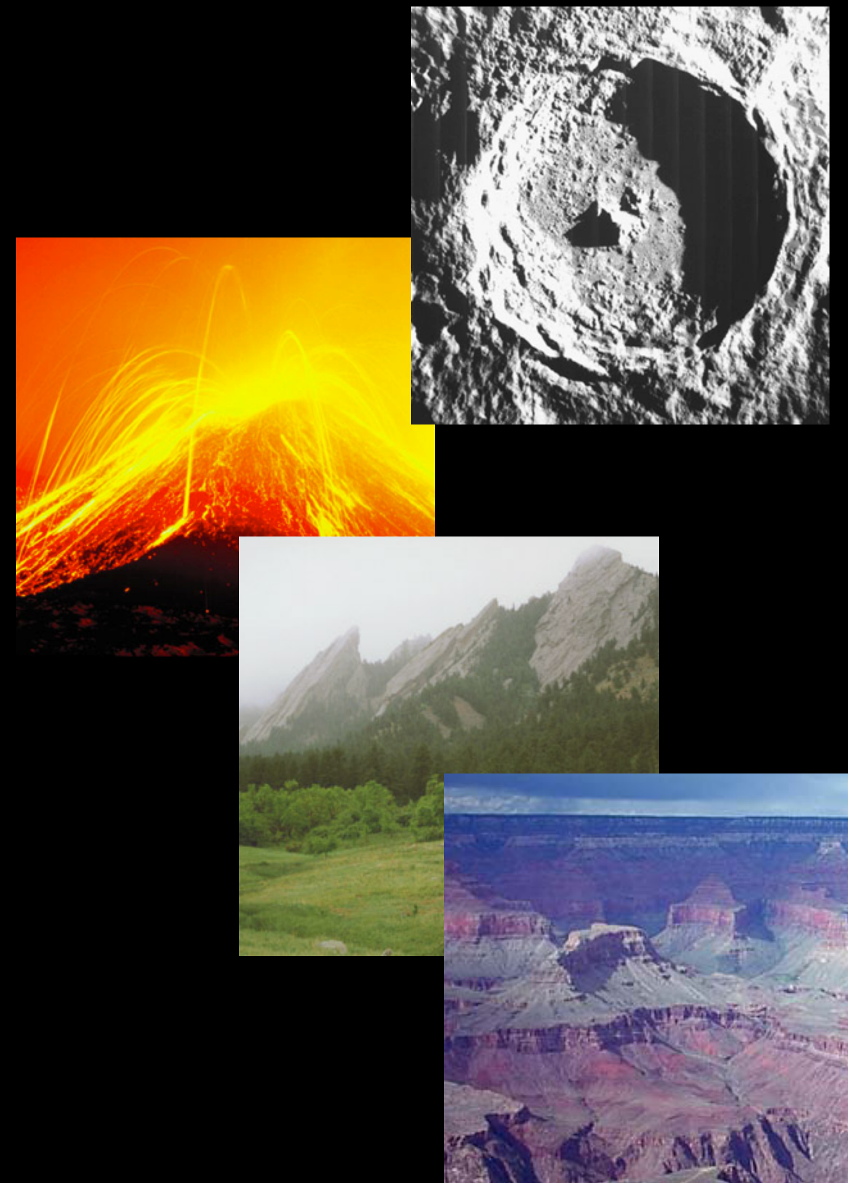
- Planets closer to the Sun are too hot for rain, snow or ice, so have little erosion
- Close planets are hotter, so they don’t retain their atmospheres as well
- Planets far from the sun are too cold for rain, limiting erosion
- Planets with liquid water have the most erosion



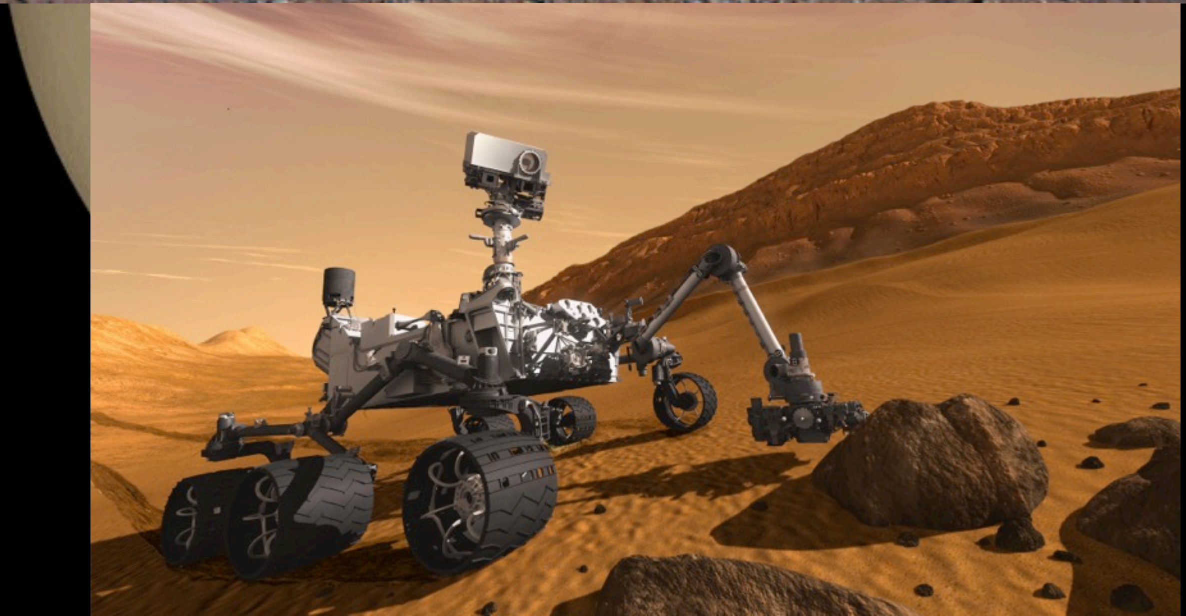
- Planets with slow rotation have less weather and less erosion, and (we think) weaker magnetic fields
- Planets with fast rotation CAN have more weather and more erosion, and stronger magnetic fields

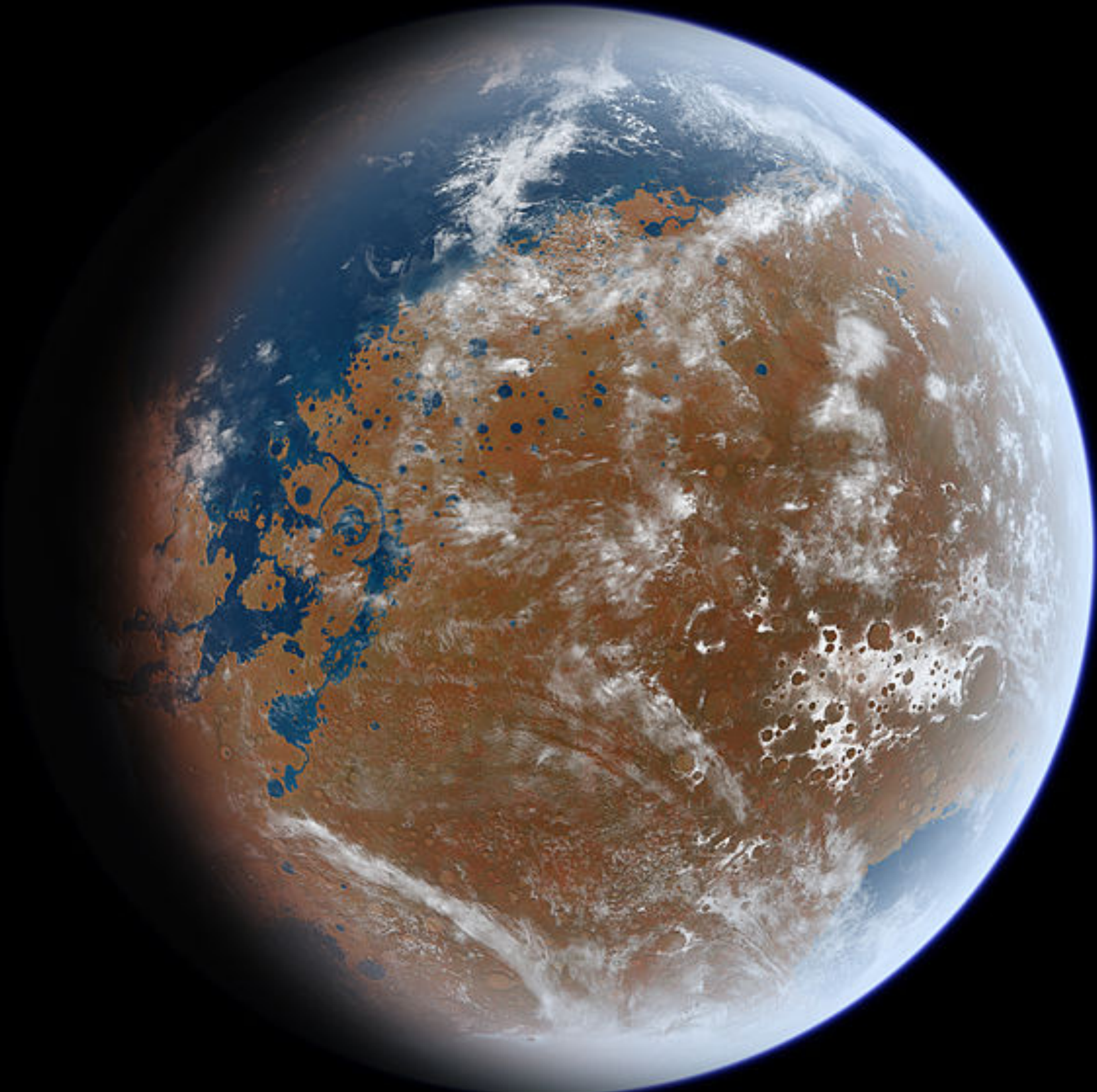
Decoding Planetary Images:
The Four Basic Geological Processes

- Impact cratering
- Volcanism
- Tectonics
- Erosion

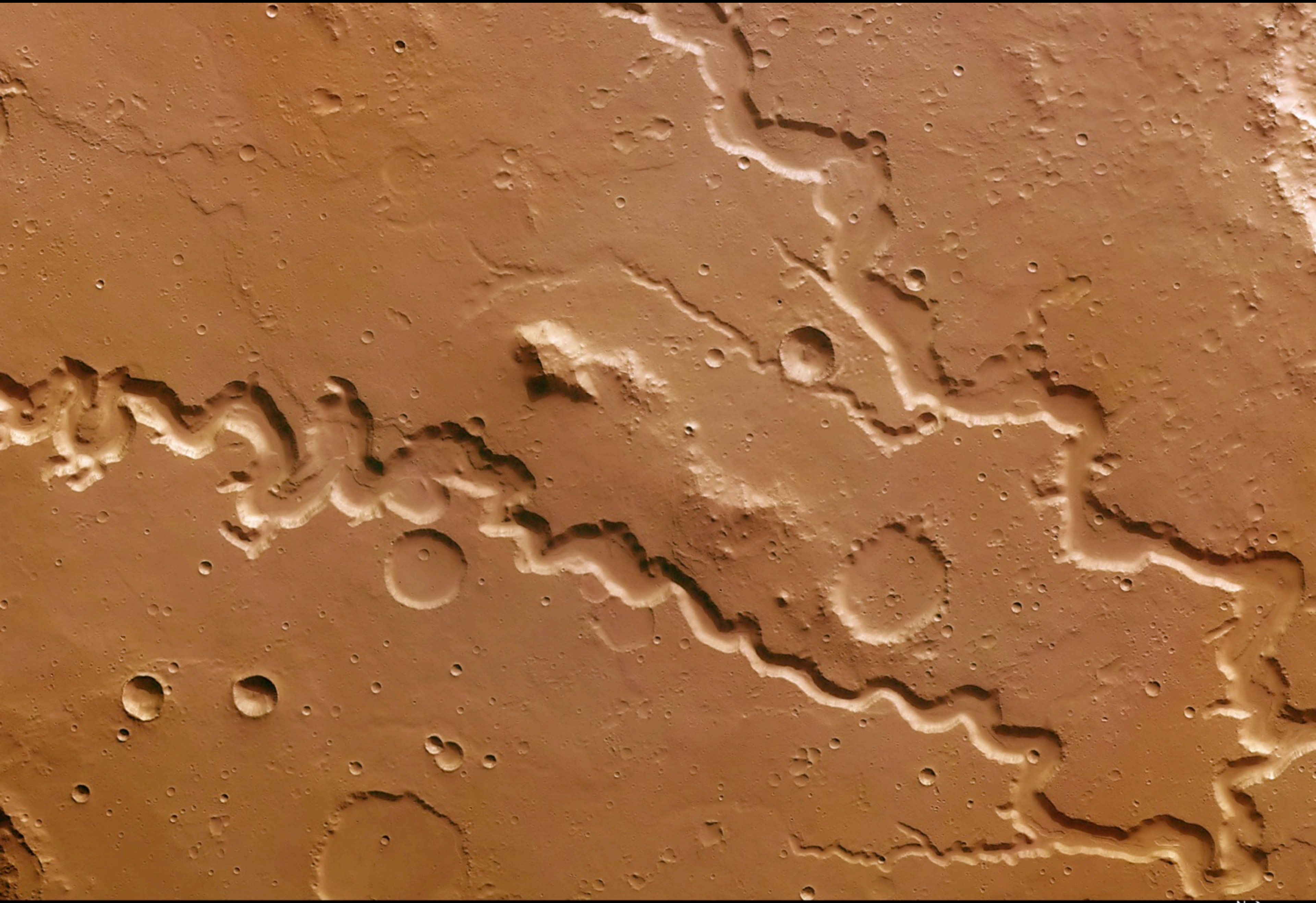


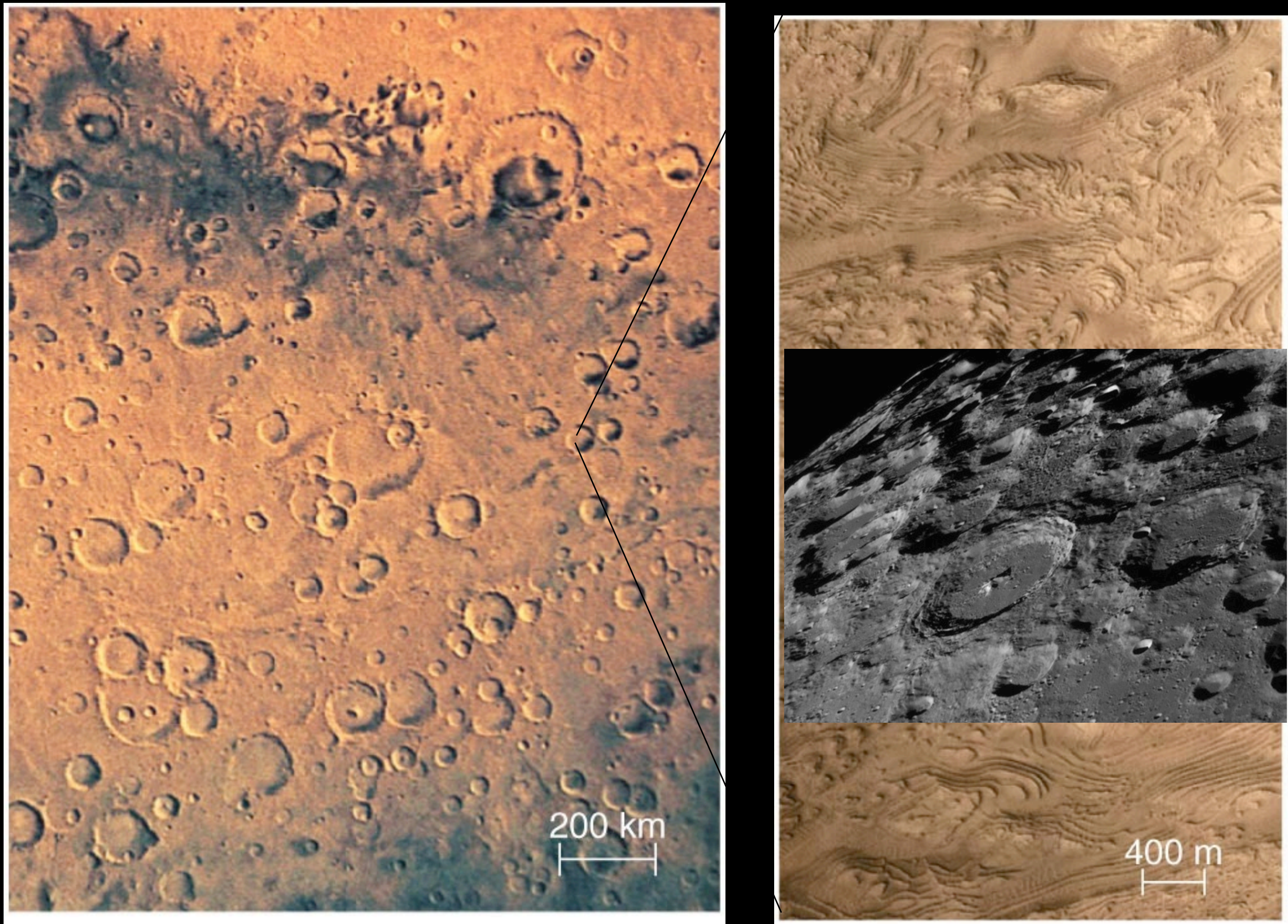
Mars Today

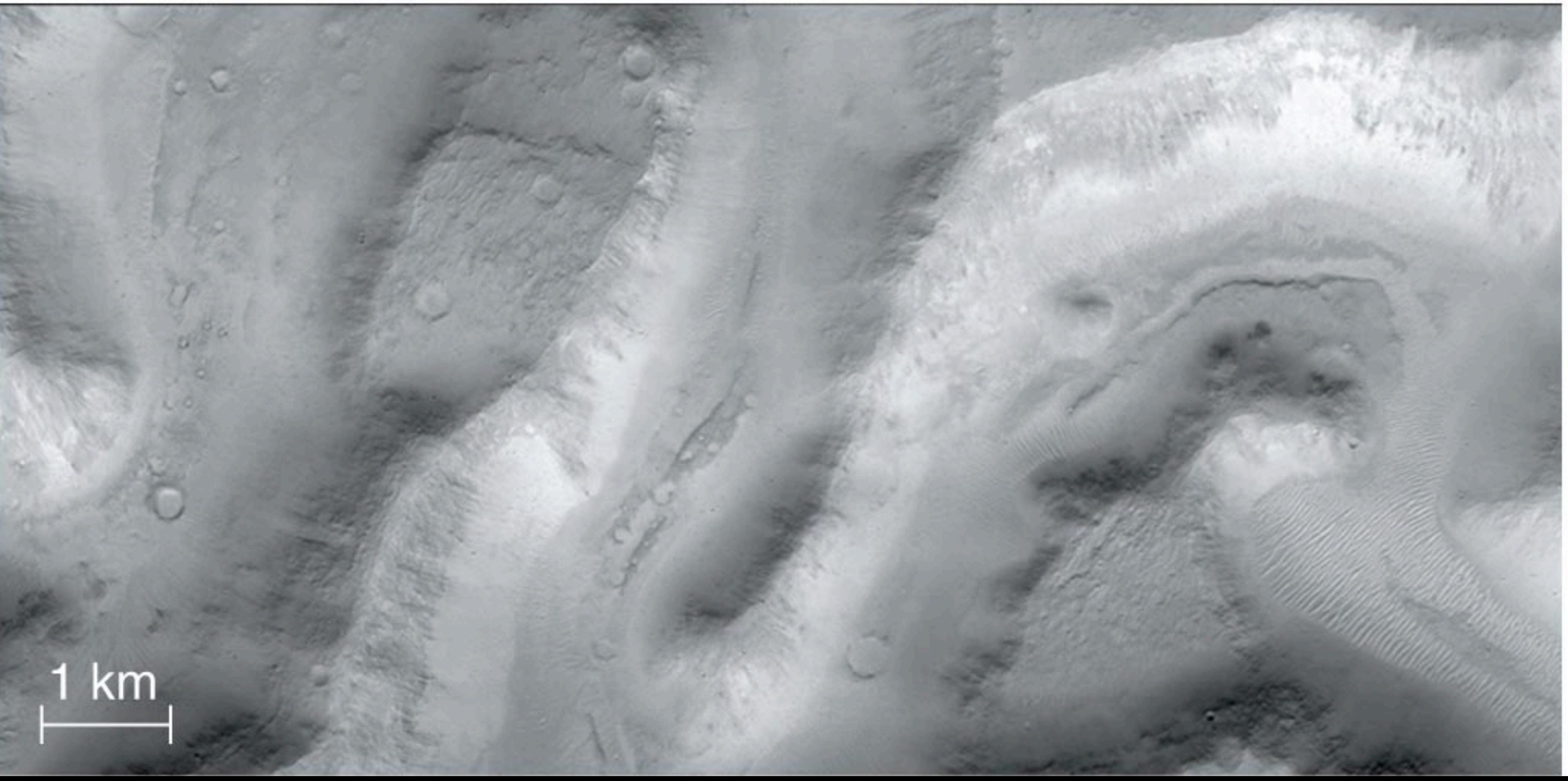


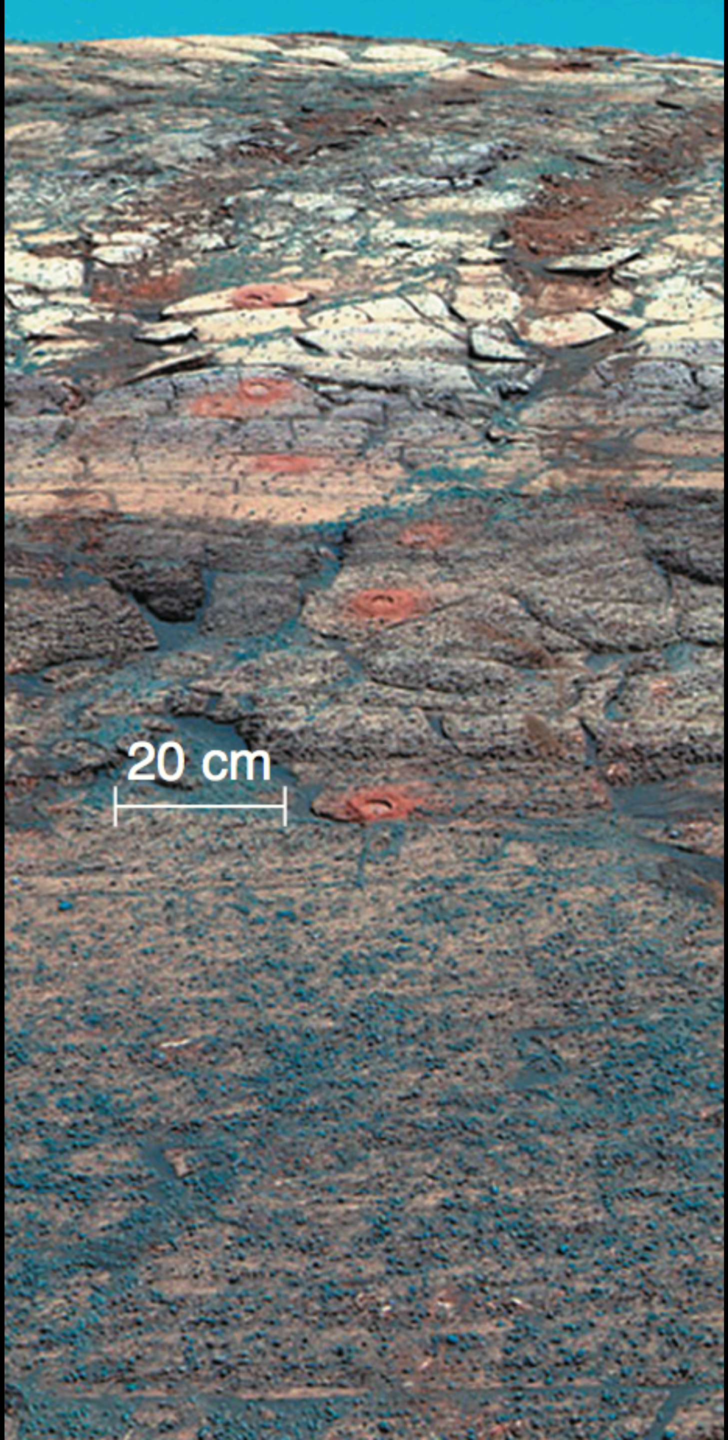


A Different Mars

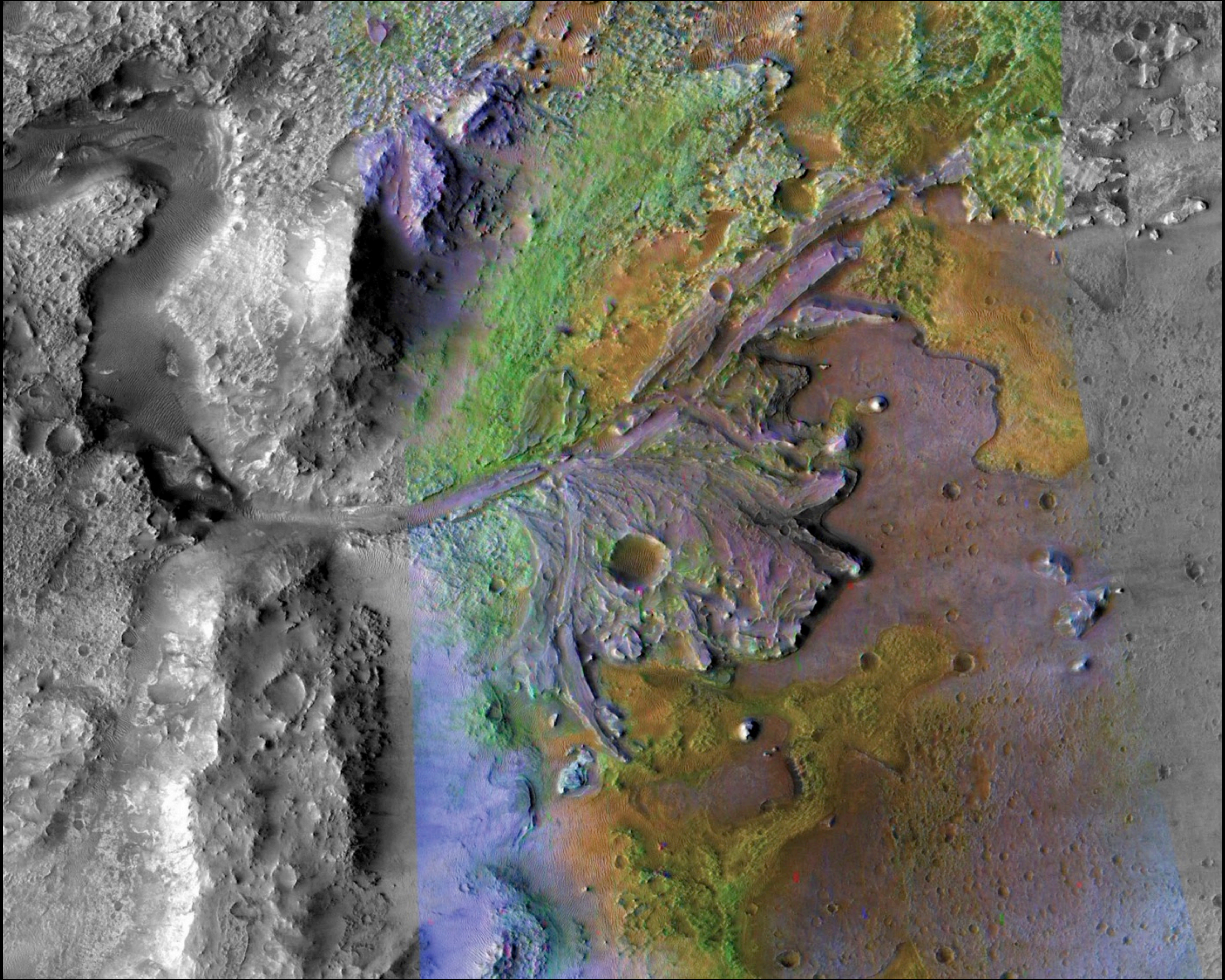

N
10 km

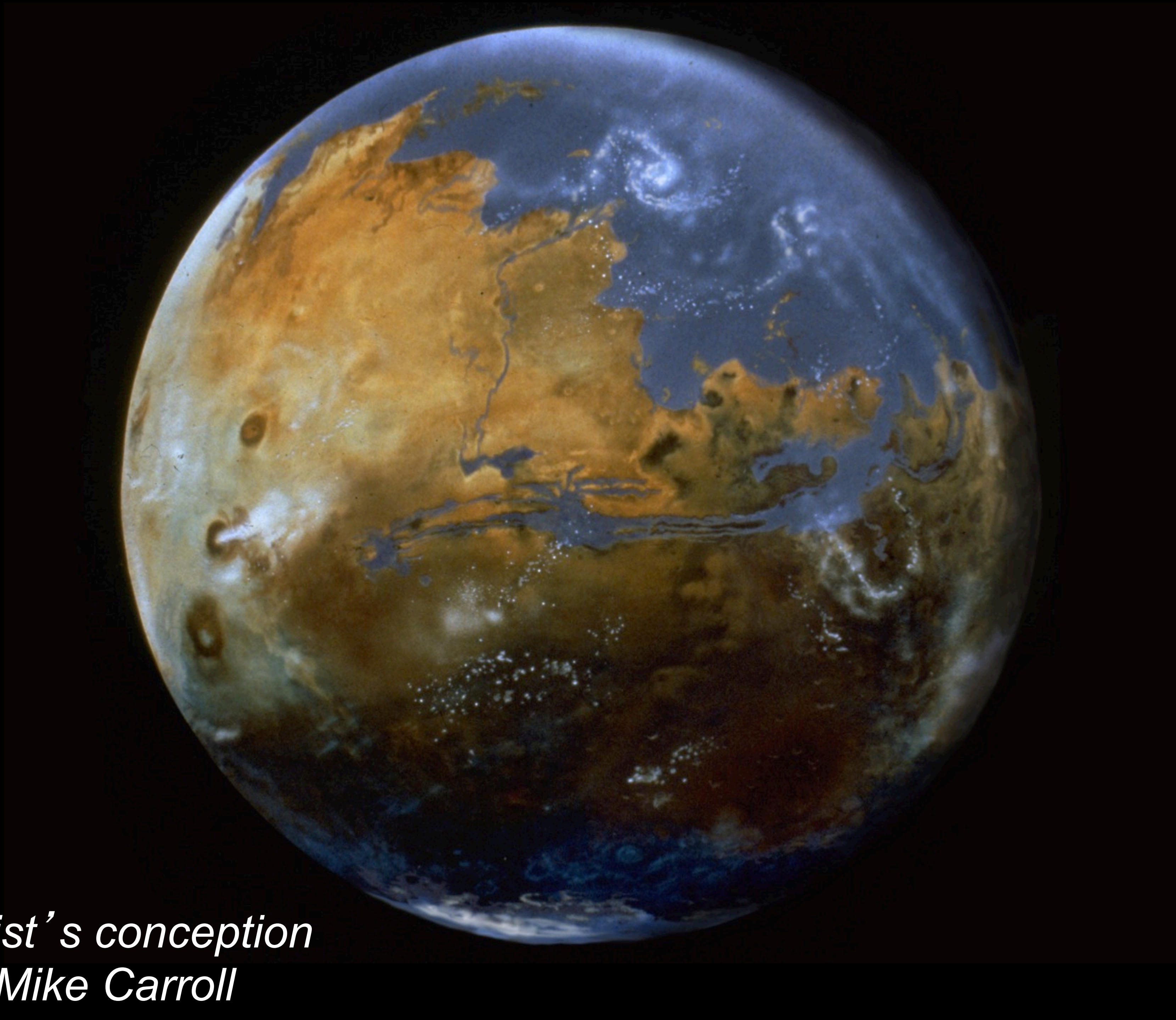

200 km
400 m


1 km


20 cm

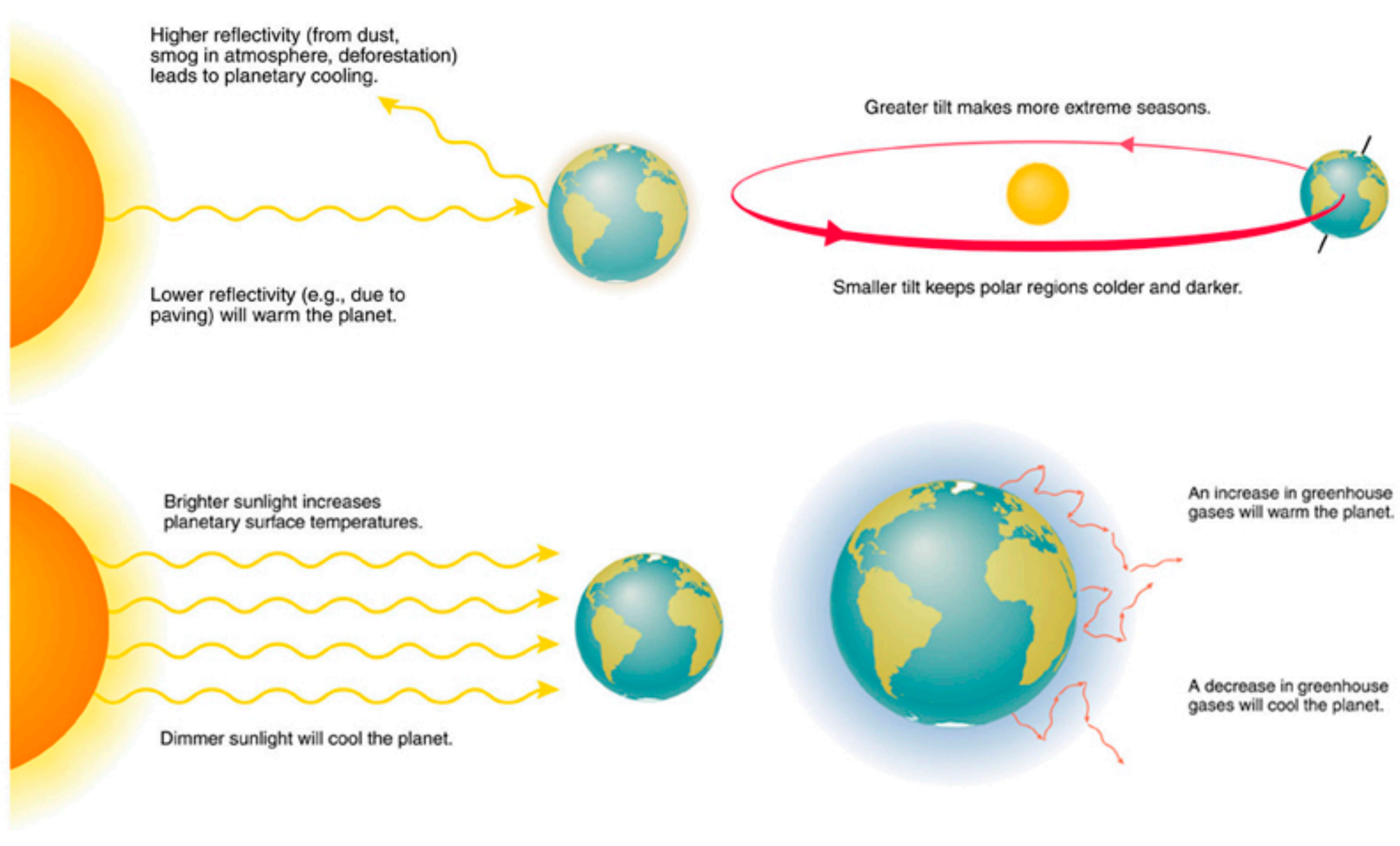

What do rocks tell us about habitability?





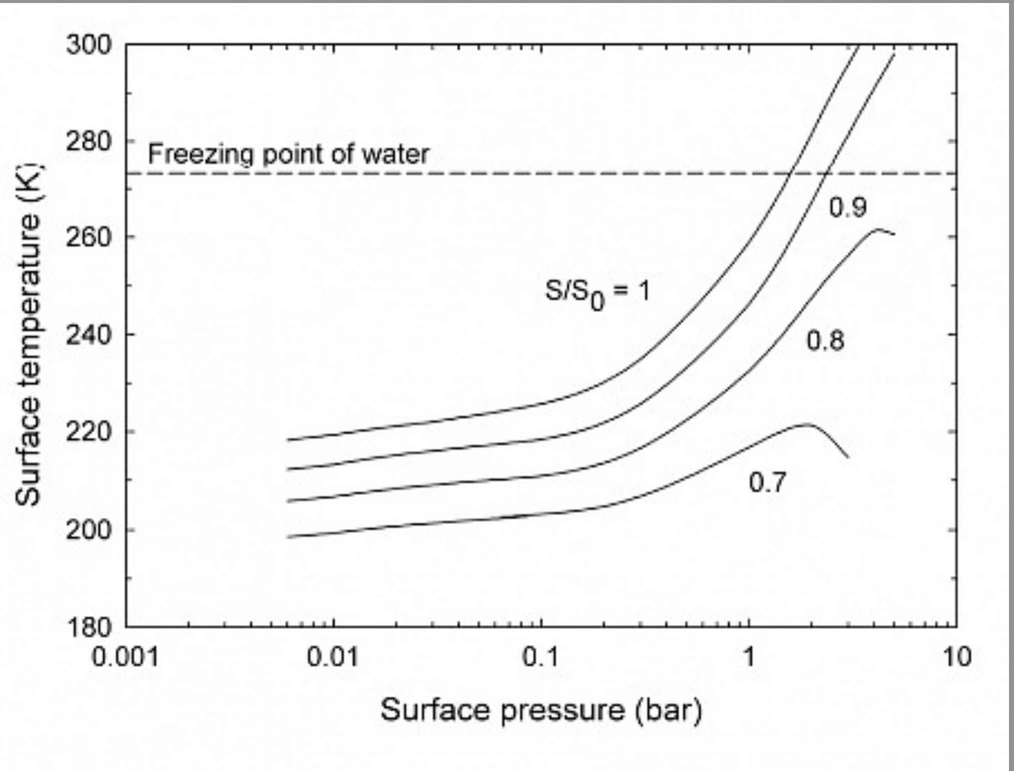
Artist's conception
by Mike Carroll

Four Major Factors which affect Long-term Climate Change



What could have sustained an early wetter environment?

- Greenhouse warming required to raise temperature from current ambient surface temperature average of ~220K.
  - Degree of greenhouse warming required unclear, since ambient temperature during warmer epoch is uncertain.
- Problem exacerbated by faint young Sun problem
  - Sun ~30% dimmer in total output 4 b.y. ago.
- Possible greenhouse agents
  - CO_2 and H_2O?
  - CH_4, NH_3?
  - Organic haze protectant?



Kasting, 1991

If Mars had a thick atmosphere, where it is now?
If Mars had an ocean, where is all the water now?

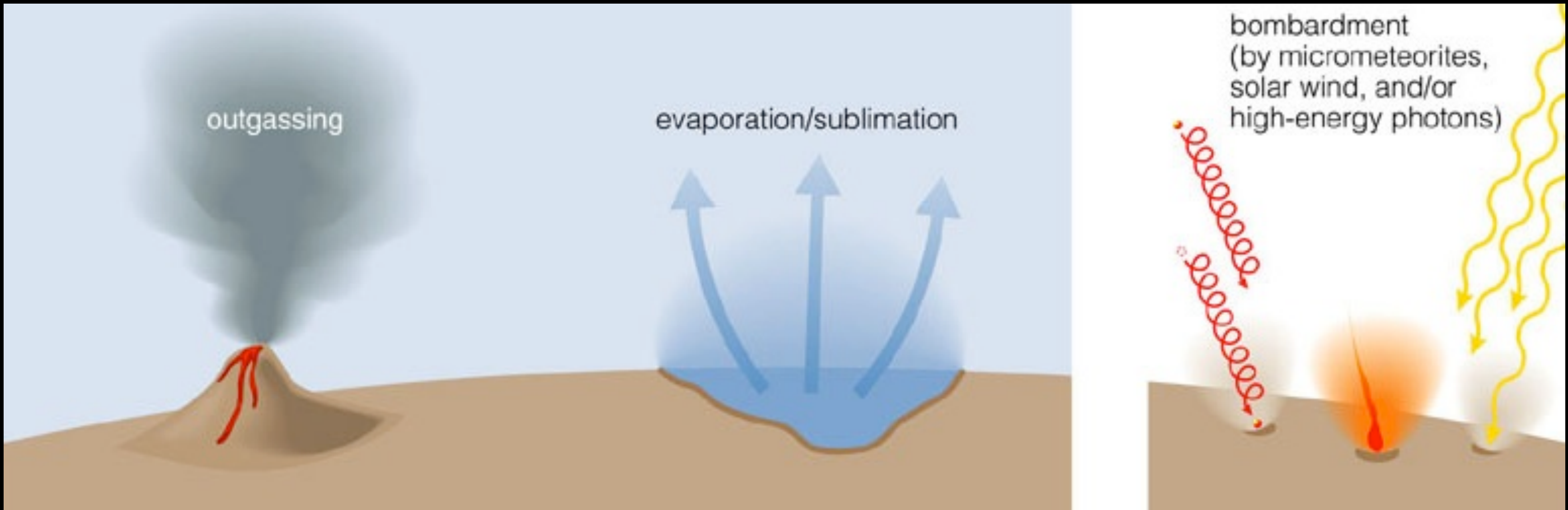
- Frozen at the poles?
  - Not enough!
- Locked underground?
  - Not *nearly* enough!

What other possibilities are left?

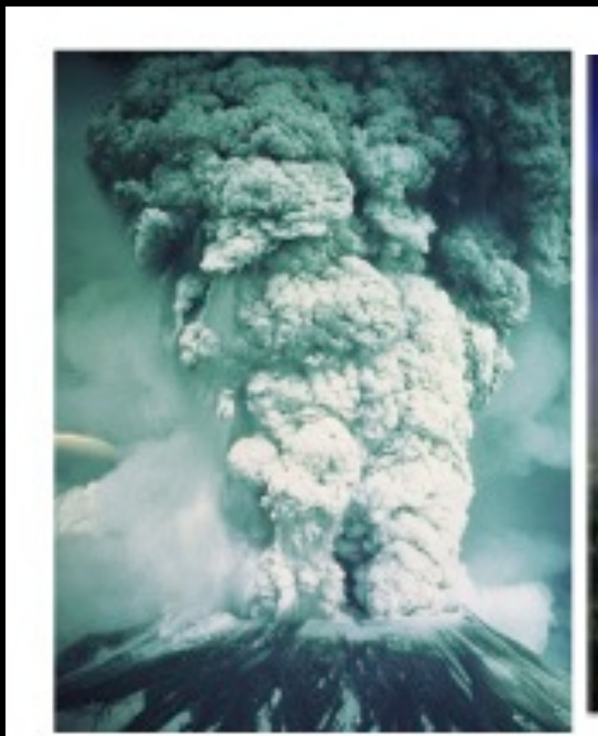
Artist's conception by Mike Carroll

3 Sources of Atmospheric Gas

- TP's too small to capture much gas from the Solar nebula.
- Sources of atmospheric gas:
  - **outgassing** – release of gas trapped in interior rock by volcanism
  - **evaporation/sublimation** –liquids or ices turn to gas when heated
  - **bombardment** or "surface ejection"– micrometeorites, Solar wind, or high-energy photons blast atoms/molecules out of surface rock
    - occurs only if the planet has no substantial atmosphere already



Volcanism: More than making mountains….




- Volcanism also releases gases from Earth’s interior into atmosphere
- Outgassing:*The origin of TP atmospheres!*

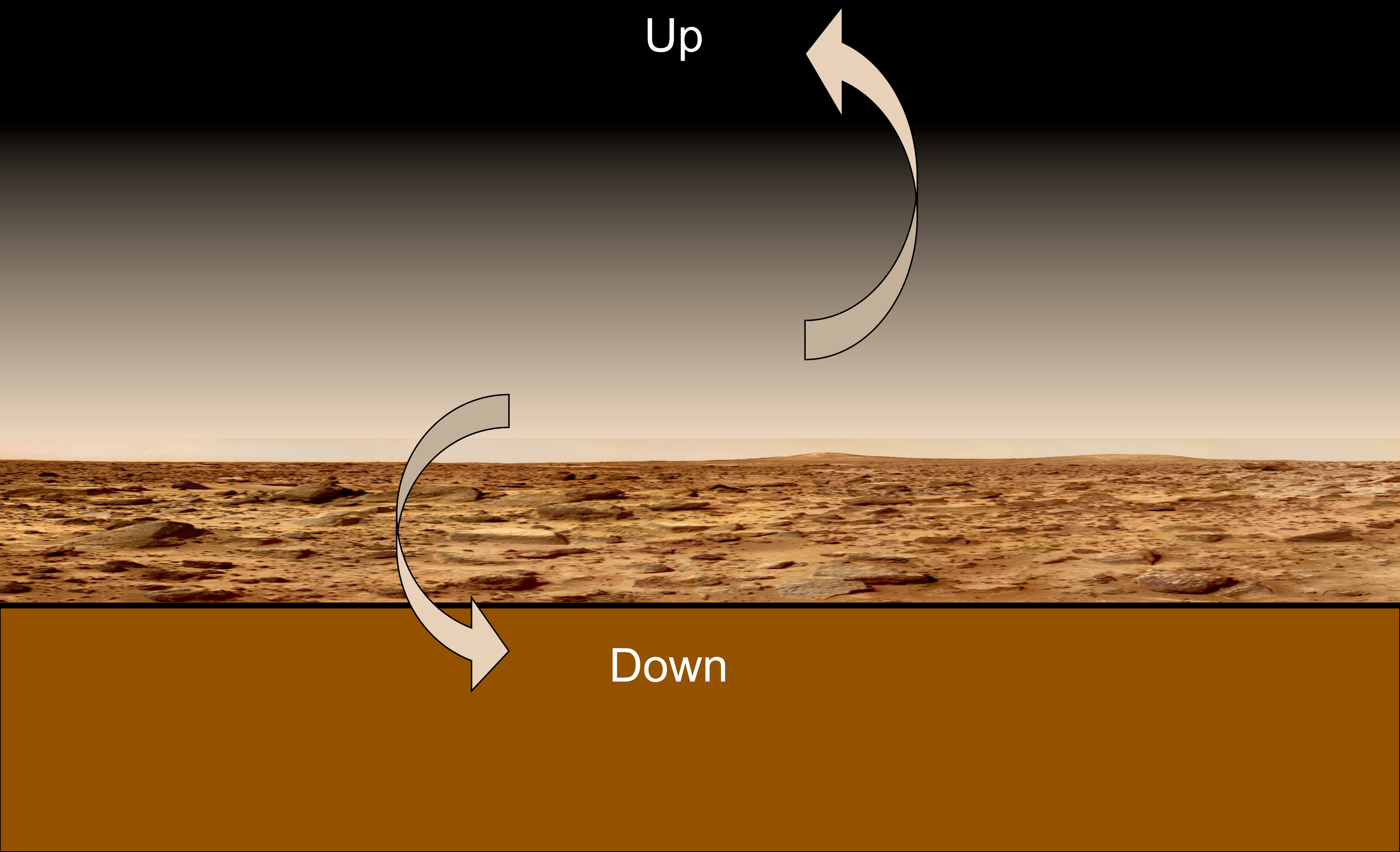
Outgassing

Important for large terrestrial planets’s (warm interior --> volcanoes)

Outgassing releases:

1. Lots of H_2O,
2. Some CO_2,
3. A little N_2,
4. A hint of sulfur-bearing gases

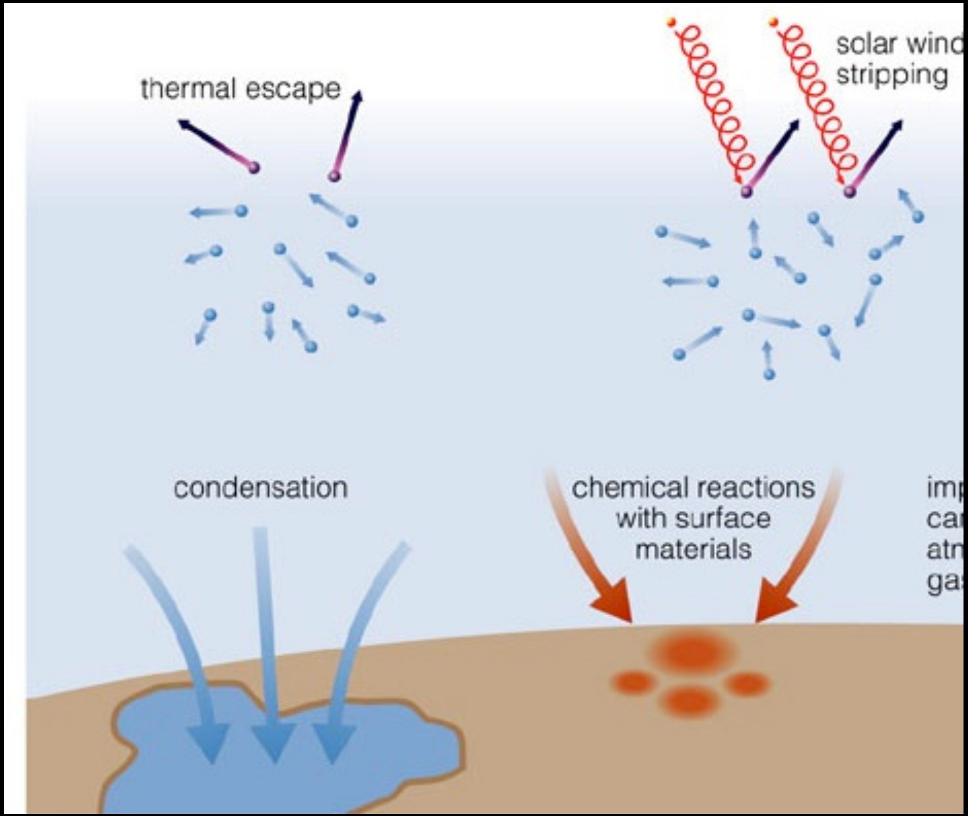
Where Did the Atmosphere Go?

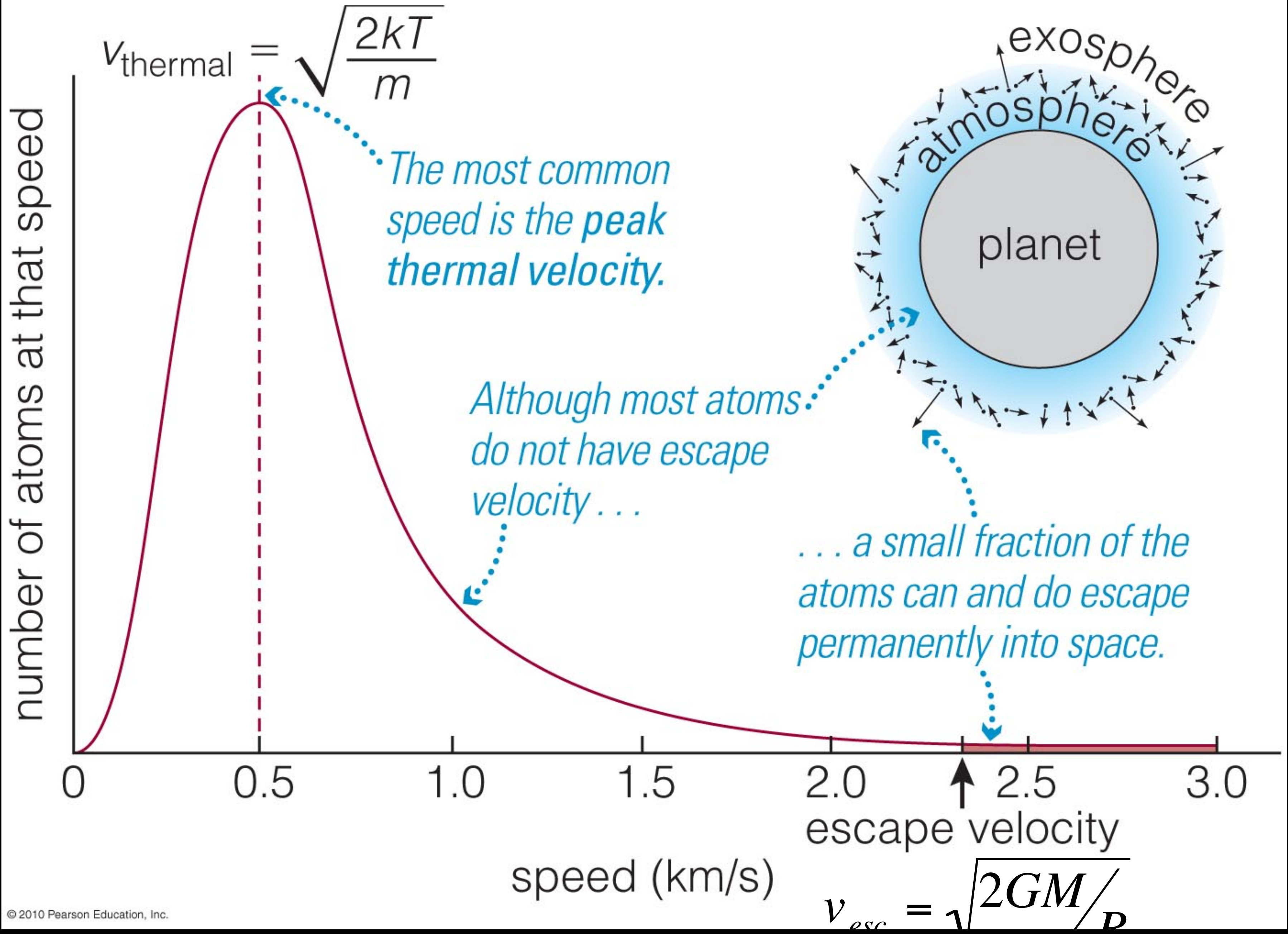


Loss Processes of Atmospheric Gas

4 Ways to lose atmospheric gas:

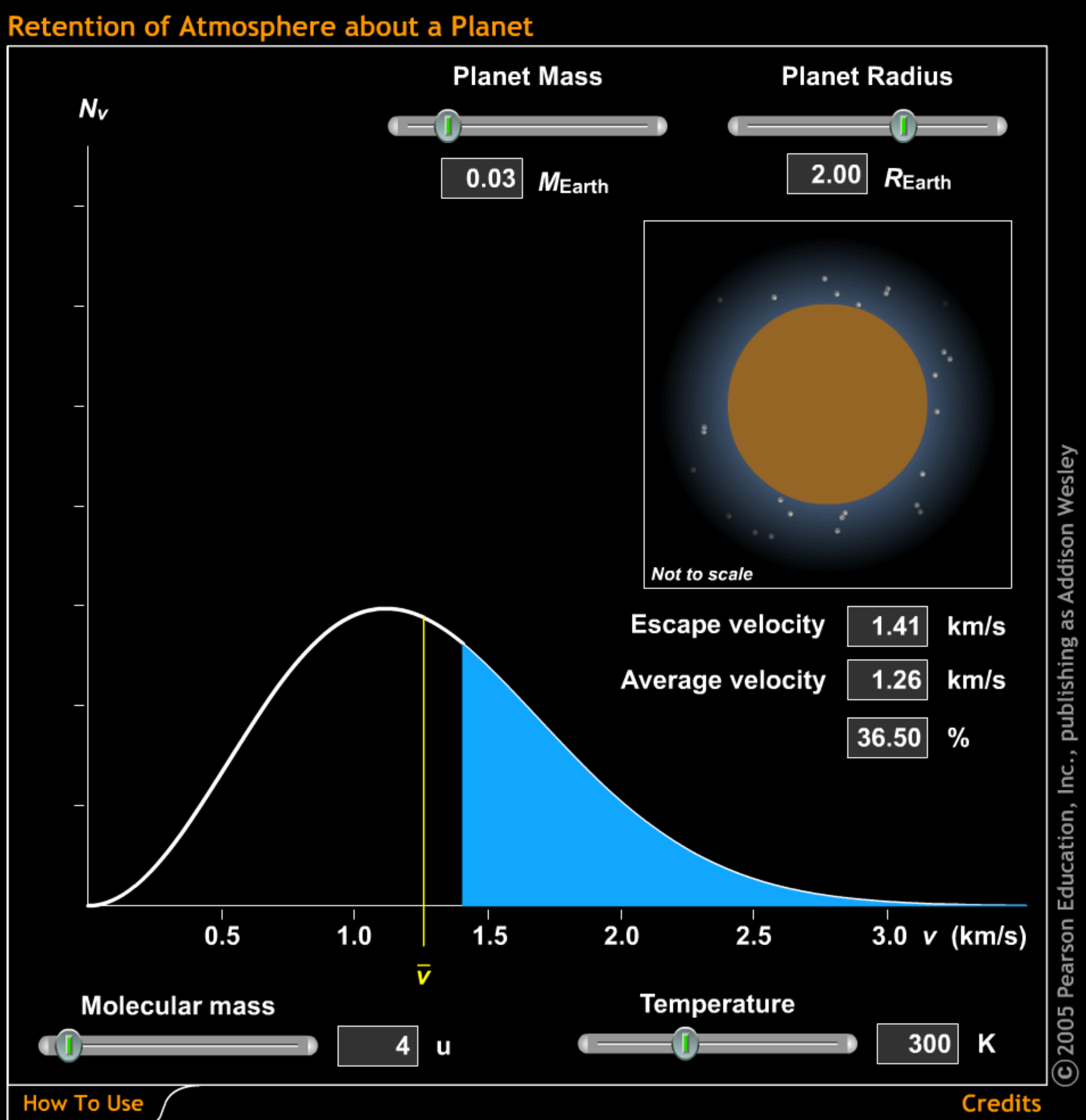
- **condensation** – gas turns into liquids/ices on the surface when cooled
- **chemical reactions** – gas is bound into surface rocks or liquids
- **SW stripping** – gas knocked out of the exosphere by Solar wind
- **thermal escape** – lightweight atoms lost to space when they achieve escape velocity





$v_{thermal} = \sqrt{\frac{2kT}{m}}$
number of atoms at that speed
The most common speed is the **peak thermal velocity.**
exosphere
atmosphere
planet
Although most atoms do not have escape velocity . . .
. . . a small fraction of the atoms can and do escape permanently into space.
0
0.5
1.0
1.5
2.0
2.5
3.0
escape velocity
speed (km/s)
$v_{esc} = \sqrt{2GM/R}$

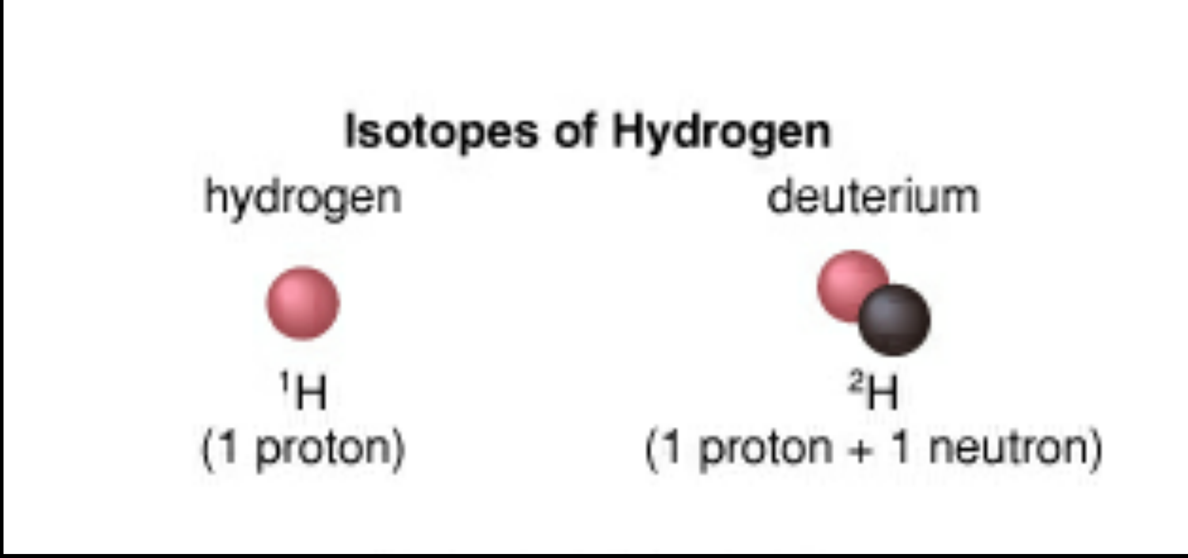
Thermal Escape Applet – Building Intuition

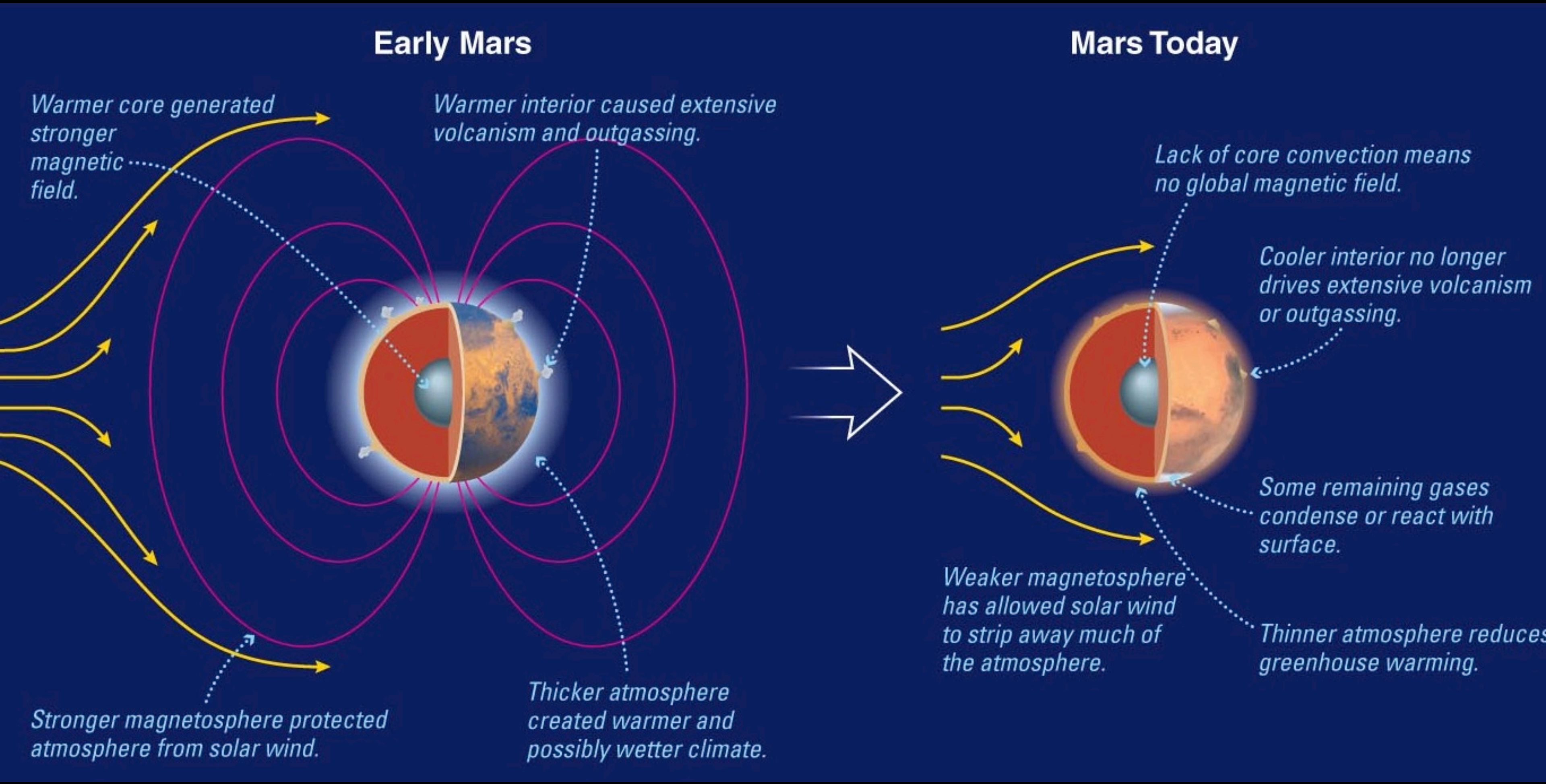


Thermal Escape

Easiest for:

- Small worlds
- Hot worlds
- Light gases





The End of the World – for Martians?

Earth

Mars