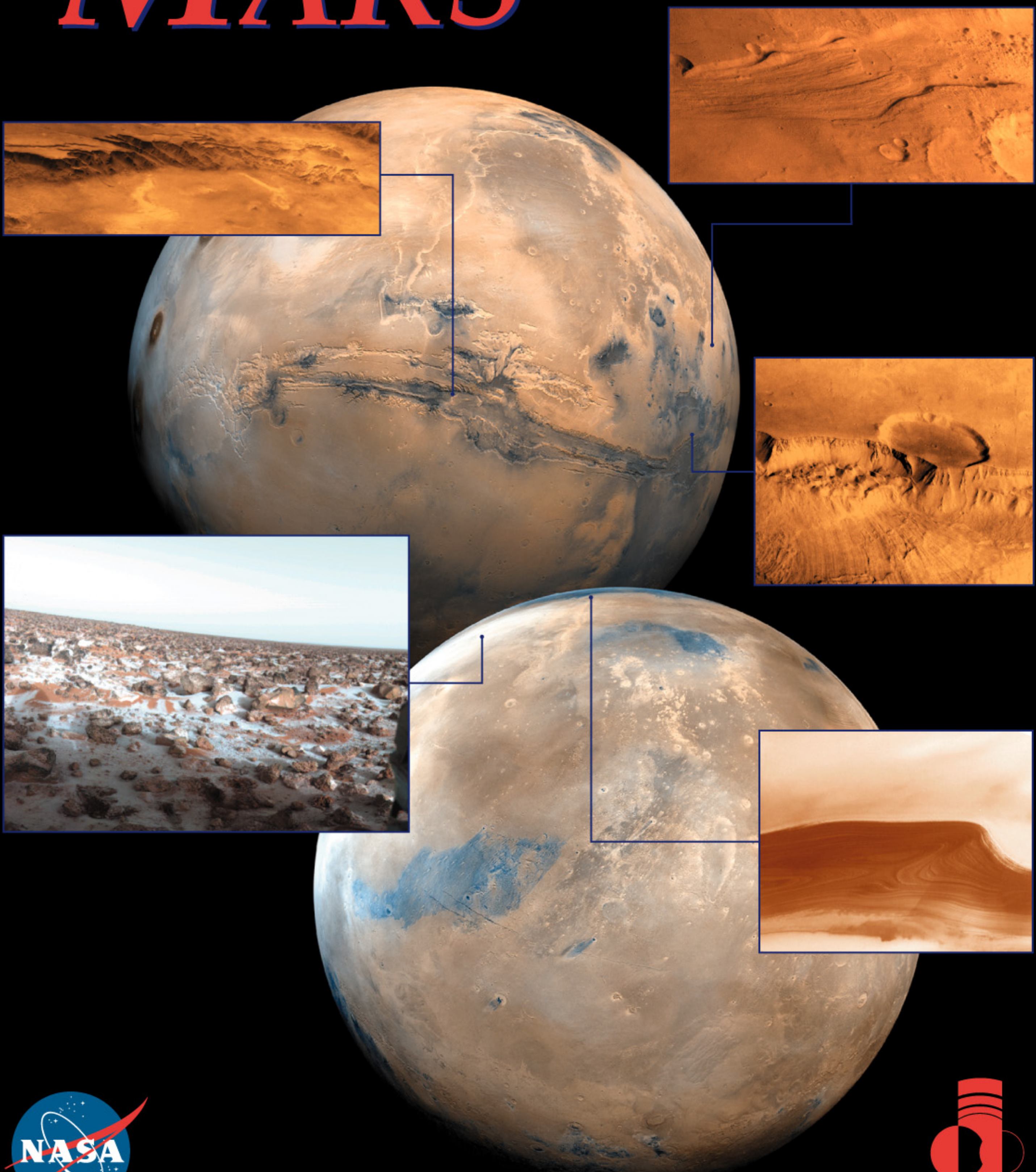
Postcards from...

MARS



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION / LUNAR AND PLANETARY INSTITUTE

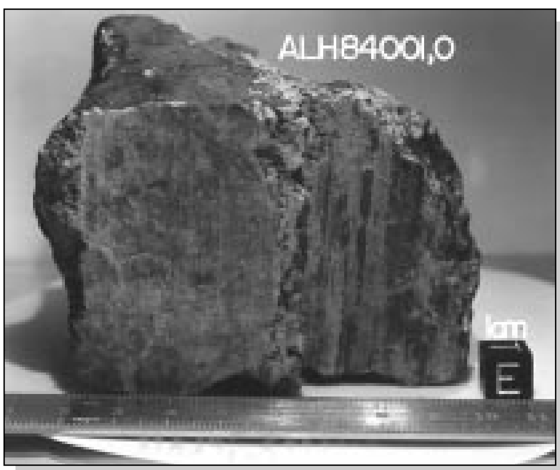
WHY MARS?

*O*f all the planets in our solar system, Mars is the most like Earth. With a thin atmosphere, weather, seasons, and a 25-hour day, Mars has a diverse and complex surface, including ice and winding channels made by flowing water in the distant past. Although the cold, dry conditions on Mars may not support life now, scientists believe that Mars was warmer, wetter, and had a much denser atmosphere early in its history. Life may have arisen in ancient martian lakes or springs. If so, fossil evidence of life might be found.

Mars has experienced a complicated geologic history. On its surface are vast expanses of sand dunes, gorges carved by running water, polar ice caps, huge volcanos, and gigantic canyons. The giant Olympus Mons volcano is three times as tall as Mt. Everest and larger than Montana; it's the largest volcano in the solar system. Valles Marineris is three times as deep and 10 times as long as the Grand Canyon.

Mars was not always the dry wasteland it is now—it was once graced by lakes and possibly even rivers and an ocean. Learning how and why Mars' climate changed will help us understand our Earth's climate and how it might change in the future.

With a land area equal to Earth's, Mars offers a wealth of natural resources. The essentials for life support, including air and water, can be found or manufactured on the martian surface. These resources will be essential for humans to live and work on Mars as we continue to explore the Red Planet.



Evidence for Ancient Life on Mars?

In August 1996, a team of researchers announced that they had found possible bacterial fossils in a meteorite from Mars. This meteorite formed on Mars about 4 billion years ago, and was blasted off Mars by an asteroid impact. After leaving Mars, the meteorite finally landed on Earth in the Antarctic, where it was found by a U.S. expedition. The possible martian fossils in the meteorite are shaped like Earth bacteria and were found with minerals and organic chemicals that occur with Earth bacteria. Many scientists are not convinced that the possible fossils really are fossils, and it will probably take a few years to find out whether the bacteria shapes really are relics of ancient life on Mars.

The picture above shows the martian meteorite ALH 84001, home to the possible martian bacteria fossils. The picture on the right is a scanning electron microscope image of the bacteria shapes inside that meteorite. These shapes might be fossils of ancient martian life, but might also have formed without any living things.

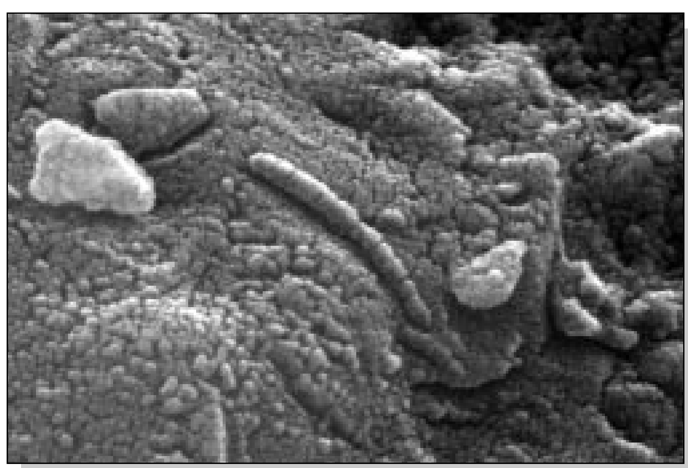


Image Descriptions

Background Image—

Mosaics of Mars were created by geologists from the U.S. Geological Survey, Flagstaff, Arizona from Viking 1 orbiter data gathered in 1980. Individual images are combined into a "point perspective" projection that gives a view of Mars as you might see it from a spacecraft window 2500 kilometers (1500 miles) above the surface. [Courtesy U.S. Geological Survey; images have been purposely reduced in density for this poster.]

Postcards...(top to bottom)—

Flood Channel

—Although Mars is very dry, it probably has lots of water inside, both as liquid groundwater and as ice in frozen ground. The underground water escapes sometimes in giant floods, and carves channels like this one, called Ravi Vallis. The water erupted from the hilly area to the right (west) and surged eastward, cutting a deep channel with streamlined mounds on its floor. This scene is about 75 kilometers across. (Viking Orbiter image 014A69, view looking south, colorized.)

Valles Marineris Wall

—The Valles Marineris canyons are longer and deeper than any on Earth. The whole Valles system stretches 5000 kilometers across Mars (as far as from New York to Los Angeles) and this view of the Valles wall is about 550 kilometers long (from New York to Washington D.C.). The Valles here is eight kilometers deep, from the plateau at the upper left to the canyon floor at the bottom. The Grand Canyon is only about one and a half kilometers deep. If the Earth's tallest mountain, Mt. Everest, were put on the Valles bottom here, its peak would just rise above the plateau elevation. If the tallest mountain in North America (Mt. McKinley) were put at the canyon bottom, its summit would only be two-thirds of the way up to the canyon rim. (Viking Orbiter image 057A27, view looking north, colorized.)

Landslide in Valles Marineris

—Although the huge canyons of the Valles Marineris originated as tectonic structures (the crust pulled apart), they have been modified by other processes, like the landslide on the south wall of Valles Marineris shown here. This landslide partially removed the rim of the crater that is on the plateau adjacent to Valles Marineris. Notice the texture of the landslide deposit where it flowed across the floor of Valles Marineris. Several distinct layers can be seen in the walls of the trough. These layers may be regions of distinct chemical composition or mechanical properties in the martian crust. The image is 60 kilometers across. (Viking Orbiter image 14A30, view looking south, colorized.)

Frost at the Viking 2 Lander (48°N,226°W)

—Viking Lander 2 is far enough north that frost deposits may form on the surface during winter. This image, taken in May 1979, shows a thin, white layer of water frost, estimated to be only micrometers (1 micrometer = 0.001 millimeters) thick, covering parts of the surface. The reddish regions are soil and rock not covered by the frost. Portions of the spacecraft are visible in the right foreground. (Viking Lander image 21I093.)

Polar Ice Cap

—Like the Earth, Mars has ice caps at its north and south poles. This wind-carved canyon shows layers of clean white ice and brownish dusty ice, like tree rings, beneath the surface of Mars' north ice cap. The layers preserve a history of the ice cap. The brownish layers probably formed when Mars was a bit warmer than now, and dust from huge storms mixed into the ice. This scene is about 55 kilometers across. (Viking Orbiter image 077B24, view looking north, colorized.)

MARS FACTOIDS

Fourth Planet From the Sun

Distance From the Sun:
Minimum: 206,000,000 kilometers
Average: 228,000,000 kilometers (1.52 times as far as Earth)
Maximum: 249,000,000 kilometers

Eccentricity of Orbit:
0.093 vs. 0.017 for Earth (0.00 is a perfectly circular orbit)

Distance From Earth:
Minimum: 56,000,000 kilometers
Maximum: 399,000,000 kilometers

Year:
1.88 Earth years = 669.3 Mars days (sols) = 686.7 Earth days

Day:
24.6 Earth hours

Tilt of Rotation Axis:
25.2° vs. 23.5° for Earth

Size:
Diameter = 6794 kilometers vs. 12,756 kilometers for Earth
Surface Gravity: 0.38 (or ~1/3) Earth's gravity
Mass: 6.4 x 10^{26} grams vs. 59.8 x 10^{26} grams for Earth
Density: 3.9 grams/cc vs. 5.5 grams/cc for Earth

Surface Temperature:
Cold
Global extremes: –125°C (–190°F) to 25°C (75°F)
Average at Viking 1 site: high –10°C (15°F); low –90°C (–135°F)

Atmosphere:
Thin, unbreathable
Surface pressure: ~6 millibars, or about 1/200th of Earth's
Contains 95% carbon dioxide, 3% nitrogen, 1.5% argon, ~0.03% water (varies with season), no oxygen. (Earth has 78% nitrogen, 21% oxygen, 1% argon, 0.03% carbon dioxide.)
Dusty, which makes the sky pinkish. Planet-wide dust storms black out the sky.

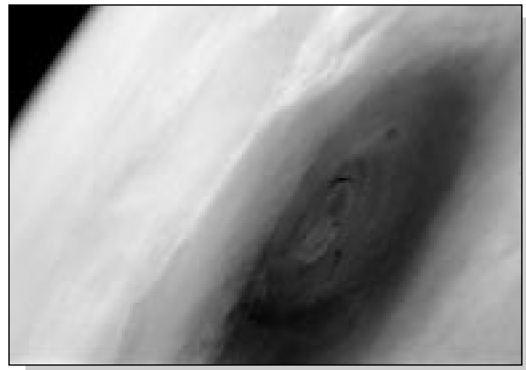
Surface:
Color: Rust red
Ancient landscapes dominated by impact craters
Largest volcano in the solar system (Olympus Mons)
Largest canyon in the solar system (Valles Marineris)
Ancient river channels
Some rocks are basalt (dark lava rocks); most others unknown
Dust is reddish, rusty, like soil formed from volcanic rock

Moons:
Phobos ("Fear"), 21 kilometers diameter
Deimos ("Panic"), 12 kilometers diameter

Mars Mysteries

*E*ven though we have begun to explore Mars with robotic spacecraft, the Red Planet still remains mysterious. There are plenty of questions for humans and machines to unravel in the coming years. Here is a sampling of some of the puzzles of Mars.

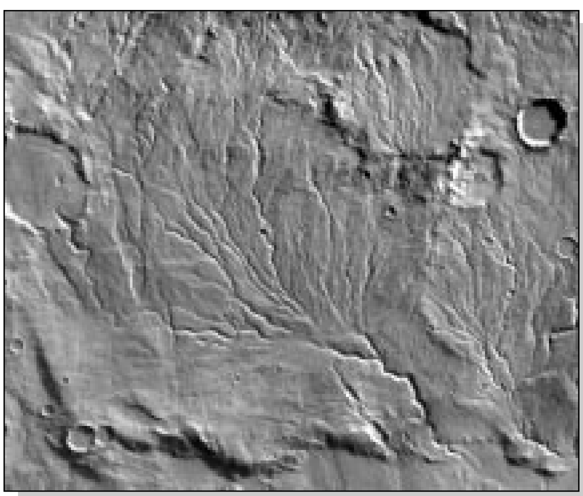
Why Are Some Features So BIG?



The volcano Olympus Mons (27 kilometers tall and 600 kilometers across, pictured) is the largest in the solar system, and other giant volcanos in the Tharsis region actually form an unusual bulge on the small planet. Valles Marineris, the enormous canyon system, would stretch across the continental United States. Scientists believe that the way heat escapes from Mars as it cools causes a different style of tectonic activity than we see on our own planet. On Earth, crustal plates spread apart and collide, continually reshaping the surface and sliding over hotspots welling up from the planet's interior. But Mars seems to be a "one-plate planet" with very little horizontal movement at the surface (with the exception of the giant canyon, of course!). How this style of tectonics works and how it produces the colossal features of the martian landscape are still unsolved mysteries.

Where Did All the Water Go?

The martian landscape shows unmistakable signs of water flowing on its surface—from branching networks of river channels (pictured) to streamlined islands to great gouges caused by sudden catastrophic floods.



Water ice is present in the polar caps of the planet today, and the Viking 2 lander photographed water frost covering the ground in the predawn light at its landing site. Some scientists believe Mars may once have had enough water to make an ocean kilometers deep! Today, the martian surface is a desert; the atmosphere is too thin and the temperature too cold to allow liquid water to exist. What happened to the once-abundant water, and why? Some must certainly have escaped to space as the small planet cooled and the climate changed. But water might still exist in underground pools of groundwater or be locked into the pores of subsurface rock as permafrost. Finding out how much water exists and where it is will be an important goal of future explorations. The answer may determine whether humans will ever live and work on Mars.

What Happened to the Atmosphere?

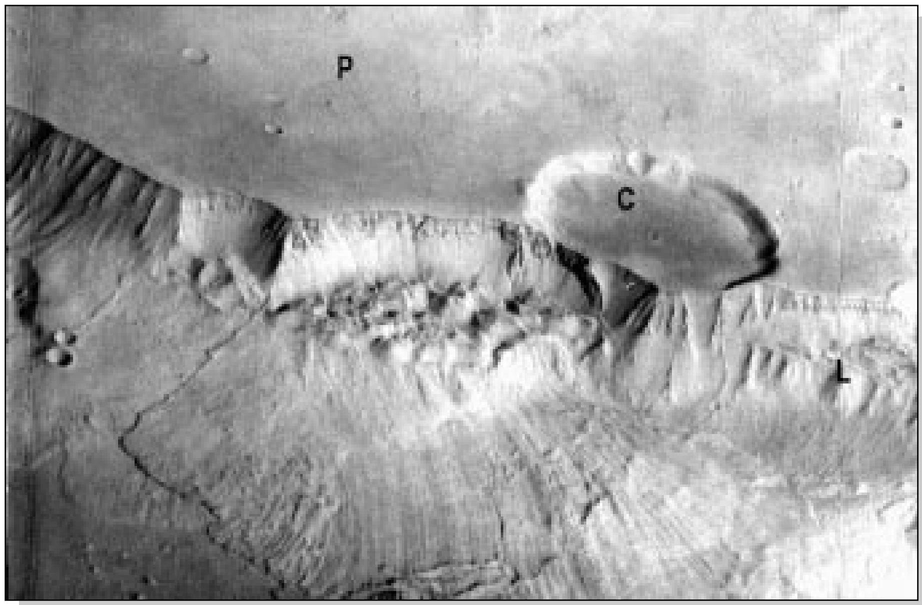
The evidence that liquid water was once abundant on the surface also means that Mars once had a much denser, warmer atmosphere. But atmospheric pressure now is less than one percent of Earth's, and the temperature is too cold for liquid water to exist. Water frosts and ice simply evaporate into the atmosphere, and form again when the seasonal temperature drops. What caused Mars to lose its once thicker, warmer atmosphere? Because Mars is small with a surface gravity only about one-third of Earth's, some of that atmosphere must have been lost to space. But scientists still seek to understand exactly how and why Mars' climate has changed so drastically over time and how rapid those changes were. The answers to these questions will tell us whether it is likely that some sort of life had time to develop under hospitable conditions.

Activity 1: "Old, Relatively"

For exploring Mars, it is important to know which events happened in which order and which areas are older than others. A simple way of figuring out the sequence of events is "superposition"—most of the time, younger things are on top of older things, and younger (more recent) events affect older things.

Superposition in Your Life

Is there a pile of stuff on your desk? On your teacher's? On a table or floor at home? Where in the pile is the thing you used most recently? The next thing used most recently? Where in the pile would you look for something you put down 10 minutes ago? When was the last time you or your teacher or parent used the things at the bottom of the pile?



Superposition on Mars

Using superposition, we can sort out many of the complicated events in the history of Mars. For example, you can sort out all the events that affected the area in the image above (also on the front of this poster). It is a small part (60 kilometers across) of the wall of the great canyon system of Valles Marineris. Toward the top is a high plateau (labeled "P"), with a large circular impact crater ("C"). It formed when a huge meteorite hit Mars' surface. Below the plateau is the wall of Valles Marineris. Here, the wall has been cut away by huge landslides ("L"), which leave bumpy rough land at the base of the wall and a thin, broad fan of dirt spreading out onto the canyon floor. In the canyon wall, almost at its top, alternating layers of light and dark rock are exposed.

To discover the history of this region, start by listing all the landscape features you can see, and the events that caused them (don't bother listing every small crater by itself). Now list the events in order from oldest to youngest. [Hints: How many separate landslides are there? Is the large crater ("C") younger than the landslides? Are the landslides younger than the rock layers at the top of the canyon wall? Are the small craters older or younger than the landslides?] Sometimes, you cannot tell which of two events was younger. What additional information would help you tell?

To learn more about this image, visit the World Wide Web site at:
http://cass.jsc.nasa.gov/education/K12/gangis/mars1.html

ACTIVITY 2: "GEOGRAPHY AND MISSION PLANNING"

Latitude	Longitude	
22°N	48°W	(Viking Site)
20°N	108°E	
44°N	10°W	
7°S	43°W	
46°N	150°W	(Viking Site)
44°N	110°W	
5°S	5°W	

These locations on Mars were considered by mission planners as possible landing sites for the two Viking landing craft.

If martians sent spacecraft to these same latitudes and longitudes on Earth, what would they find? Would they find life or evidence of an advanced civilization? Use a globe or world map to identify these spots on Earth. Use geography reference books to describe what the martians would see at each site.

If you were a martian, why would you explore Earth? Does Earth have resources you might need? What would you want to know about the Earth? Where would you land first and why?
—(From B.M. French, The Viking Discoveries, NASA EP-146, October 1977)

For Reference: Mars Map

U.S. Geological Survey (1991) Topographic Maps of Polar, Western, and Eastern Regions of Mars, U.S. Geological Survey Miscellaneous Investigations Map I-2160. USGS Information Services, 1-800-USA-MAPS

WEBSITES

Mars

Ames Center for Mars Exploration	**http://cmex-www.arc.nasa.gov/**
Hubble Space Telescope Images of Mars	**http://www.stsci.edu/pubinfo/PR/95/17.html**
Lunar and Planetary Institute	**http://cass.jsc.nasa.gov/expmars/expmars.html**
Mars Multi-Scale Map	**http://www.c3.lanl.gov/~cjhamil/Browse/mars.html**
Mars Global Surveyor Project	**http://spacelink.nasa.gov/NASA.Projects/ S.Science/Solar.System/Mars.Global.Surveyor/**
Mars Pathfinder Project	**http://mpfwww.jpl.nasa.gov/**
Mars K–12 Curriculum Guide (Arizona State University)	**http://esther.la.asu.edu/asu_tes/TES_Editor/CURRIC_GUIDES/ curric_guideMENU.html**
Mars Surveyor Orbiter	**http://mars.jpl.nasa.gov/msp98/news/news4.html**
Mars Surveyor Lander	**http://mars.jpl.nasa.gov/msp98/lander/**
Viking Orbiter Image Archive	**http://barsoom.msss.com/http/vikingdb.html**
Viking Lander Image Data	**http://www-pdsimage.jpl.nasa.gov/PDS/public/vikingl/vl_images.html**

Tours of the Solar System

Views of the Solar System	**http://www.athena.ivv.nasa.gov/curric/space/planets/index.html**
The Nine Planets (Bill Arnett/SEDS)	**http://seds.lpl.arizona.edu/nineplanets/nineplanets/nineplanets.html**
Welcome to the Planets (JPL)	**http://pds.jpl.nasa.gov/planets/**

Education

NASA On-line Resources for Educators	**http://www.hq.nasa.gov/education**
Lunar and Planetary Institute	**http://cass.jsc.nasa.gov/**

ACTIVITY 3: "THE SHADOW OF PHOBOS"
(MATHEMATICS AND CONCEPTS FOR UPPER GRADES)

1. How Fast Do Mars' Moons Move? The two moons of Mars, Phobos and Deimos, were discovered in 1877 by Asaph Hall. He measured how far they were from Mars, and so learned the size of their orbits. By watching the moons as they moved, he also measured how long each took to orbit Mars, (its orbital period). Because they are close to Mars, they move very fast.

How fast do Phobos, Deimos, and our own Moon move? To calculate their speeds, remember that:

speed = distance/time, and that the distance around a circle is 2π x radius.

Moon	Radius of Orbit (km)	Orbit Period (Earth days)	Orbit Period (seconds)
Phobos	9,380	0.32	2.75×10^4
Deimos	23,500	1.26	1.1×10^5
Moon	384,400	27.33	2.4×10^6

2. How Much Does Mars Weigh? Back in the 1600s, Isaac Newton proved that the speed of a moon was related to the mass of its planet and its distance from the planet:

$$M = \frac{r v^2}{G}$$

where M is the mass of the planet (kilograms), v is the moon's speed (kilometers/second), r is the radius of the moon's orbit (kilometers), and G (the universal gravitational constant) is $6.67 \times 10^{-20} kg^{-1}\ km^3\ s^{-2}$. So, with the data and speeds you calculated above, what is Mars' mass? How massive is Mars compared to the Earth?

3. Phobos in the Sky With Deimos. Both Mars and the Earth rotate so that the Sun rises in the east and sets in the west, and their moons all orbit in the same direction as the planets rotate. Earth's Moon has a very long orbital period compared to the length of an Earth day, so on a given day our Moon moves east to west across the sky with minor movement relative to the sun or stars. However, this is not the case for Mars' moons. By comparing their orbital periods with the length of a martian day (1.026 Earth days), determine how the martian moons will appear to move across the sky to an observer on the surface. [Hint: Sketch how the orbits of Mars and its moons look to an observer looking down at Mars from very far above Mars' north pole. From this view, Mars rotates counterclockwise, and its moons orbit counterclockwise.] In one Mars day, Mars rotates on its axis once. In that Mars day, how many times do Phobos and Deimos go around Mars?.

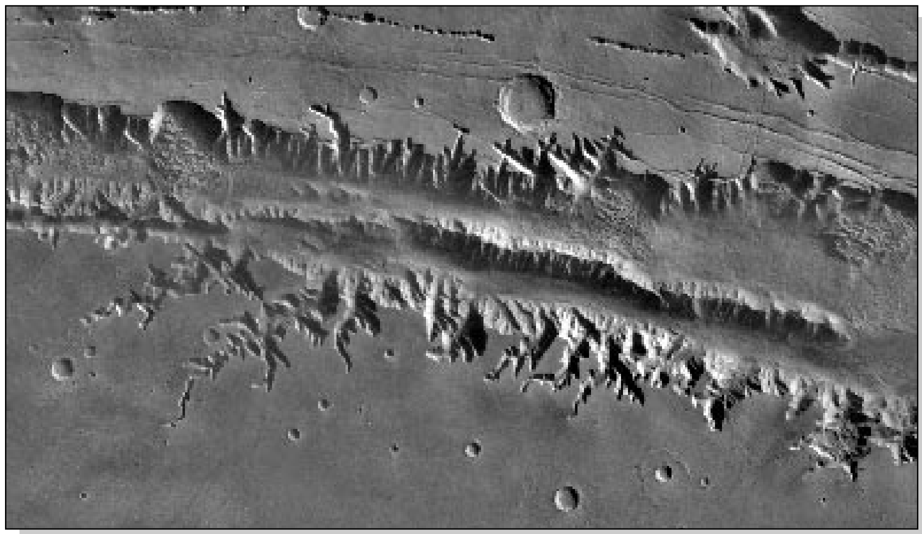
4. The Shadow of Phobos. You are standing on the equator of Mars at noon and Phobos, about 21 km in diameter, passes directly overhead. How long will you be in the shadow of Phobos? To figure this out, compare the velocity of Phobos in orbit to your velocity on the equator of Mars, 0.2405 km/s, and calculate the velocity of Phobos relative to you. The time you will be in shadow is simply the length of Phobos' shadow divided by its velocity relative to you.

ACTIVITY 4: "CANYONS AND VALLES MARINERIS"

The great canyon of Valles Marineris stretches 4000 kilometers across Mars. The image below shows part of Ius Chasma, the southwestern part of the Valles Marineris.

Working for Scale (Geography and Math)

The scene in this picture is 600 kilometers east-to-west (left to right) viewed from directly overhead. At this scale, how many centimeters (or inches) on the picture represent 100 kilometers on Mars? How many kilometers from top to bottom of the scene? How big is the largest circular impact crater you can see? How far is it across your home town?



Sketch the outline of your home state at this scale. Would it fit inside Ius Chasma? Which states would fit inside? Ius Chasma is about five kilometers deep. For comparison, how tall (in kilometers) is Mt. Everest, the tallest mountain on Earth? How tall is Mt. McKinley (Denali), the tallest in North America?

Find a map of Arizona or the western U.S. that shows the Grand Canyon. Trace the path of the Colorado River as it flows through the Canyon. Now redraw your tracing at the same scale as this picture of Ius Chasma. Which canyons in Ius Chasma are comparable in size to the Grand Canyon? How wide is the Grand Canyon, and how wide are the canyons on the south side of Ius Chasma?

(Advanced) Imagine you are standing on the floor of Ius Chasma at its south wall at the very eastern edge of the picture. How tall does the north wall of the Chasma appear to be? As tall as a telephone pole seen from a block away? Did you consider that Mars is a spherical planet (more or less) and its surface is curved?

Straight and Crooked Paths

Ius Chasma is basically straight because its edges follow huge geologic faults. On a map of your home state, trace out the channels of rivers and streams; are any straight like Ius Chasma? From a map of Arizona, examine the main channels and canyons in the Grand Canyon. Is the Grand Canyon as crooked as the canyons on the south wall of the Chasma? Find the East African Rift on a topographic map of Africa. The Rift's walls are huge geologic faults—are any parts of the rift as long and straight as Ius Chasma?

More About Mars

Books

Beatty, J.K., and A. Chaikin, eds. (1990) *The New Solar System*, Third Edition, Sky Publishing Corp., Cambridge.

Carr, M.H. (1981) *The Surface of Mars*, Yale University Press, New Haven. A highly readable account of our knowledge of Mars at the end of the Viking program.

Christiansen, E.H., and W.K. Hamblin (1995) *Exploring the Planets*, Second Edition, Prentice Hall, Englewood Cliffs, New Jersey.

Cooper, H.S.F. (1980) *The Search for Life On Mars: Evolution of an Idea*, Holt, Rinehart, and Winston, New York.

Lowell, P. (1895) *Mars*, Houghton, Mifflin, Boston, New York. Percival Lowell's fascinating, passionate, and highly erroneous interpretations of his longtime observations of Mars. Especially interesting when read with Sheehan's *Planets* & *Perception*.

Murray, B. (1989) *Journey Into Space: The First Thirty Years of Space Exploration*, W.W. Norton, New York. Describes humankind's robotic exploration of Mars and the rest of the solar system, as witnessed by this former director of the Jet Propulsion Laboratory.

Sheehan, W. (1988) *Planets & Perception: Telescopic Views and Interpretations, 1609–1909,* University of Arizona Press, Tucson. An introduction to the physical, social, and psychological pitfalls of observing distant worlds, especially Mars. This makes an excellent companion to Lowell's *Mars*.

Sheehan, W. (1996) *The Planet Mars: A History of Observation and Discovery*, University of Arizona Press, Tucson. A popular history of discoveries and ideas about Mars, emphasizing the era of visual and telescopic observations.

Viking Lander Imaging Team (1978) *The Martian Landscape*, NASA SP 425. A compilation of photographs obtained by the Viking Landers.

Viking Orbiter Imaging Team (1980) *Viking Orbiter Views of Mars*, NASA SP 441. A compilation of photographs obtained by the Viking Orbiters.

Wilford, J.N. (1990) *Mars Beckons*, Alfred A. Knopf, New York.

Science Fiction

Since telescopes first revealed seasonal color changes on Mars, Earthlings have been fascinated with the possibility of life on the Red Planet. These classics (among hundreds of others) trace human notions of martian "society" through the 20th century and hold up a mirror to the concerns and crises of our own.

Bradbury, Ray (1950) *The Martian Chronicles*, various publishers.

Heinlein, Robert (1986) *Red Planet*, Del Ray Books, Ballantine.

Wells, H.G. (1898) *The War of the Worlds*, various editions, various publishers.

Information and imagery for this wall chart were developed, compiled, and designed by the Lunar and Planetary Institute under contract NASW-4574 with the National Aeronautics and Space Administration. Image processing, except where noted, by LPI's Computer Center for Planetary Data Analysis. LPI Contribution No. 910.

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