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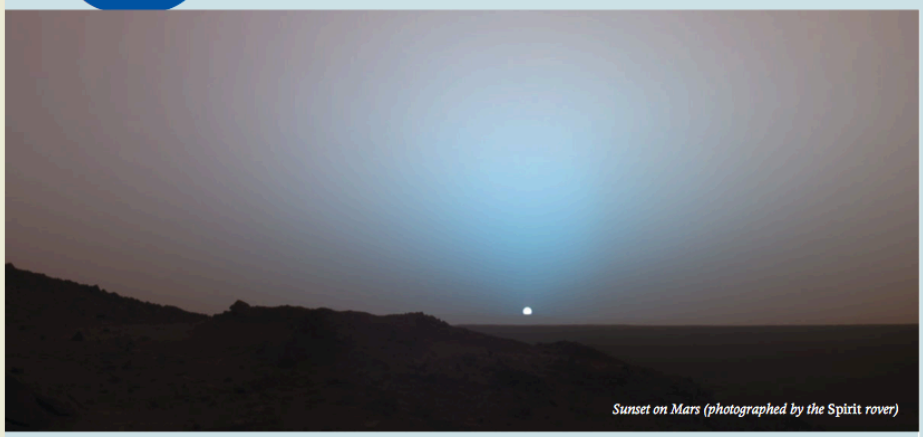


Sunset on Mars (photographed by the Spirit rover)

Mars

Mars

LEARNING GOALS

8.1 FANTASIES OF MARTIAN CIVILIZATION
- How did Mars invade popular culture?

8.2 A MODERN PORTRAIT OF MARS
- What is Mars like today?
- What are the major geological features of Mars?
- What evidence tells us that water once flowed on Mars?

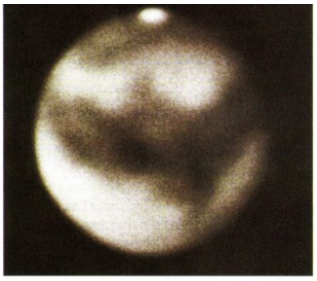
8.3 THE CLIMATE HISTORY OF MARS
- Why was Mars warmer and wetter in the past?
- Why did Mars change?
- Is Mars habitable?

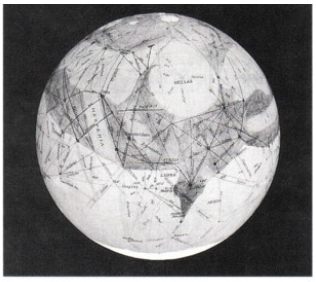
8.4 SEARCHING FOR LIFE ON MARS
- Is there any evidence of life on Mars?
- How do we plan to search for life on Mars?
- Should we send humans to Mars?

THE PROCESS OF SCIENCE IN ACTION

8.5 MARTIAN METEORITES
- Is there evidence of life in martian meteorites?

A Little History





Percival Lowell thought that Mars was inhabited and that the canals were a from a civilization attempting to channel water to their cities.

The belief that intelligent life existed on Mars was so pervasive in our society that H. G. Wells' "War of the Worlds" set of a nationwide panic!

The New York Times.

NEW YORK, MONDAY, OCTOBER 31, 1938.

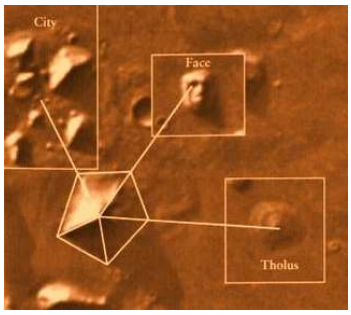
Radio Listeners in Panic, Taking War Drama as Fact

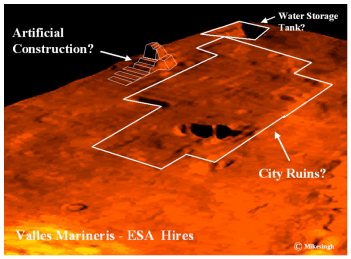
Many Flee Homes to Escape 'Gas Raid From Mars'—Phone Calls Swamp Police at Broadcast of Wells Fantasy

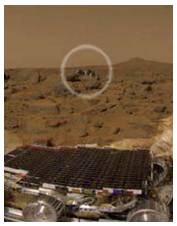
FIGURE 7.2 This front-page story from the *New York Times* described the panic caused by Orson Welles's 1938 broadcast of *The War of the Worlds*.

Today's Wackos

The truth







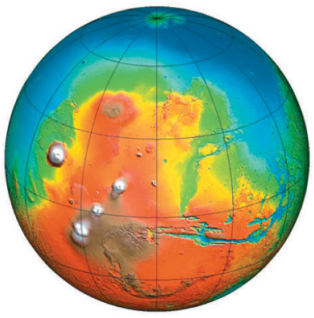
Cities, snakes, bones, frogs, squirrels…

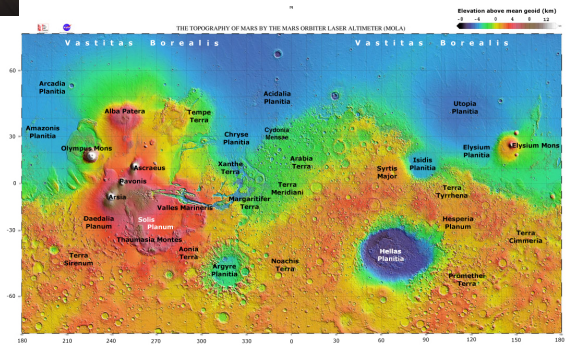
Mars Today

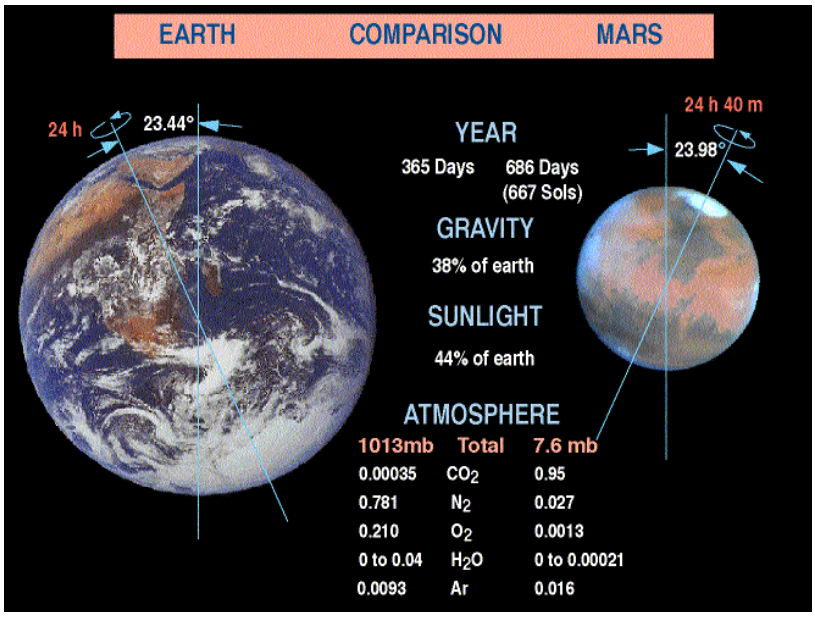
TABLE 8.1 *Basic Mars Data*

Average Distance from Sun	1.52 AU = 227.9 million km
perihelion distance	206 million km
aphelion distance	249 million km
Orbital Period	1.881 Earth yr
Equatorial Radius	3397 km
Mass (Earth = 1)	0.107
Rotation Period	24 hr 37 min
Surface Gravity (Earth = 1)	0.38
Atmospheric Composition	95% CO_2, 2.7% N_2, 1.6% argon
Average Surface Temperature	−50°C
Average Surface Pressure	0.007 bar*

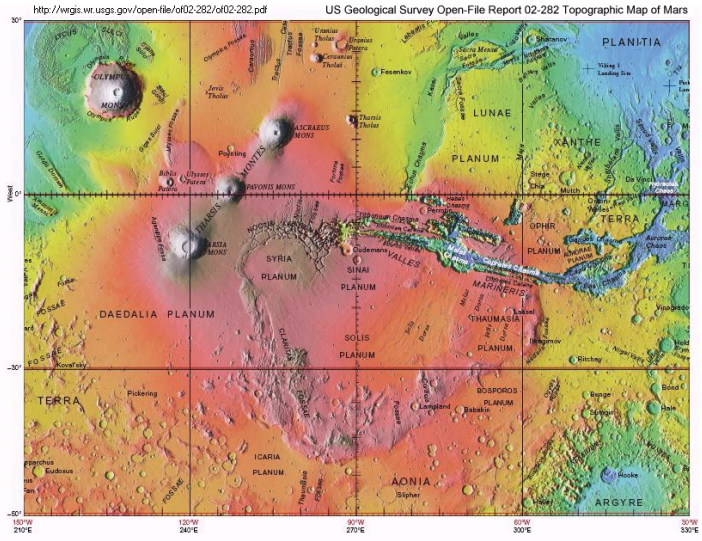
* 1 bar ≈ sea level pressure on Earth



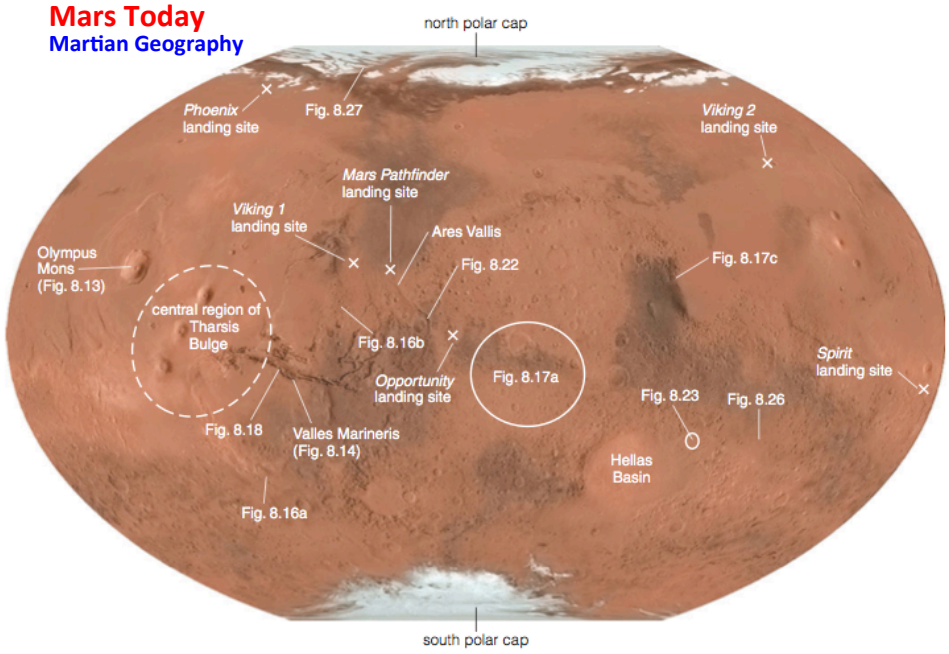




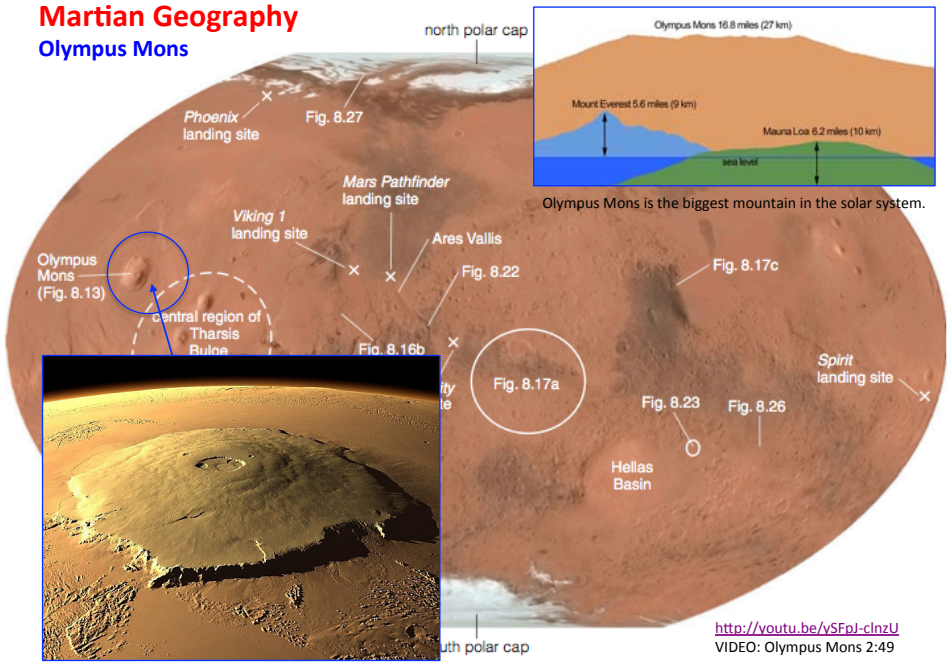
Mars Today
Martian Geography



Mars Today
Martian Geography



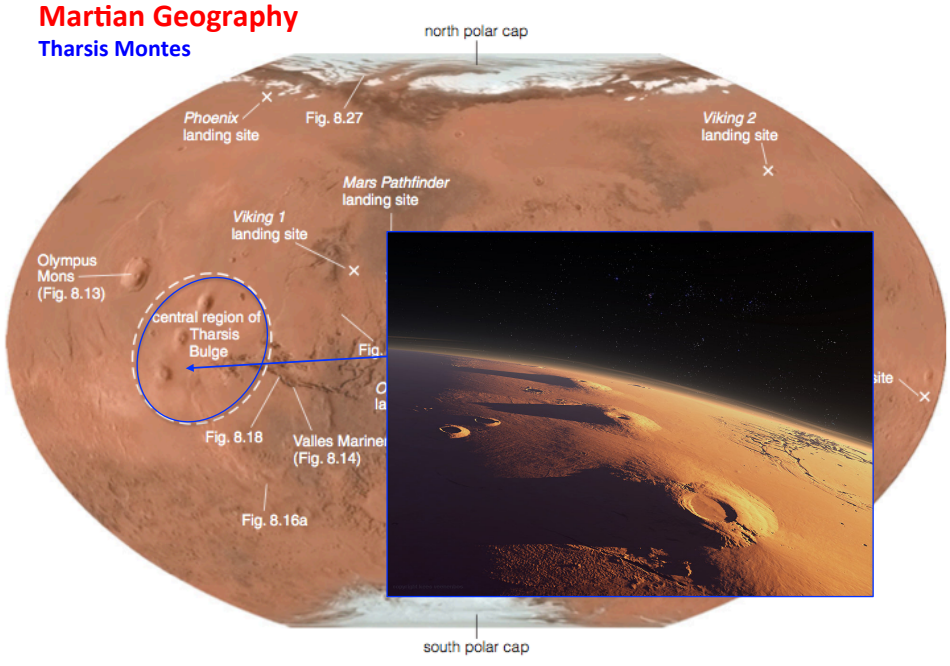
Martian Geography
Olympus Mons



Olympus Mons is the biggest mountain in the solar system.

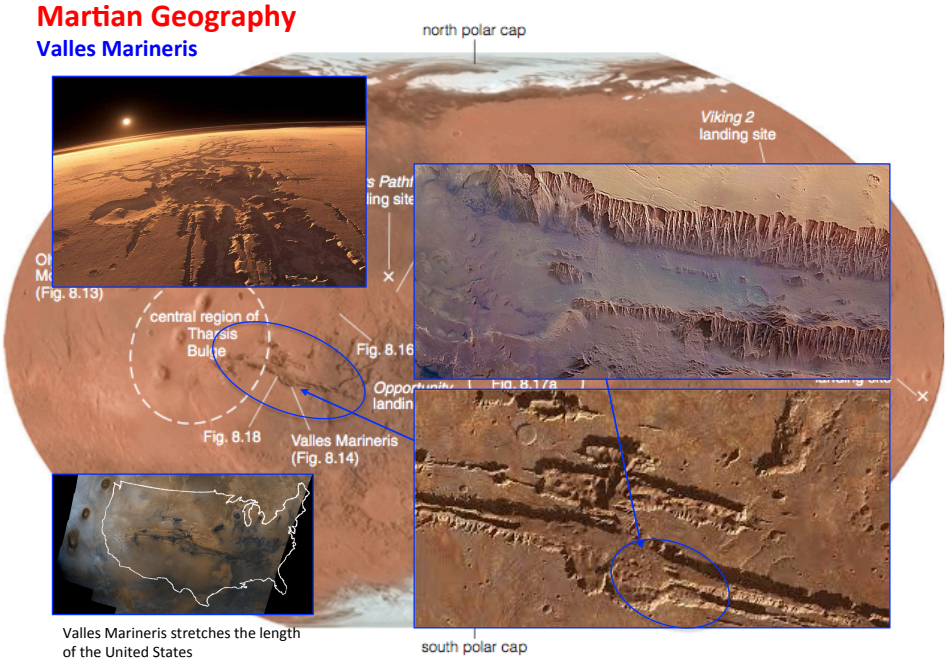
http://youtu.be/ySFpJ-clnzU
VIDEO: Olympus Mons 2:49

Martian Geography
Tharsis Montes



Martian Geography

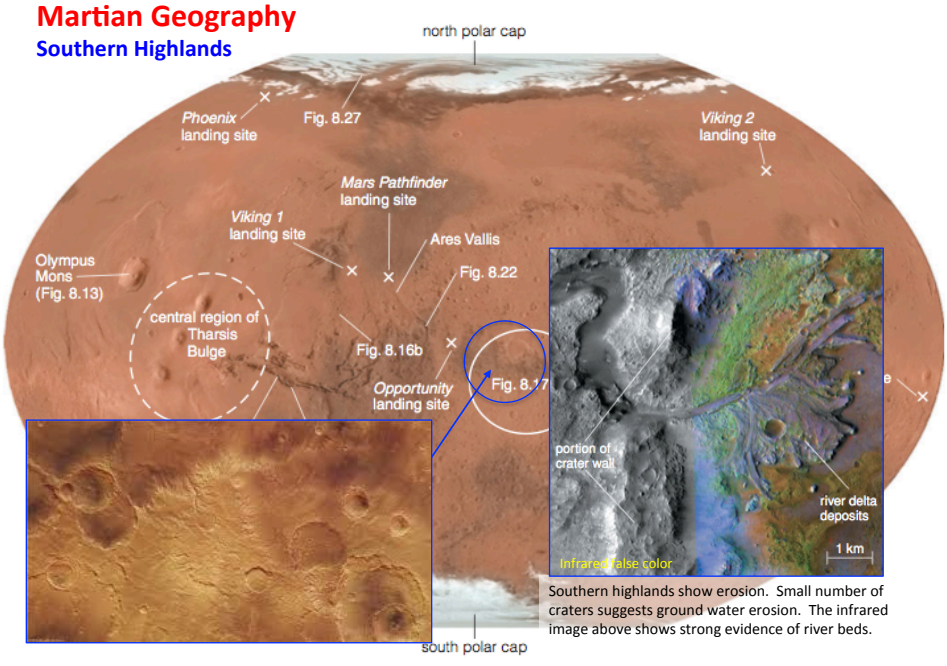
Valles Marineris



Valles Marineris stretches the length of the United States

Martian Geography

Southern Highlands



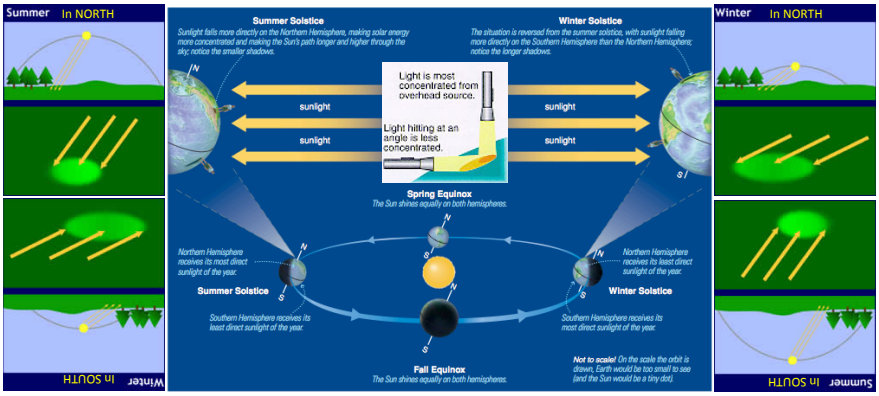
Southern highlands show erosion. Small number of craters suggests ground water erosion. The infrared image above shows strong evidence of river beds.

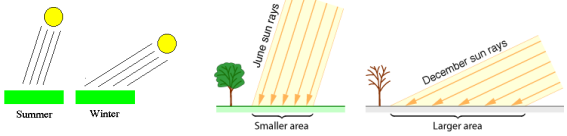
Mars Today
The Seasons (Earth tutorial)

- Due to the Earth's tilt (23.5 degrees)
- Earth's orbit is less than 3% eccentricity, so Earth's distance to the Sun changes very little over its orbit

June-July

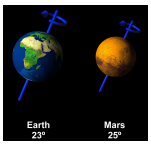
Dec-Jan





Seasons in opposite hemispheres can be ***enhanced*** if the orbit is more elliptical

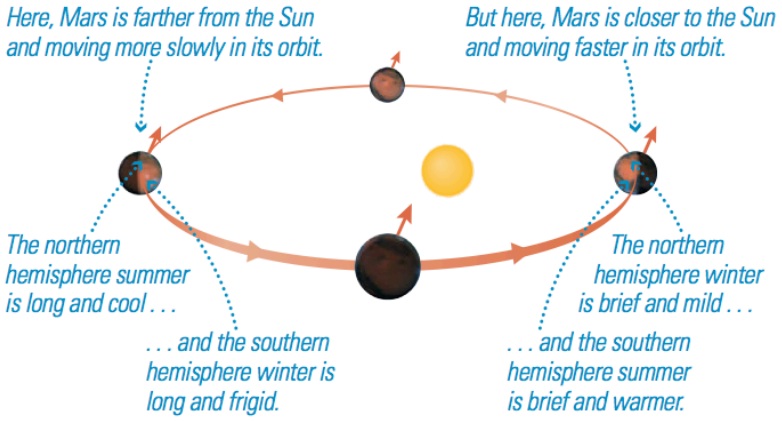
Mars Today
The Seasons



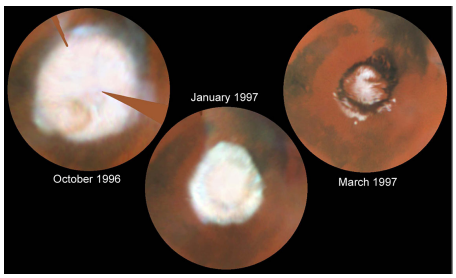
Seasons in opposite hemispheres can be ***enhanced*** if the orbit is more elliptical

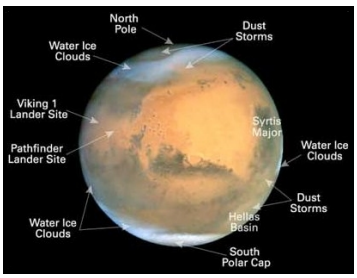
Mars' orbit has 9% eccentricity, the means there is a substantial difference in the sun-Mars distance over the course of it's orbit. This leads to enhanced seasonal variations on Mars.

Seasons on Mars



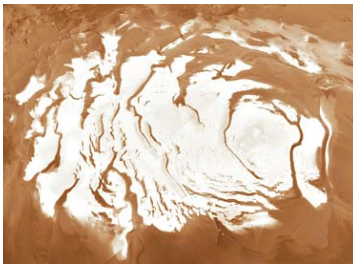
Mars Today
The Seasons





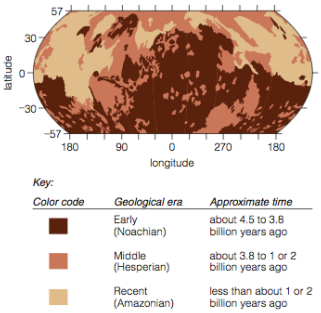
The major observable for Martian seasons is how the polar ice caps behave.

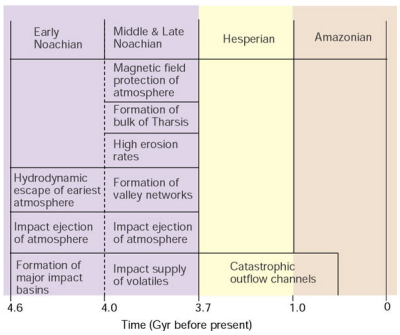
The polar caps are made mostly of carbon dioxide ice and some water ice. The carbon dioxide and water sublimate into the atmosphere, thin water-ice clouds can form. The polar material migrates from pole to pole in a seasonal cycle in this way.

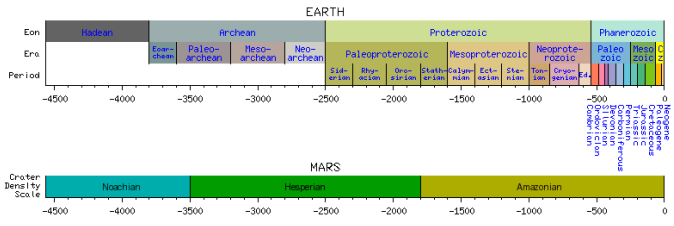


Martian Geological History

So little is known about Mars that its geological history, which broken into three eras.







Climate History of Mars

(where of where has my atmosphere gone?)

Fact: liquid water and an atmosphere was present in the Noachian Era

Mars used to have a warm climate. What conditions would need to be present?

1. For liquid water to have been stable on Mars, the atmospheric pressure would need to be about 3 times that of today's Earth
2. Greenhouse gases probably contributed (carbon dioxide), but would need to be about 400 times current level of carbon dioxide
3. But, sun was 30% as bright during Noachian era, so carbon dioxide alone could not have kept atmosphere at required level. Additional greenhouse gas? Methane? We do not know.
4. If Martian volcanoes outgassed similar to those of today's Earth, Mars could have been completely covered by water to a depth of tens to hundreds of meter! Apparently was not.

Important questions

Why was Mars warmer and wetter in the past?
How/Why did Mars Change?
Is Mars currently Habitable?
Is there evidence for life on Mars?

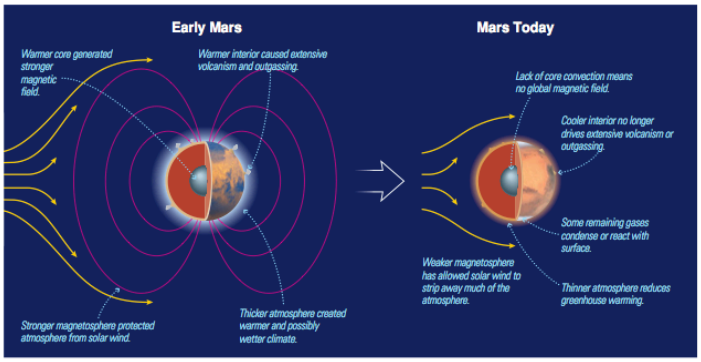
Climate History of Mars

Cooling of Interior and Loss of Magnetic Field

$$\frac{\text{Surface area sphere}}{\text{Volume sphere}} = \frac{4\pi r^2}{\frac{4}{3}\pi r^3} = \frac{3}{r}$$

Heat loss through surface of planet -- heat loss rate scales with surface area
Heat content contained in volume of planet – the larger the planet the greater the heat content
The time duration for heat loss depends on surface area to volume ratio of planet
Larger planets hold their heat content for much longer than small planets in proportion to the radius

Mars cooled off toward end of Noachian era, core gelled, magnetic field shut down , mantle cooled/thickened, volcanism shut down, plate movement shut down.



Climate History of Mars

Cooling and Loss of Atmosphere

No Volcanoes means no continued source of greenhouse gases, so if carbon dioxide is lost, then it cannot be replenished: atmosphere/planet surface will cool. The fate of Mars' carbon dioxide is not well understood, but two hypothesized mechanisms are…

1. Shock waves from impact blasts (Noachian era)
2. Energized to escape speed by solar wind particles

Once Mars lacked a magnetic field of sufficient strength to "delfect" solar wind, it is believed that the second process contributed greatly to the loss of the atmosphere…

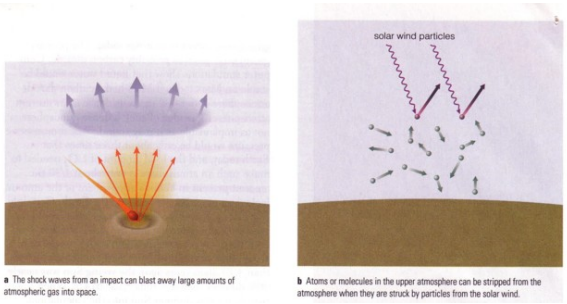
Loss of Water Vapor

http://youtu.be/zTAUfXMQgFE VIDIO: due to asteroids? 3:48
http://www.dailymotion.com/video/xtvc6k_how-mars-lost-its-atmosphere_tech VIDEO: sputtering? 2:01
http://youtu.be/q5cAD2MI7mA VIDEO: Death of Mars 4:42

Hydrogen dissociated from oxygen due to *ultraviolet light* (because no ozone layer) … free hydrogen escapes easily because it has low mass

The free oxygen had no hydrogen then to combine into water vapor!

Rocks on mars were then oxidized, or literally rusted into their present orange/red colors!



a The shock waves from an impact can blast away large amounts of atmospheric gas into space.

b Atoms or molecules in the upper atmosphere can be stripped from the atmosphere when they are struck by particles from the solar wind.

Climate History of Mars

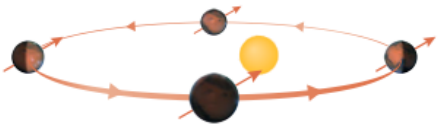
A rough transition- the role of tilt stability

Changes from a warm, wet planet, to a cold dry planet probably occurred at the transition from the Noachian to the Hesperian eras.

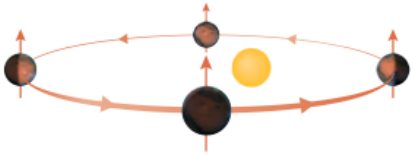
Change was probably **not** smooth with time…

Evidence is that mars inclination angle (tilt) probably varied with time more than Earth's ever did. Earth has a stabilization built in… the Moon.

On Mars, this affected melting/sublimation of polar caps, causing episodes where atmosphere was thicker in water and carbon dioxide (high inclination, a) and then episodes where poles froze over again (low inclination, b) and atmosphere then thinned out via ultraviolet light and solar wind energy processes…



a When the axis is highly tilted, the summer pole receives fairly direct sunlight and becomes quite warm.



b When the axis tilt is small, the poles receive little sunlight at any time of year.

We really don't know….

Climate History of Mars

A Summary

The hypotheses we have described suggests that Mars changed primarily because of its relatively small size.

It was big enough for volcanism and outgassing to release plenty of water and atmospheric gas early in its history, but too small to maintain the internal heat needed to prevent this loss of water and gas.

As its interior cooled, its volcanoes quieted and released far less gas into the atmosphere, while its relatively weak gravity and the loss of its magnetic field allowed existing gas to be stripped away to space.

If Mars had been as large as Earth, so that it could still have outgassing and a global magnetic field, it might still have a pleasant climate today.

Mars's distance from the Sun also helped seal its fate: Even with its small size, Mars might still have some flowing water if it were significantly closer to the Sun, where the extra warmth could melt the water that remains frozen underground and at the polar caps.

Is Mars Habitable?

Young planet probably was as habitable as Earth during life formation periods. If life "took" then extremophiles could still persist. But these would be of the cold variety, not the high temperature.

Today, it depends upon the presence of liquid water. This water is probably located in small underground reservoirs. If they exists, then Mars satisfied all three criteria required for habitability: elements, energy, and water. **Mars life in Caves?**

Cave Research

"We have thought about what the life might look like on the surface [of other worlds], but in light of the huge biodiversity of microorganisms in the subsurface of Earth, the subsurface in general and caves in particular will be an important place to look for life on other bodies. I believe that there may be many planets, including Mars, where the only life on the planet will be restricted to the subsurface."

Penny Boston (NMT) and Diana Northup (UNM), caving for studying cave ecosystems.

How to Send an Experiment to Mars? 6:32

https://www.youtube.com/watch?v=XRCIzZHpFtY&spfreload=10

What Needs to be Figured Out to Send Humans to Mars? 10:01

- A rapid fire 10 minute lecture!!!

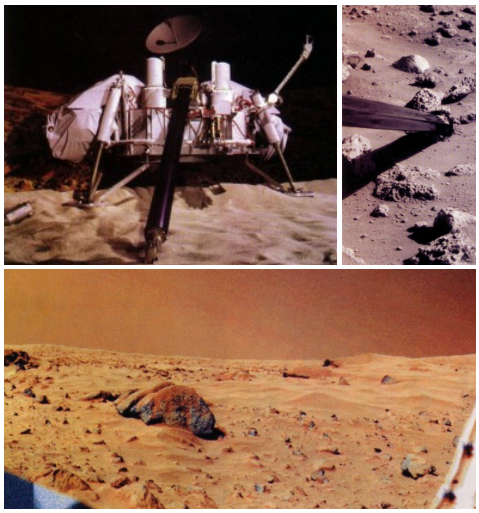
https://www.youtube.com/watch?v=vw09bLwd3Ak&spfreload=10

The *Viking* Experiments 1977

1. Carbon Assimilation Experiment
2. Gas Exchange Experiment
3. Labeled Release Experiment
4. Gas Mass Spectrometer Experiment

Each of these four experiments tested for life in the Martian soil.

The location was no ideal, but having the lander set down safely was a primary consideration…



UPSHOT: no evidence for life, but there was a big surprise that at first made it appear that there might be life.

1. no life
2. no life
3. hmm, could be life
4. no, 3 was not life

1. Carbon Assimilation

Mixed Martian soil with Earth's carbon dioxide and carbon monoxide, tagged with carbon-14

Hypothesis: If incorporated into the soil, then living creatures used ingested gas as source of carbon in their metabolism

Result: carbon-14 was incorporated into soil!

After heating soil (to kill possible life forms before exposing to carbon-14) and rerunning the experiment, the carbon-14 was still incorporated

NO LIFE

2. Gas Exchange

Mixed Martian soil with "broth" of organic molecules brought from Earth

Hypothesis: Release of gases, including oxygen, would indicate respiration from microbes

Result: oxygen was released into the chamber! But us happened in the dark too (not photosynthetic)

After heating soil (to kill!) and rerunning, the oxygen was still released. Also happened when soil exposed only to water vapor.

NO LIFE

3. Labeled Release

Mixed Martian soil with organic nutrients from Earth tagged with *radioactive* carbon-14 and sulfur-35

Hypothesis: If nutrients metabolized via respiration, then radioactivity would rise as radioactive gasses released into chamber and then level off as consumed

Result: Radioactivity rised and then leveled off!

After heating soil (to kill), the radioactivity did not rise! As expected if life killed before mixing soil!

HMMM, COULD BE LIFE

4. Gas Mass Spectrometer

Not really for testing for life, but to measure abundance of Martian organic molecules, which could have been seeded by meteorite impacts

After heating soil (to break up organic molecules and vaporize them), the vapor was sent through a gas chromatograph (separator), and then a mass spectrometer (identifier)

Result: no organic molecules (just solvent from Earth used to clean the instrument!)

SOIL DOES NOT CONTAIN LIVING ORGANISMS
NULLIFIED LABEL RELEASE POSSIBILITY

The Story of ALH84001

(Allen Hills region, 1984, first one found)

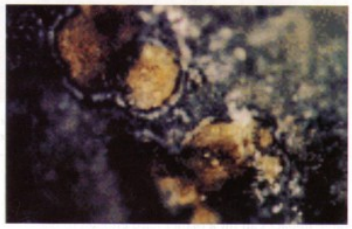
Volcanic rock that formed 3.9 billion years ago
Spent 16 million years wandering solar system
Lands on Earth 13,000 years ago

Sat in a lab for 10 years before being studied!

Was once infiltrated by liquid water

Time	Event
4.5 billion years ago	Solidifies from molten rock in the southern highlands of Mars
4.0–4.5 billion years ago	Affected by nearby impacts, but not launched into space
3.9 billion years ago	Infiltrated by water, leading to the formation of carbonate grains within the rock
16 million years ago	Blasted into space by an impact on Mars
13,000 years ago	Falls to Earth in Antarctica
December 27, 1984	Found by scientists
October 1993	Recognized as a martian meteorite
August 1996	Announcement that ALH84001 contains possible evidence of martian life

a The martian meteorite ALH84001, before it was cut open for detailed study. The small block shown for scale to the lower right is 1 cubic centimeter, about the size of a typical sugar cube.



b A microscopic view of a thin slice of ALH84001 shows orange carbonate globules, indicating that the rock was once infiltrated by liquid water. The grains are about 0.1–0.2 millimeter across. The globules formed about 3.9 billion years ago.

In iron rich layers, crystals of magnetite are found similar in size and shape to those made by bacteria on Earth

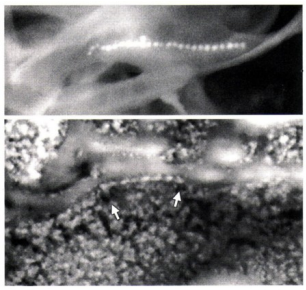


FIGURE 7.31 Top: Microscopic chains of magnetite crystals produced by bacteria on Earth. Bottom: Similar chains of magnetite crystals found in the carbonate globules of ALH84001. The similarity to the terrestrial chains has been cited as evidence of life on Mars.

Carbonate globules have alternating layers of magnesium, iron, and calcium-rich carbonates.

This is found on Earth due to biological activity

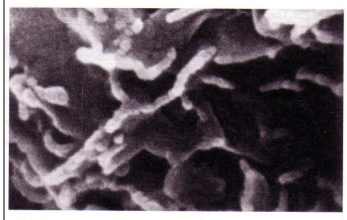
These contain polycyclic aromatic hydrocarbons – but can have biological and non-biological origins

a This photo shows rod-shaped structures found in the carbonate globules of ALH84001. They measure about 100 nanometers in length and are as small as 10–20 nanometers in width.

Rod-shaped structure with segments were found in images of the rock

Look like ordinary Earth bacteria but 100 times smaller

Could be "nanobacteria" or "nanobes" as recently discovered on Earth (but these new "organisms" are not known to be living, though appear to contain DNA)



b This photo shows terrestrial "nanobacteria" in a sample of volcanic rock from Sicily. They are close in size to the structures seen in ALH84001. The scale bar at the bottom is 1 micrometer, or 1,000 nanometers.