ASTRONOMY

Chapter 10 EARTHLIKE PLANETS: MARS ?
[I SAY MORE CRATERED WORLDS]

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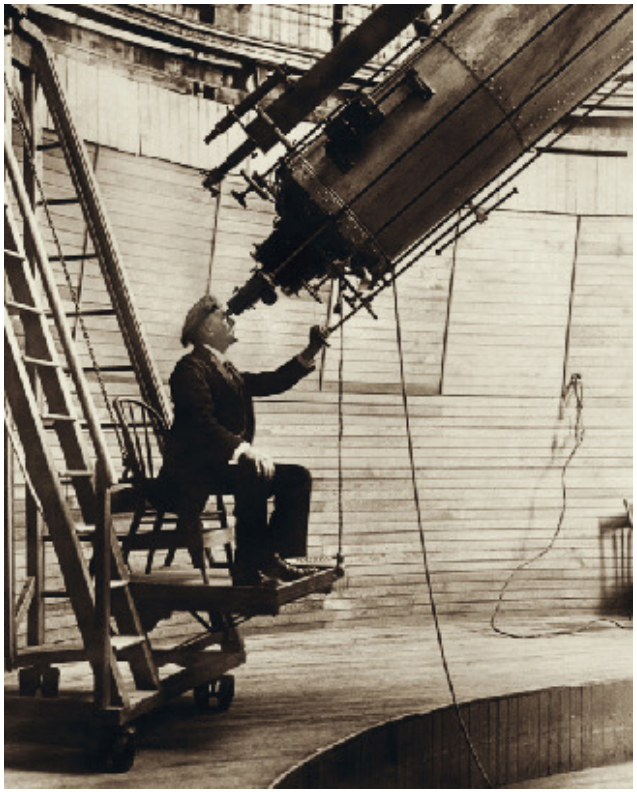
FIGURE 10.13

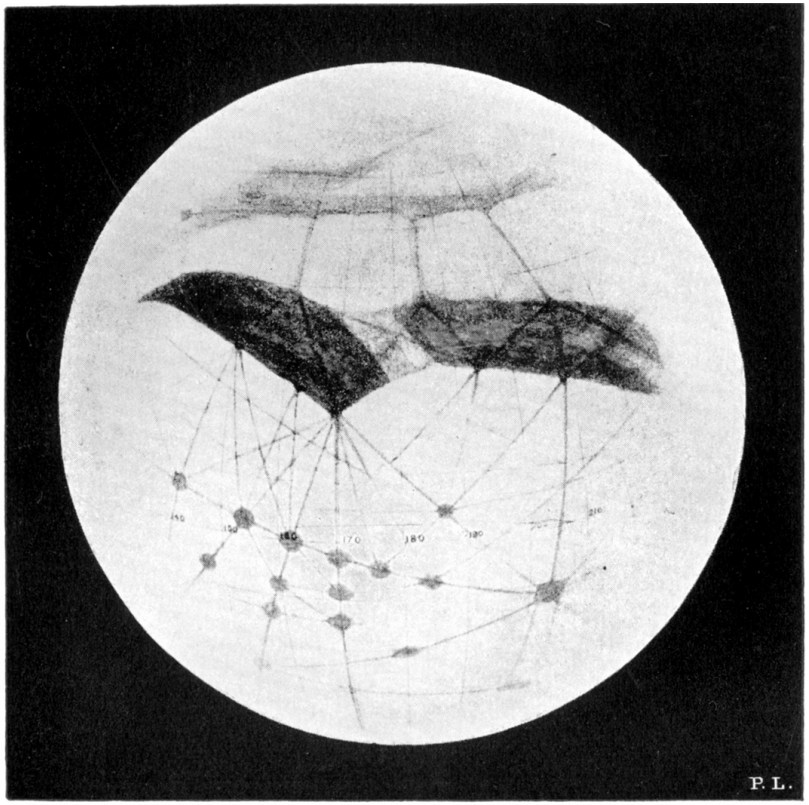
Mars Photographed by the Hubble Space Telescope. This is one of the photos of Mars taken from our planet, obtained in June 2001 when Mars was only 68 million kilometers away. The resolution is about 20 kilometers—much better than can be obtained with ground-based telescopes but still insufficient to reveal the underlying geology of Mars. (credit: modification of work by NASA and the Hubble Heritage Team (STScI/AURA))

FIGURE 10.5



Percival Lowell (1855–1916). This 1914 photograph shows Percival Lowell observing Venus with his 24-inch telescope at Flagstaff, Arizona.

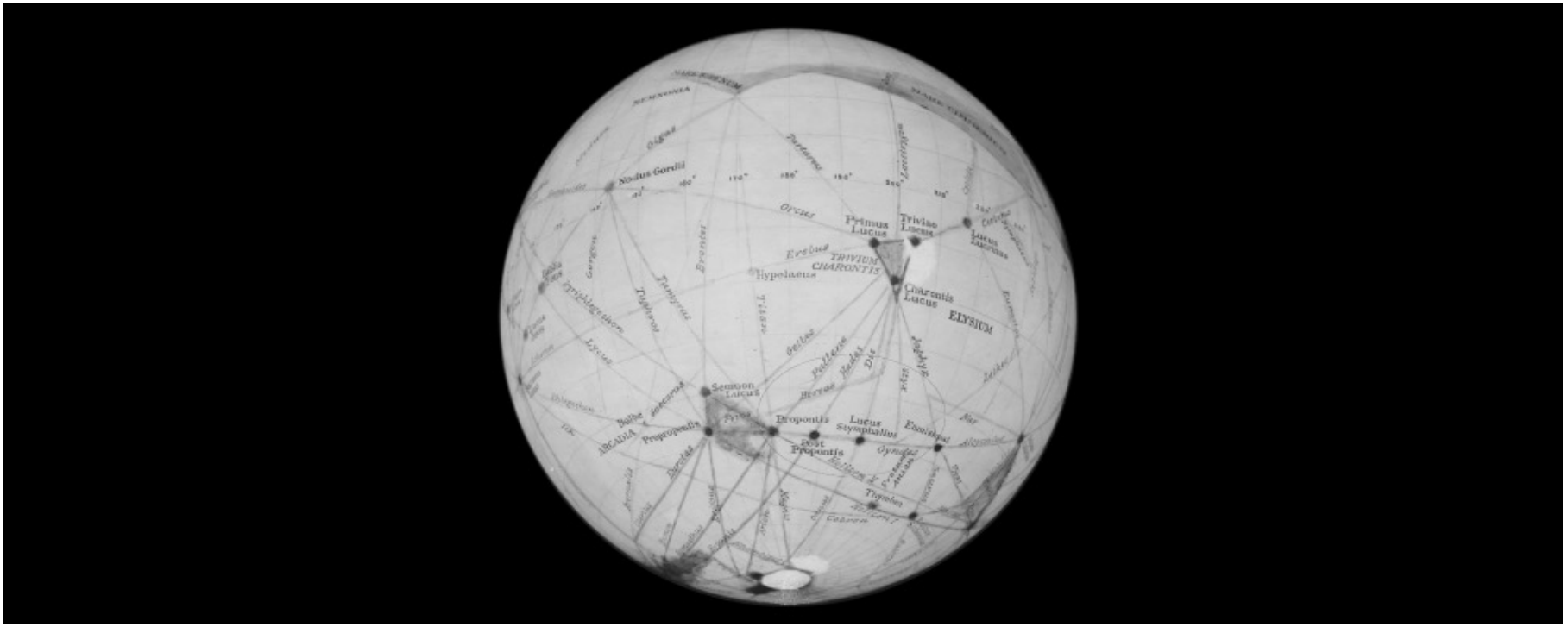
PERCIVAL LOWELL'S CANALS ON MARS



Seasonal variations in both the size of its polar caps and brightness of mid-latitude features led to the speculation by Percival Lowell around 1900 that the poles consist of water with "canals" that provide irrigation for crops grown by an advanced civilization (An original sketch by Percival Lowell)

http://ircamera.as.arizona.edu/NatSci102/NatSci102/lectures/mars.htm

FIGURE 10.4



Lowell's Mars Globe. One of the remarkable globes of Mars prepared by Percival Lowell, showing a network of dozens of canals, oases, and triangular water reservoirs that he claimed were visible on the red planet.

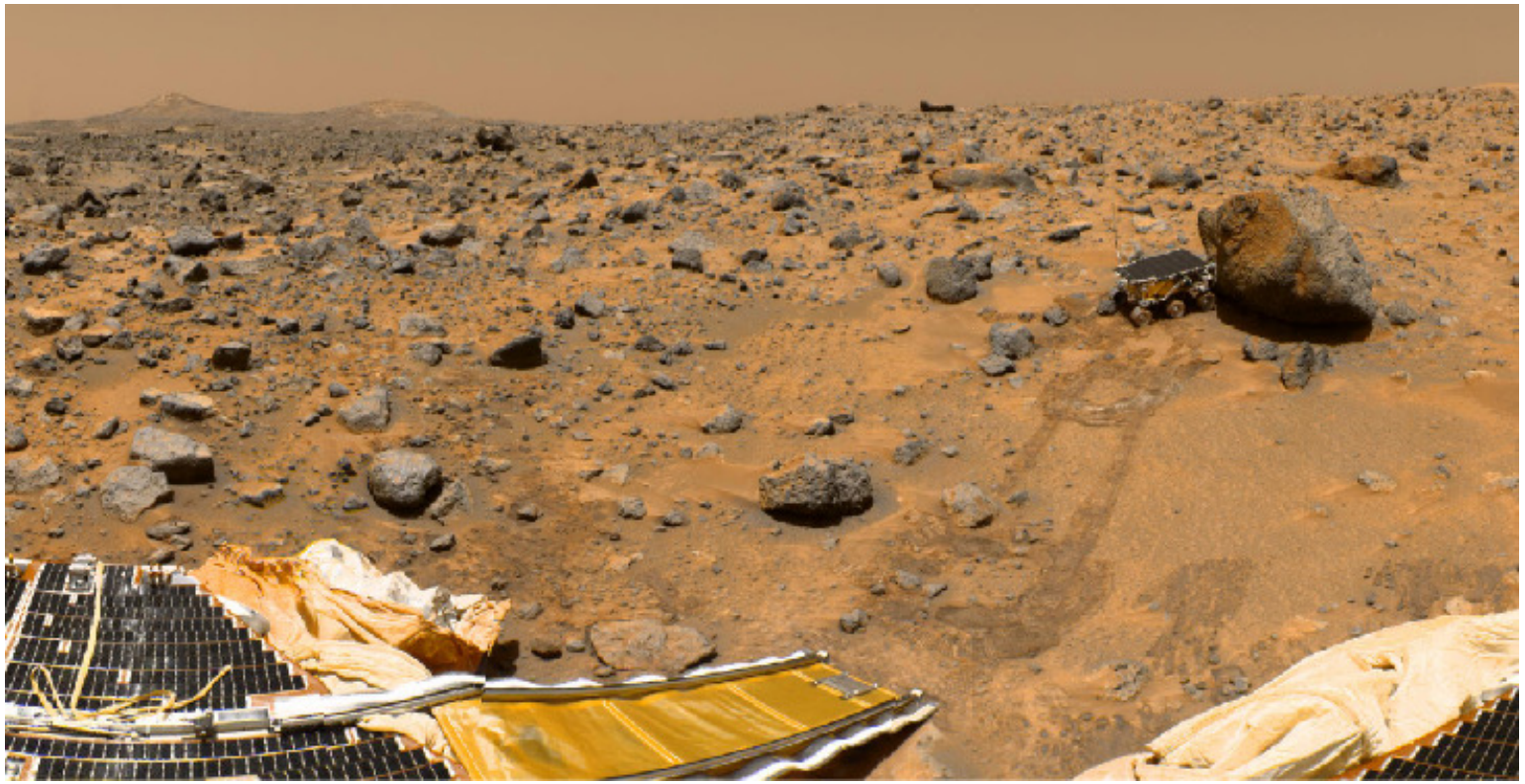
FIGURE 10.21

Three Martian Landing Sites. The Mars landers Viking 1 in Chryse, Pathfinder in Ares Valley, and Viking 2 in Utopia, all photographed their immediate surroundings. It is apparent from the similarity of these three photos that each spacecraft touched down on a flat, windswept plain littered with rocks ranging from tiny pebbles up to meter-size boulders. It is probable that most of Mars looks like this on the surface. (credit “Viking 1”: modification of work by Van der Hoorn/NASA; credit “Pathfinder”: modification of work by NASA; credit “Viking 2”: modification of work by NASA; credit Mars: modification of work by NASA/Goddard Space Flight Center)

FIGURE 10.1

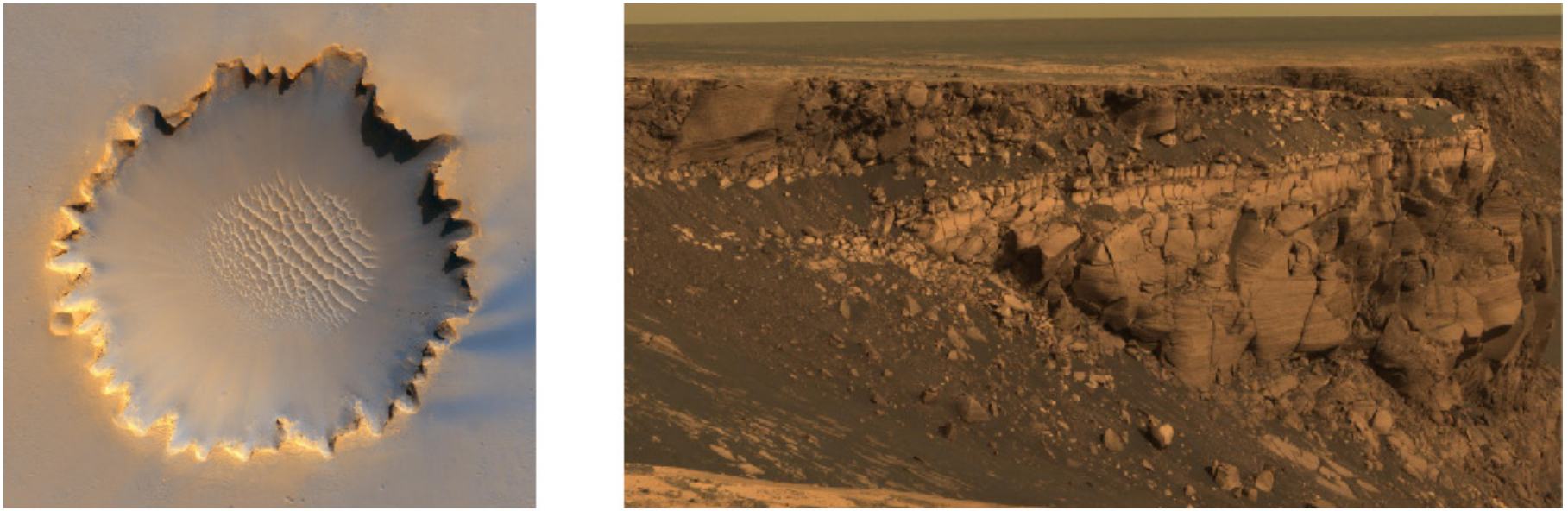
Spirit Rover on Mars. This May 2004 image shows the tracks made by the Mars Exploration *Spirit* rover on the surface of the red planet. *Spirit* was active on Mars between 2004 and 2010, twenty times longer than its planners had expected. It “drove” over 7.73 kilometers in the process of examining the martian landscape. (credit: modification of work by NASA/JPL/Cornell)

FIGURE 10.14



Surface View from Mars Pathfinder. The scene from the Pathfinder lander shows a windswept plain, sculpted long ago when water flowed out of the martian highlands and into the depression where the spacecraft landed. The *Sojourner* rover, the first wheeled vehicle on Mars [1997+], is about the size of a microwave oven. Its flat top contains solar cells that provided electricity to run the vehicle. You can see the ramp from the lander and the path the rover took to the larger rock that the mission team nicknamed “Yogi.” (credit: NASA/JPL)

FIGURE 10.15



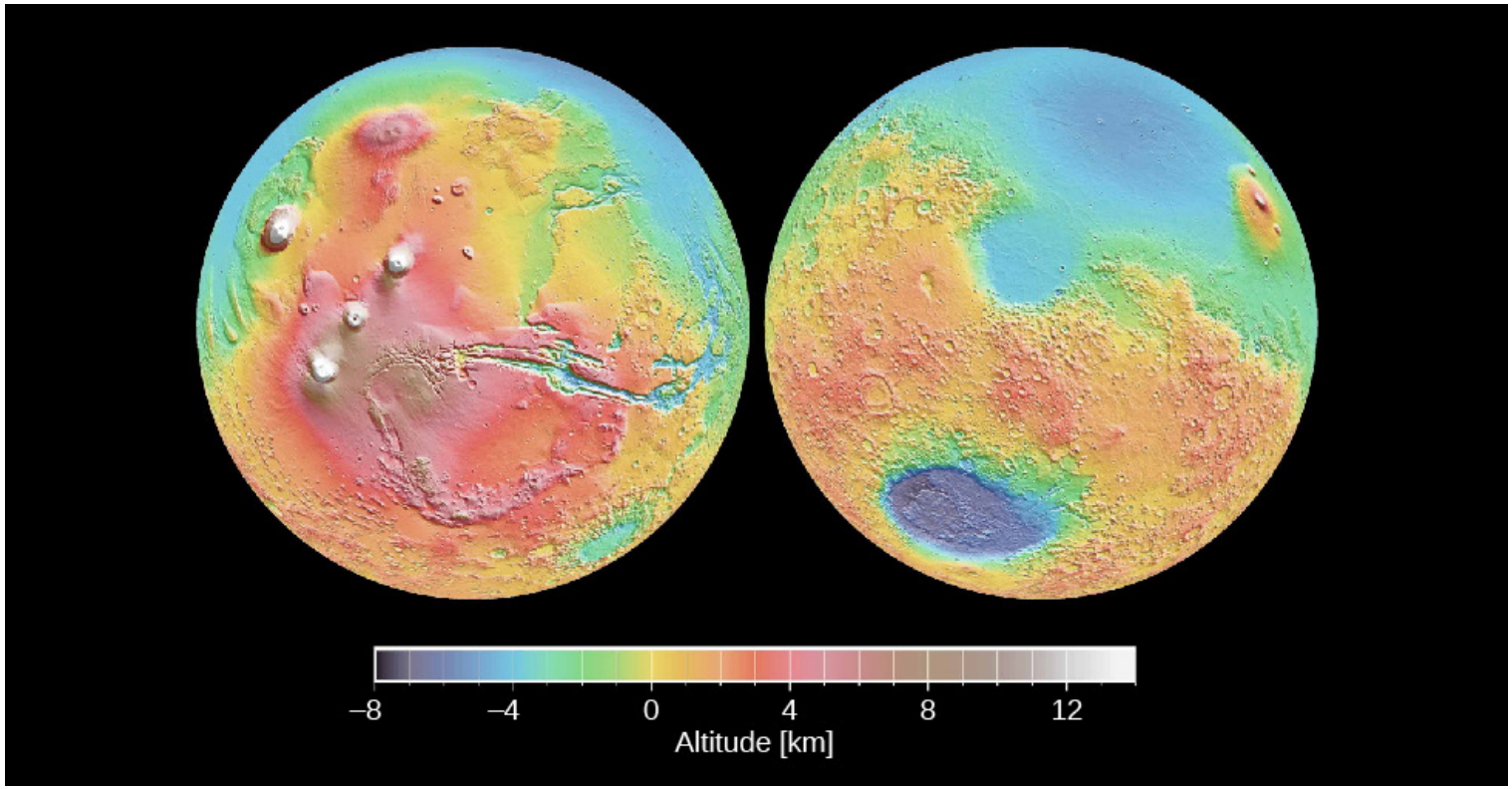
(a) (b)

Victoria Crater.

(a) This crater in Meridiani Planum is 800 meters wide, making it slightly smaller than Meteor crater on Earth. Note the dune field in the interior.

(b) This image shows the view from the *Opportunity* (2004-2018) rover as it scouted the rim of Victoria crater looking for a safe route down into the interior. (credit a: modification of work by NASA/JPL-Caltech/University of Arizona/Cornell/Ohio State University; credit b: modification of work by NASA/JPL/Cornell)

FIGURE 10.17



Mars Map from Laser Ranging. These globes are highly precise topographic maps, reconstructed from millions of individual elevation measurements made with the *Mars Global Surveyor*. Color is used to indicate elevation. The hemisphere on the left includes the Tharsis bulge and Olympus Mons, the highest mountain on Mars; the hemisphere on the right includes the Hellas basin, which has the lowest elevation on Mars. (credit: modification of work by NASA/JPL)

THE OLYMPUS MONS VOLCANO

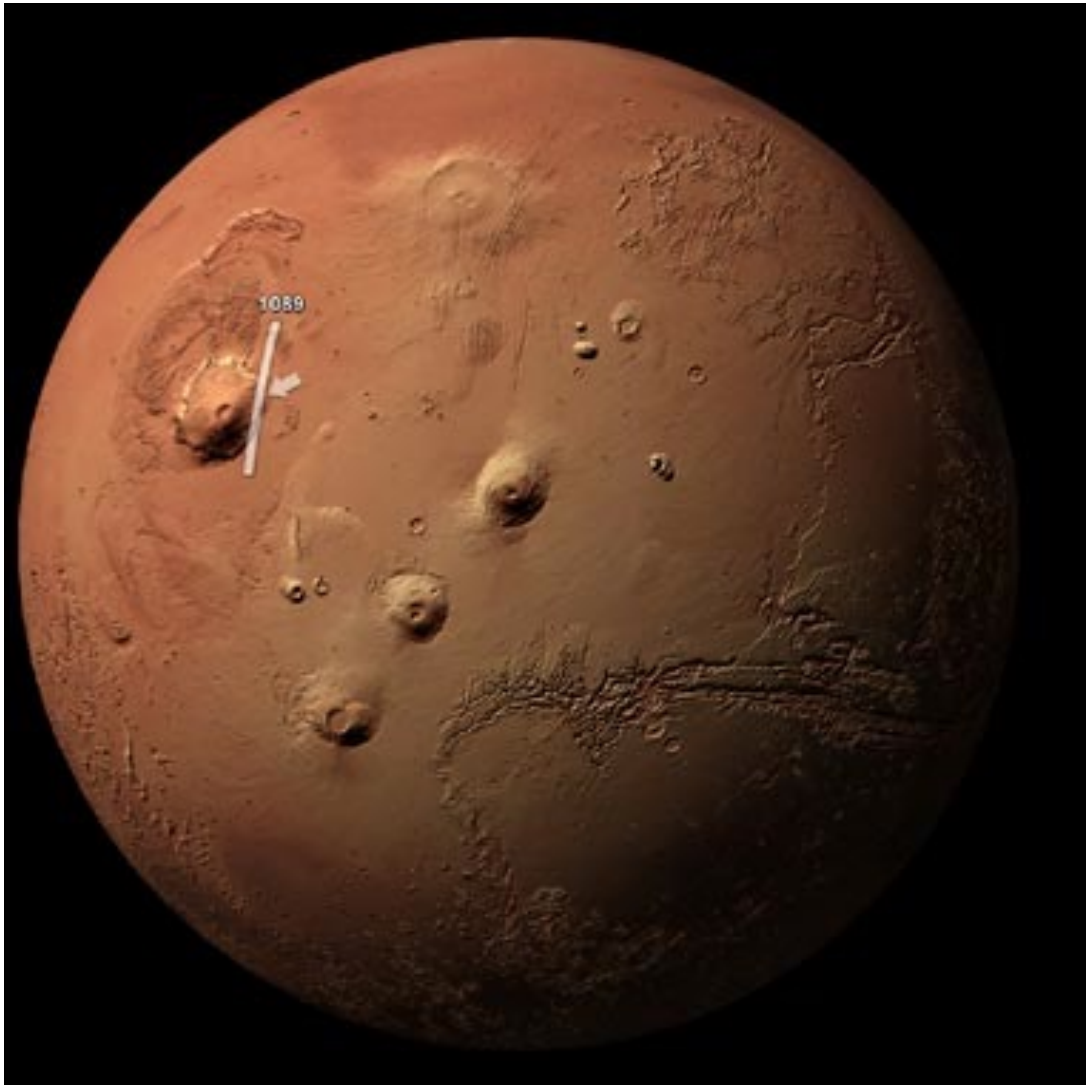
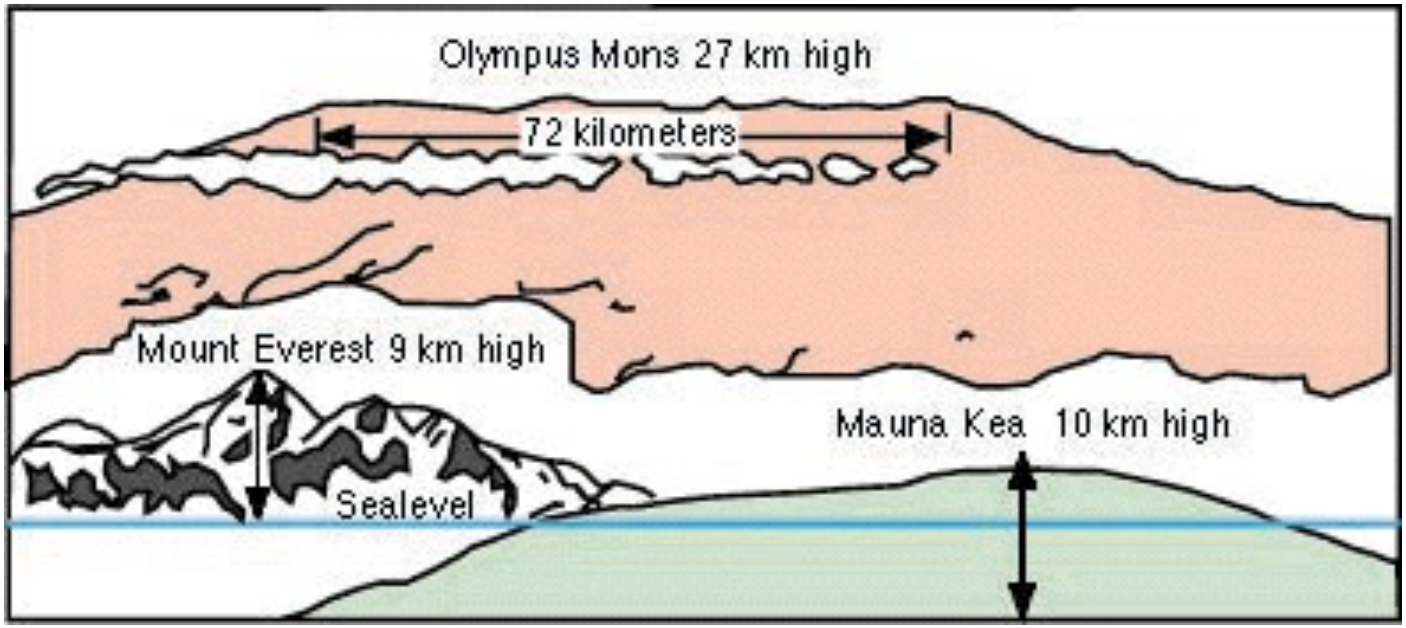


FIGURE 10.18

Olympus Mons. The largest volcano on Mars, and probably the largest in the solar system, is Olympus Mons, illustrated in this computer-generated rendering based on data from the *Mars Global Surveyor's* laser altimeter. Placed on Earth, the base of Olympus Mons would completely cover the state of Missouri; the caldera, the circular opening at the top, is 65 kilometers across, about the size of Los Angeles. (credit: NASA/Corbis)

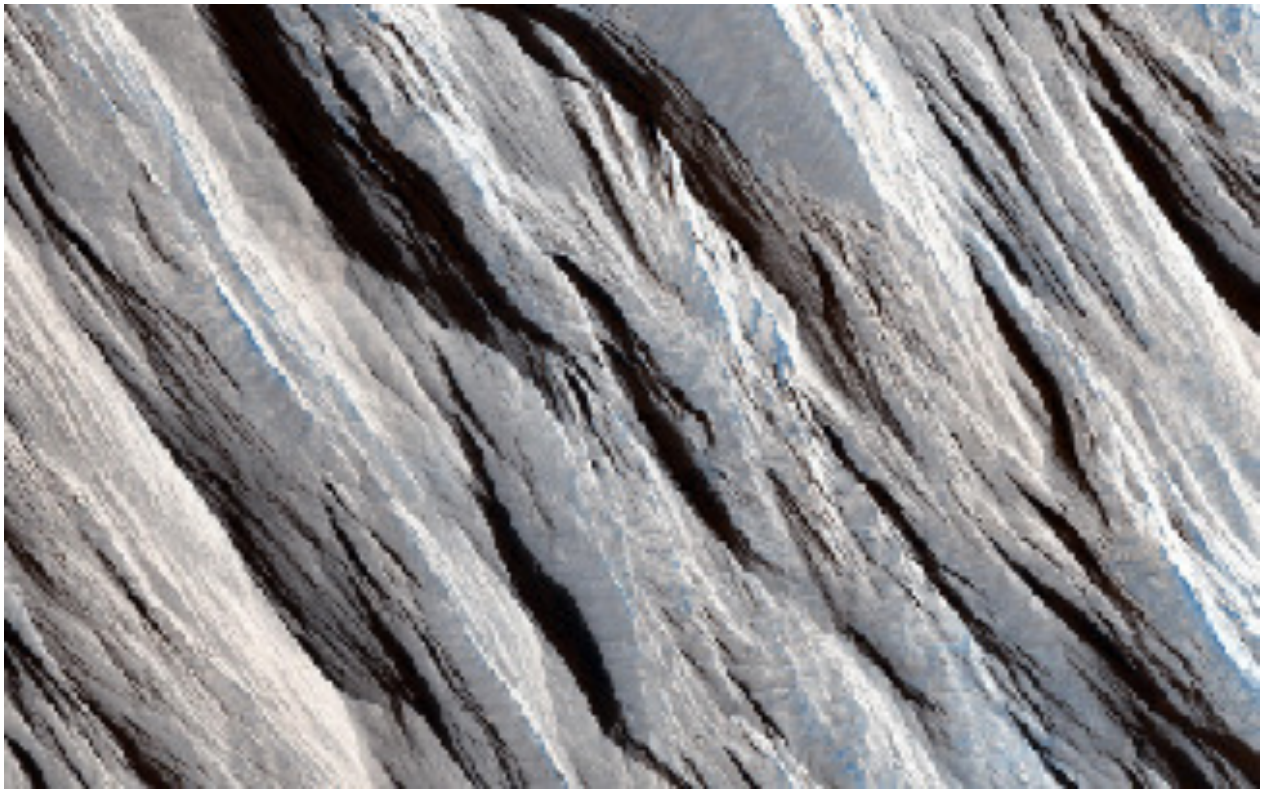
MARS HAS HUGE SHIELD VOLCANOES

The Martian volcanos grew to huge size because there are no plate motions on Mars



http://ircamera.as.arizona.edu/NatSci102/NatSci102/lectures/mars.htm

FIGURE 10.24



Wind Erosion on Mars. These long straight ridges, called yardangs, are aligned with the dominant wind direction. This is a high-resolution image from the *Mars Reconnaissance Orbiter* and is about 1 kilometer wide. (credit: NASA/JPL-Caltech/University of Arizona)

DUST ON MARS

http://ircamera.as.arizona.edu/NatSci102/NatSci102/lectures/mars.htm

(http://www.spacedaily.com/news/mars-odyssey-01b.html)

DAYS AND SEASONS ON MARS

Days are similar to Earth, seasons more extreme (and colder) because Mars' orbit is more eccentric than the Earth's and Mars' polar axis tilt is a little more than for the Earth's (25.2^{o} as compared to Earth's 23.5^{o})

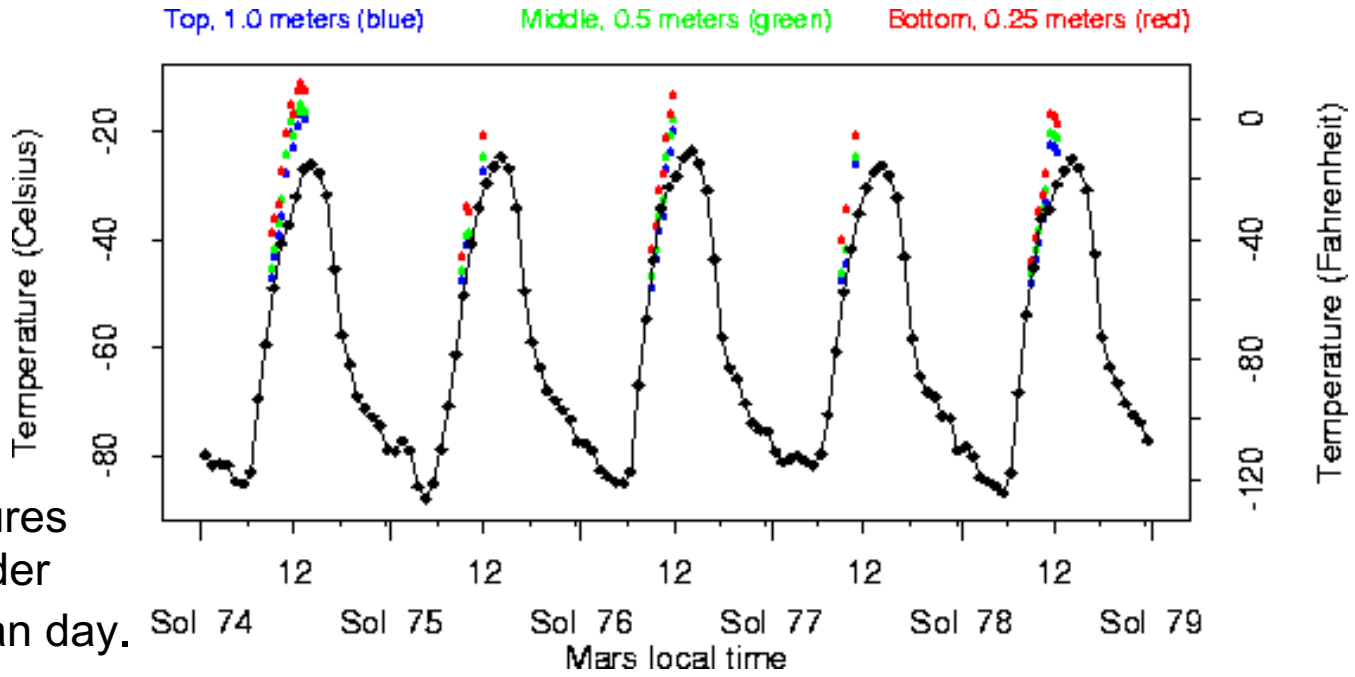
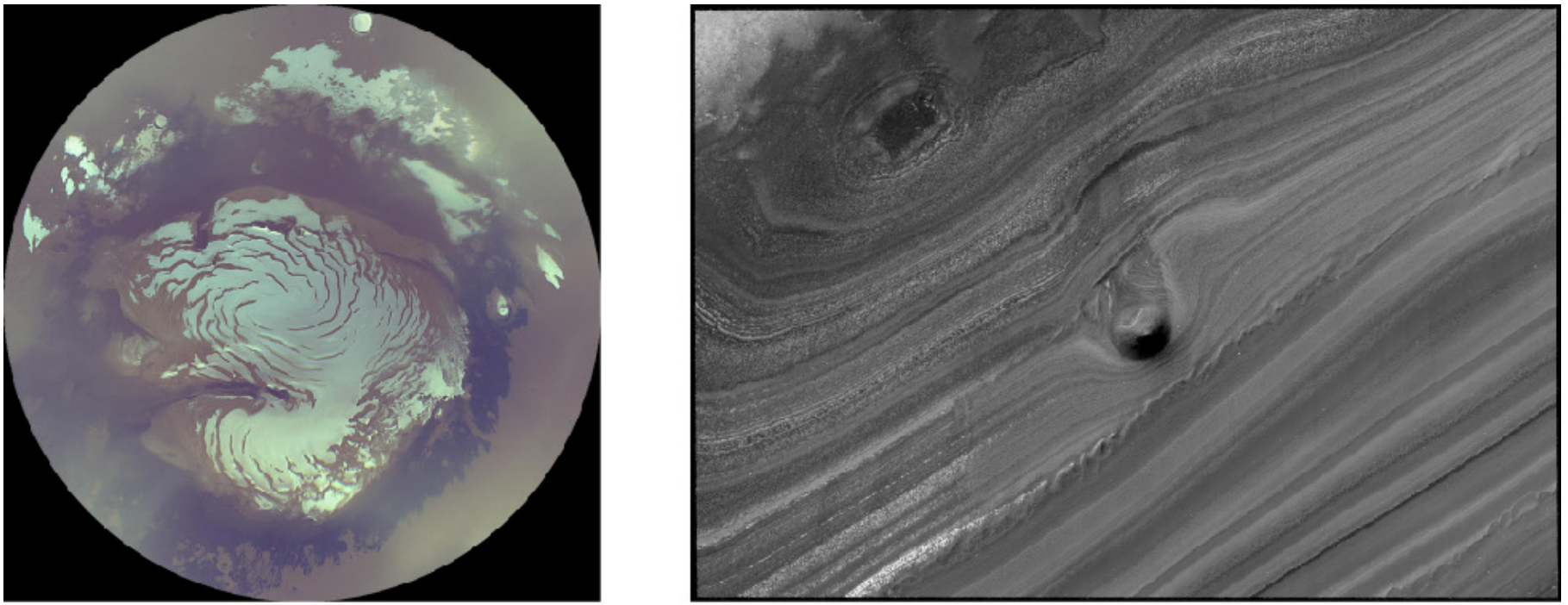


Chart of temperatures from Mars Pathfinder -- a Sol is a Martian day.

http://ircamera.as.arizona.edu/NatSci102/NatSci102/lectures/mars.htm

FIGURE 10.25



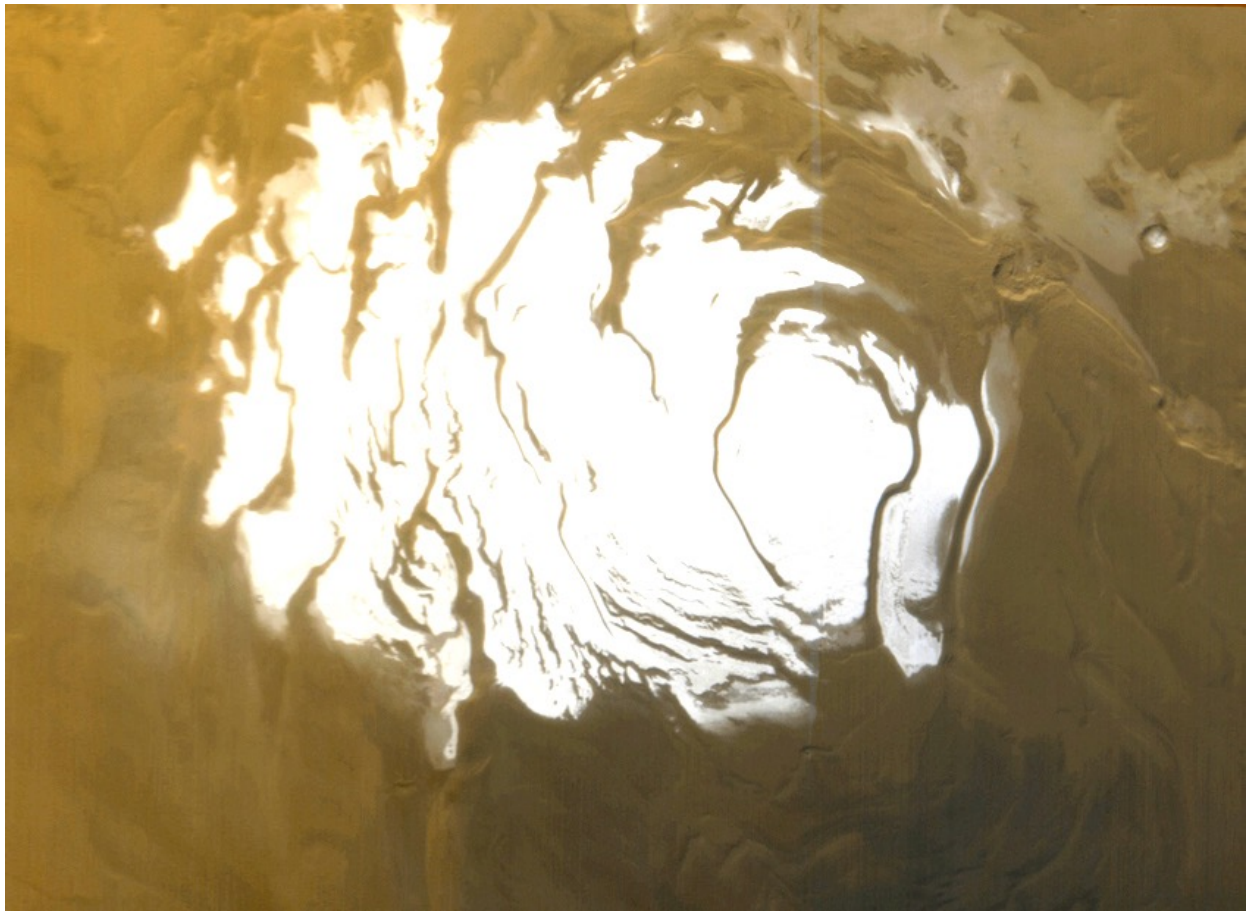
(a) (b)

Martian North Polar Cap.

(a) This is a composite image of the north pole in summer, obtained in October 2006 by the *Mars Reconnaissance Orbiter*. It shows the mostly water-ice residual cap sitting atop light, tan-colored, layered sediments. Note that although the border of this photo is circular, it shows only a small part of the planet.

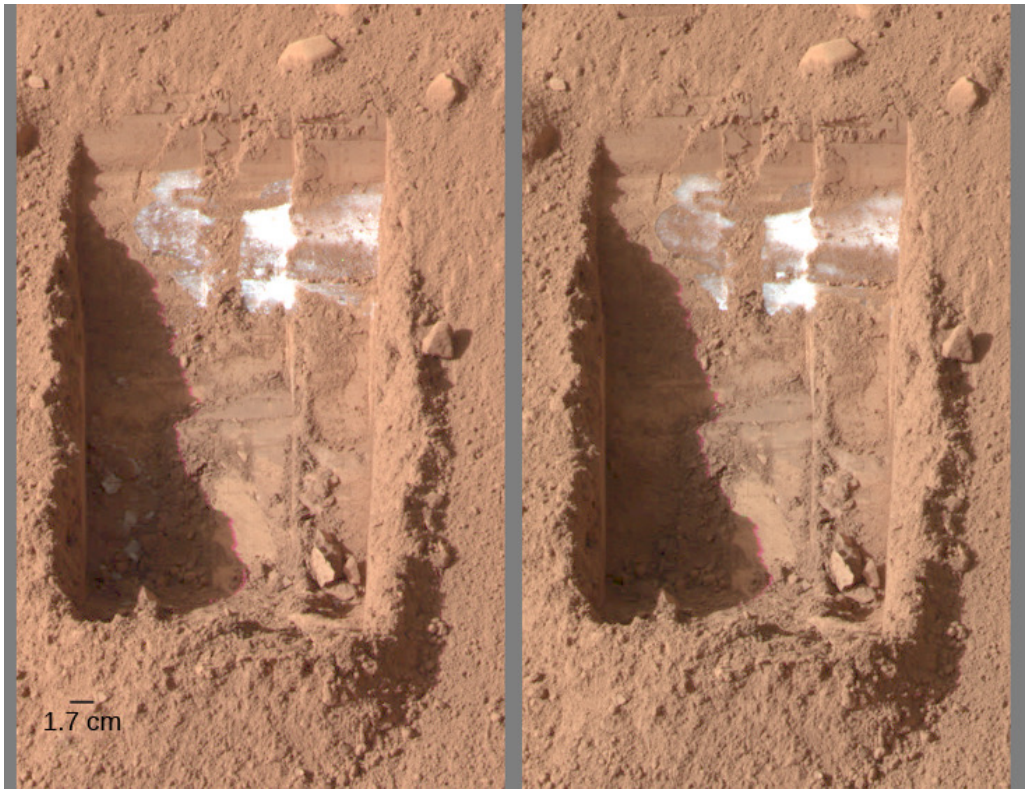
(b) Here we see a small section of the layered terrain near the martian north pole. There is a mound about 40 meters high that is sticking out of a trough in the center of the picture. (credit a: modification of work by NASA/JPL/MSSS; credit b: modification of work by NASA/JPL-Caltech/University of Arizona)

SOUTH POLAR CAP



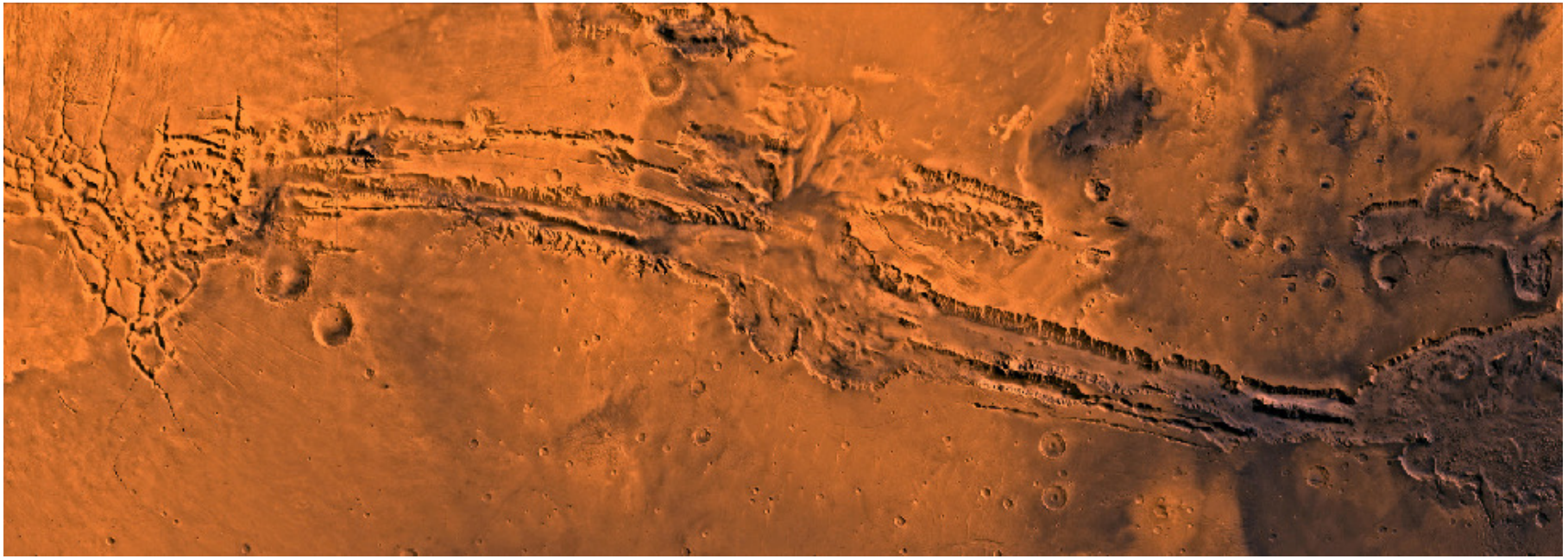
Picture from Mars Global Surveyor:
http://www.msss.com/mars_images/moc/4_27_00_spcap/index.html

FIGURE 10.26



Evaporating Ice on Mars. We see a trench dug by the *Phoenix* lander in the north polar region four martian days apart in June 2008. If you look at the shadowed region in the bottom left of the trench, you can see three spots of ice in the left image which have sublimated away in the right image. (credit: modification of work by NASA/JPL-Caltech/University of Arizona/Texas A&M University)

FIGURE 10.19



Heavily Eroded Canyonlands on Mars. This image shows the Valles Marineris canyon complex, which is 3000 kilometers wide and 8 kilometers deep. (credit: NASA/JPL/USGS)

FIGURE 10.27

(a)

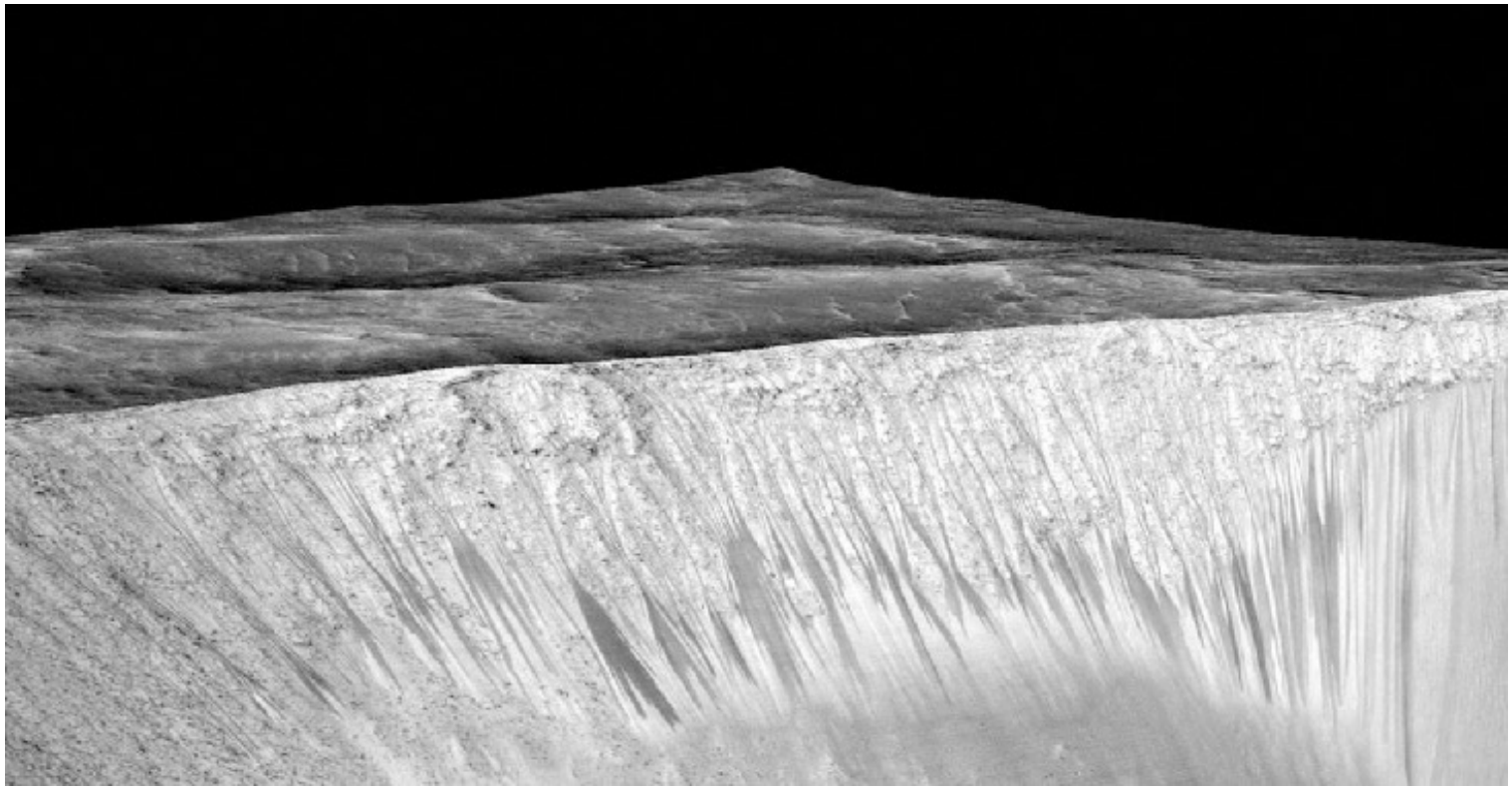
(b)

Runoff and Outflow Channels.

(a) These runoff channels in the old martian highlands are interpreted as the valleys of ancient rivers fed by either rain or underground springs. The width of this image is about 200 kilometers.

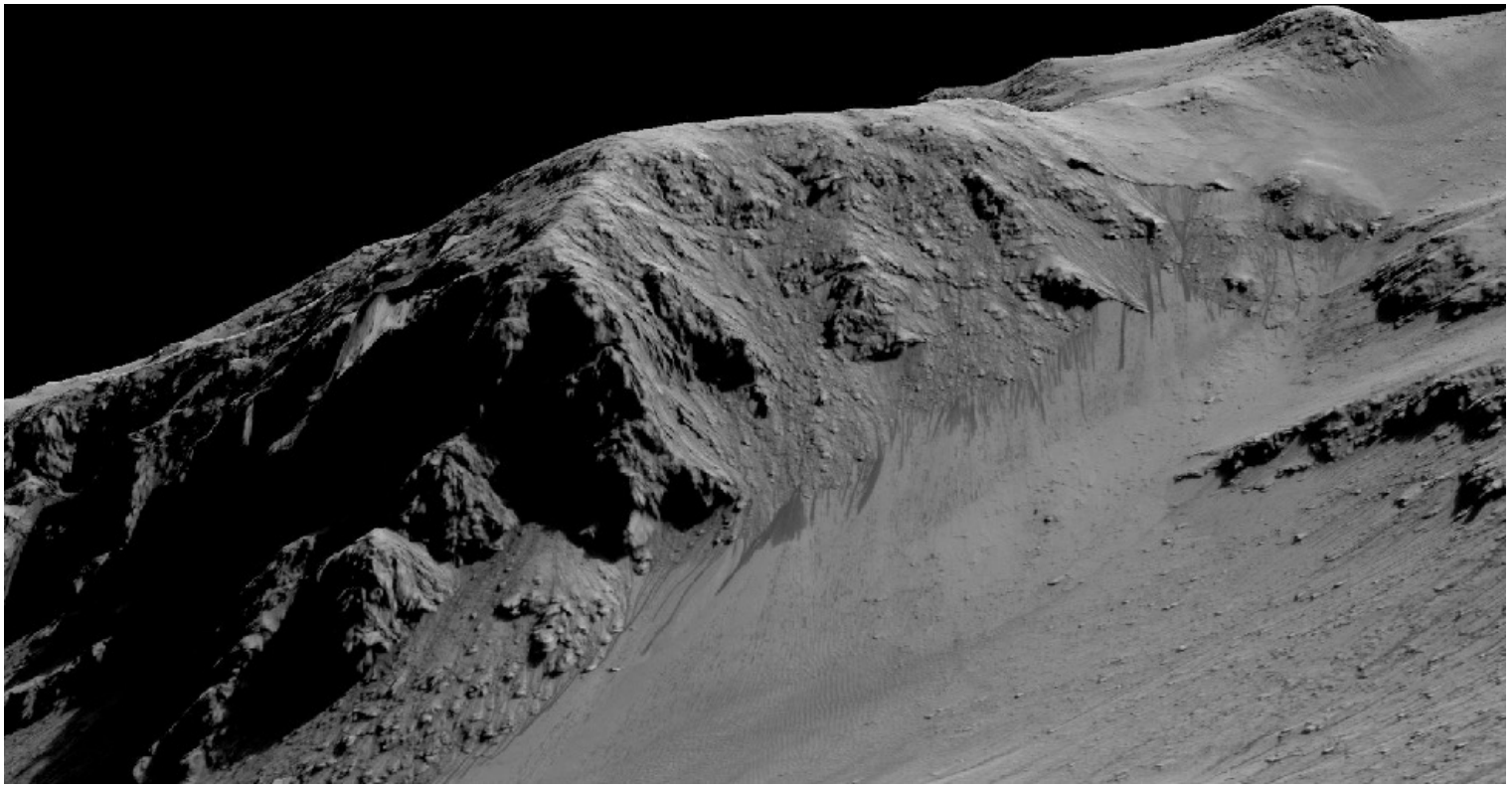
(b) This intriguing channel, called Nanedi Valles, resembles Earth riverbeds in some (but not all) ways. The tight curves and terraces seen in the channel certainly suggest the sustained flow of a fluid like water. The channel is about 2.5 kilometers across. (credit a: modification of work by Jim Secosky/NASA; credit b: modification of work by Jim Secosky/NASA)

FIGURE 10.28



Gullies on the Wall of Garni Crater. This high-resolution image is from the *Mars Reconnaissance Orbiter*. The dark streaks, which are each several hundred meters long, change in a seasonal pattern that suggests they are caused by the temporary flow of surface water. (credit: NASA/JPL-Caltech/University of Arizona)

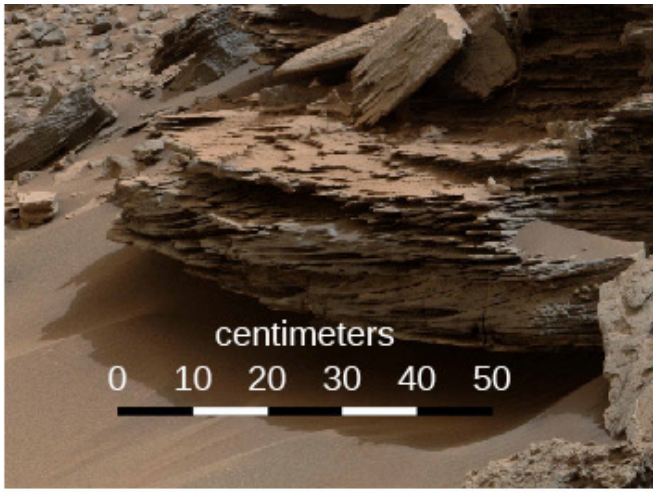
FIGURE 10.29



Evidence for Liquid Water on Mars. The dark streaks in Horowitz crater, which move downslope, have been called recurring slope lineae. The streaks in the center of the image go down the wall of the crater for about a distance of 100 meters. Spectra taken of this region indicate that these are locations where salty liquid water flows on or just below the surface of Mars. (The vertical dimension is exaggerated by a factor of 1.5 compared to horizontal dimensions.) (credit: NASA/JPL-Caltech/University of Arizona)

FIGURE 10.30

(a)



(b)

Gale Crater.

(a) This scene, photographed by the *Curiosity* rover, shows an ancient lakebed of cracked mudstones.

(b) Geologists working with the *Curiosity* rover interpret this image of cross-bedded sandstone in Gale crater as evidence of liquid water passing over a loose bed of sediment at the time this rock formed. (credit a: modification of work by NASA/JPL-Caltech/MSSS; credit b: modification of work by NASA/JPL-Caltech/MSSS)

CLIMATE CHANGE ON MARS

We conclude that most erosion features on Mars must date from one or more periods in the past when Mars had a thicker atmosphere and a stronger greenhouse effect, so the greater air pressure and warmer temperatures could have allowed liquid water to flow.

The timing and extent of these warm and wet periods remain subject to considerable scientific debate, but there's little doubt that Mars eventually underwent a major and permanent climate change, turning a world that was once wet and warm into a frozen wasteland.

THE PROBLEM

If Martian volcanoes out-gassed carbon dioxide and water in the same proportions as volcanoes on Earth, Mars would have had enough water to fill oceans tens or even hundreds of meters deep.

The big question, then, is what happened to all that atmospheric gas?

A CHANGE IN MARS'S MAGNETIC FIELD

Early in its history, Mars had enough internal heat to have molten convecting metals in its core, much like Earth today.

These convecting metals should have produced a magnetic field that protected the Martian atmosphere from the solar wind. Mars could therefore have had a much thicker atmosphere while this protection held.

However, because Mars is much smaller than Earth, its interior cooled until core convection ceased, which greatly weakened the magnetic field.

The solar wind was then able to strip carbon dioxide gas from the top of the Martian atmosphere and into space, drastically weakening the greenhouse effect and turning the surface of Mars into a frozen wasteland.

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WHY MARS IS RED?

Mars may also have lost a great deal of its original water to space.

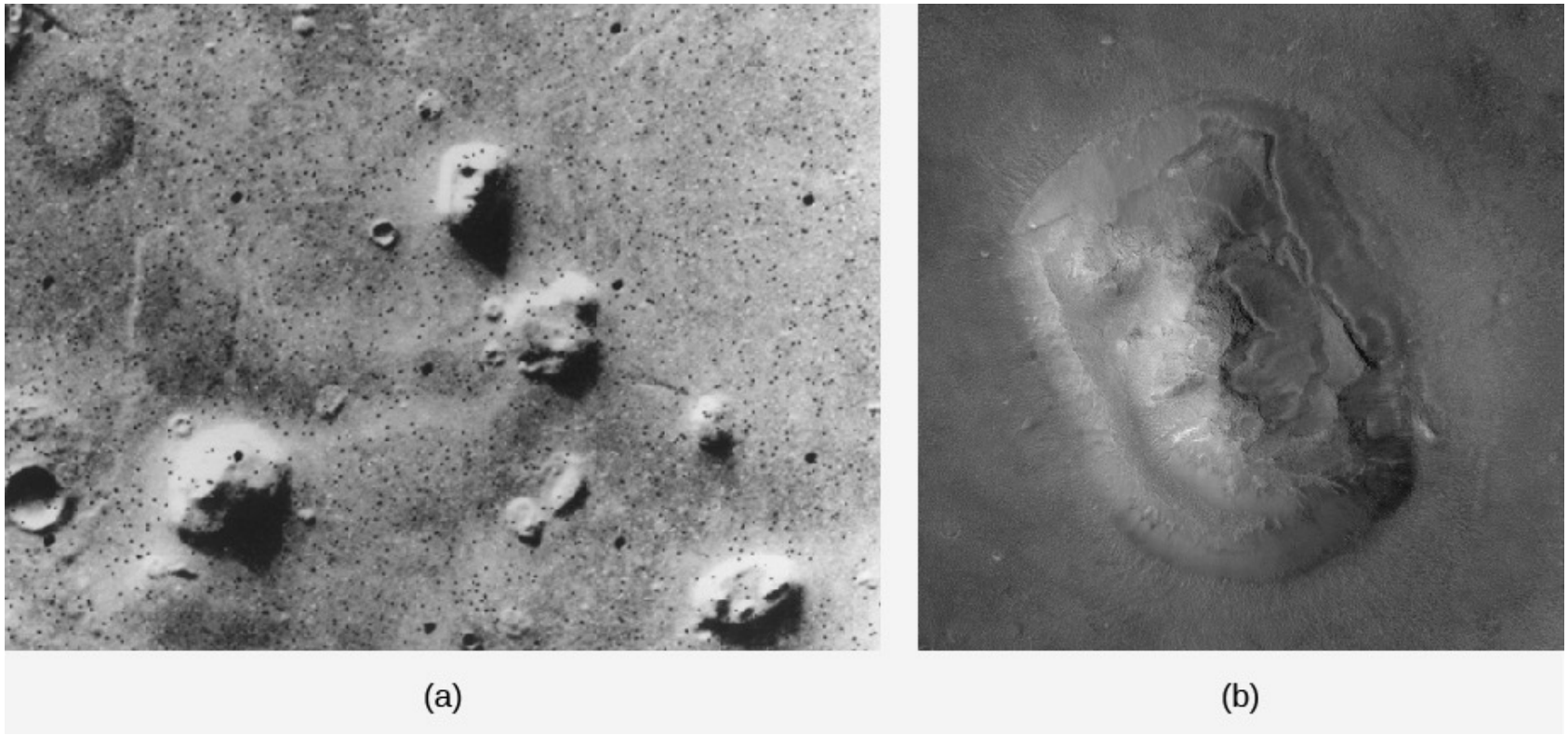
Because Mars lacks ultraviolet-absorbing gases, ultraviolet light from the Sun can break apart atmospheric water molecules.

Hydrogen atoms that broke away, being lightweight, would have rapidly escaped to space, leaving oxygen from the water molecules in the atmosphere.

Eventually, this oxygen either was stripped away by the solar wind or was drawn out of the atmosphere by chemical reactions with surface rock.

The oxygen absorbed by these rocks rusted the surface of Mars, giving the planet its distinctive red tint.

FIGURE 10.31



Face on Mars. The so-called “Face on Mars” is seen (a) in low resolution from Viking (the “face” is in the upper part of the picture) and (b) with 20 times better resolution from the *Mars Global Surveyor*. (credit a: modification of work NASA/JPL; credit b: modification of work by NASA/JPL/MSSS)