Markus Hotakainen

MARS

From Myth and Mystery to Recent Discoveries

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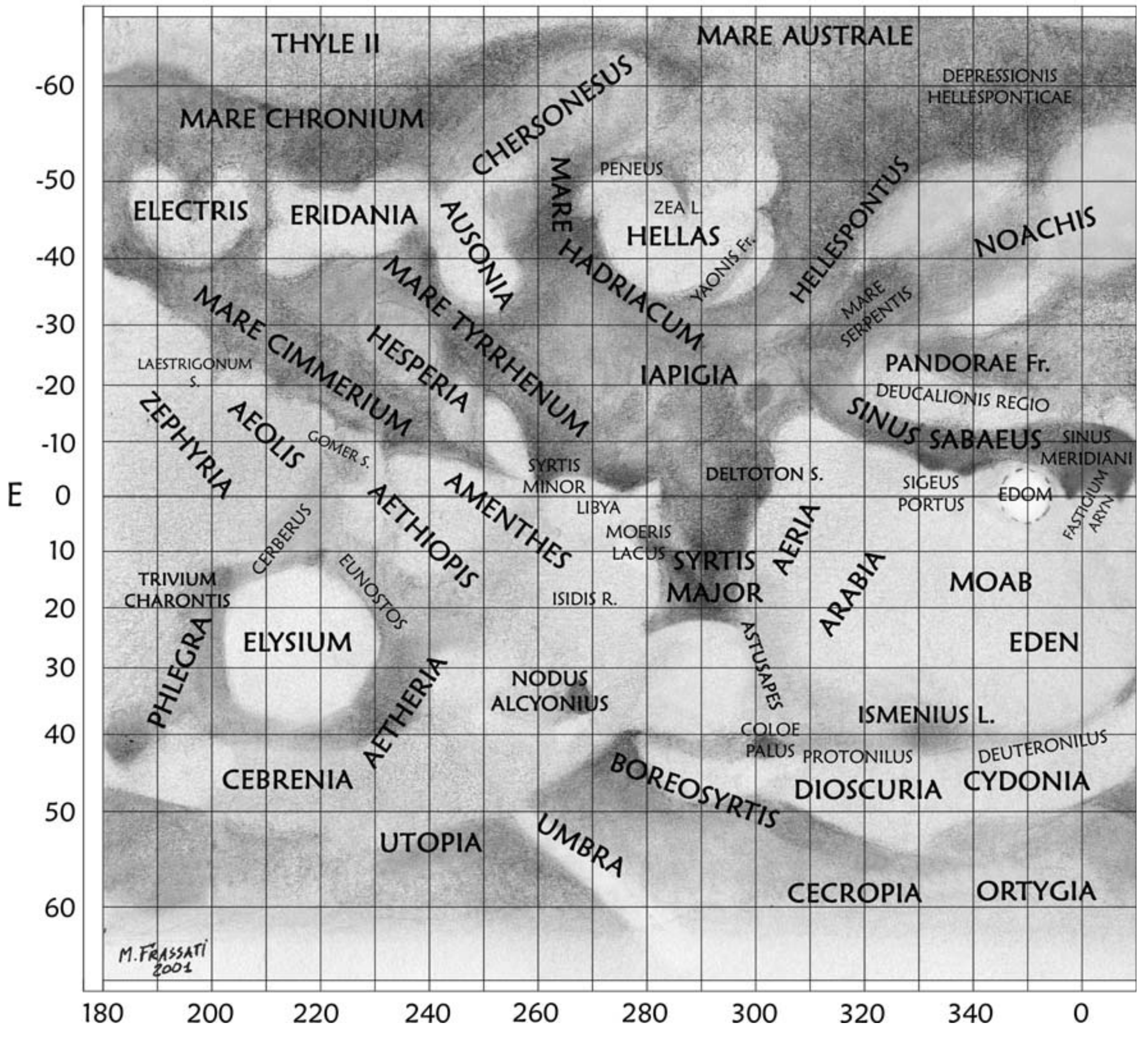

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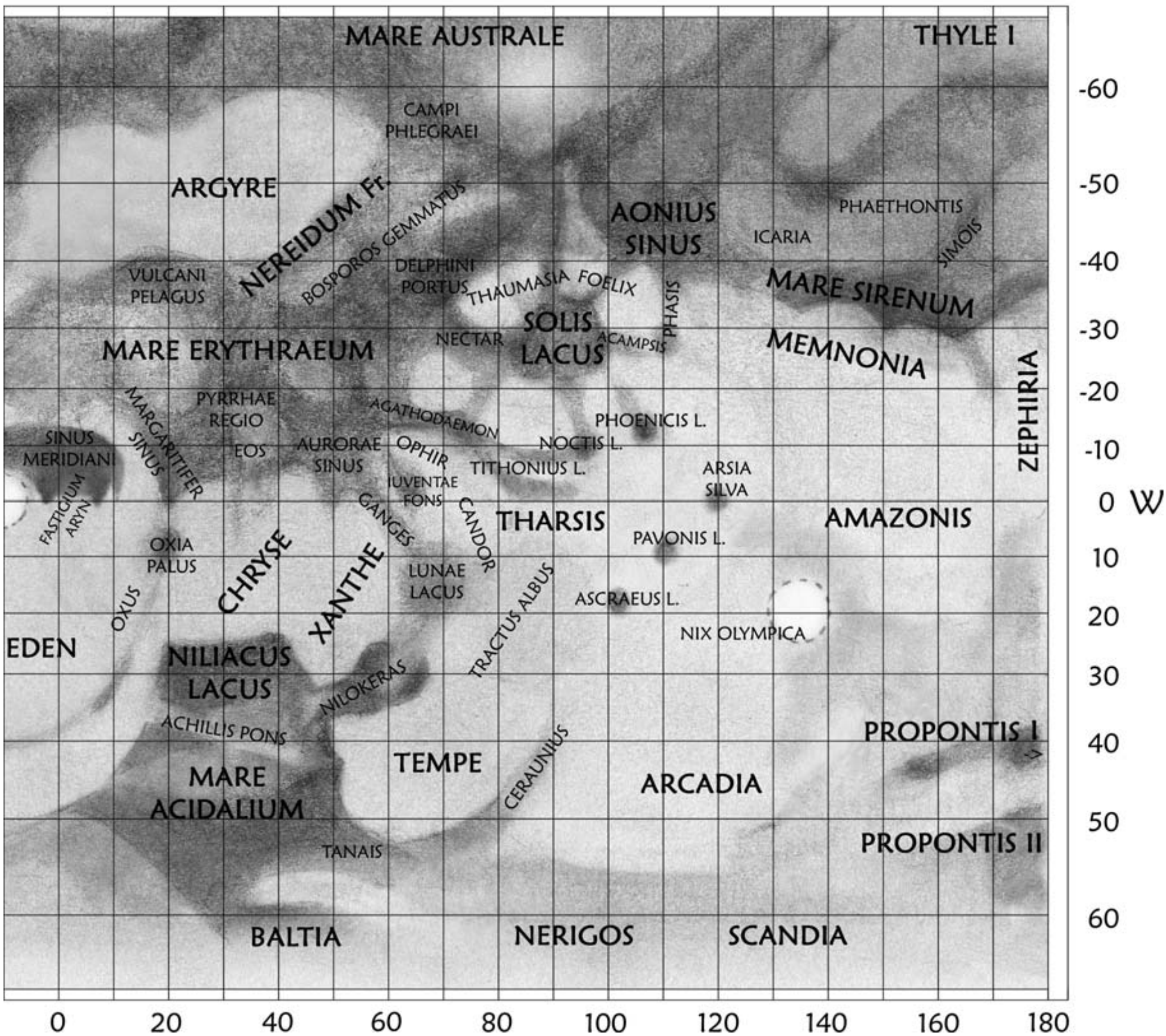

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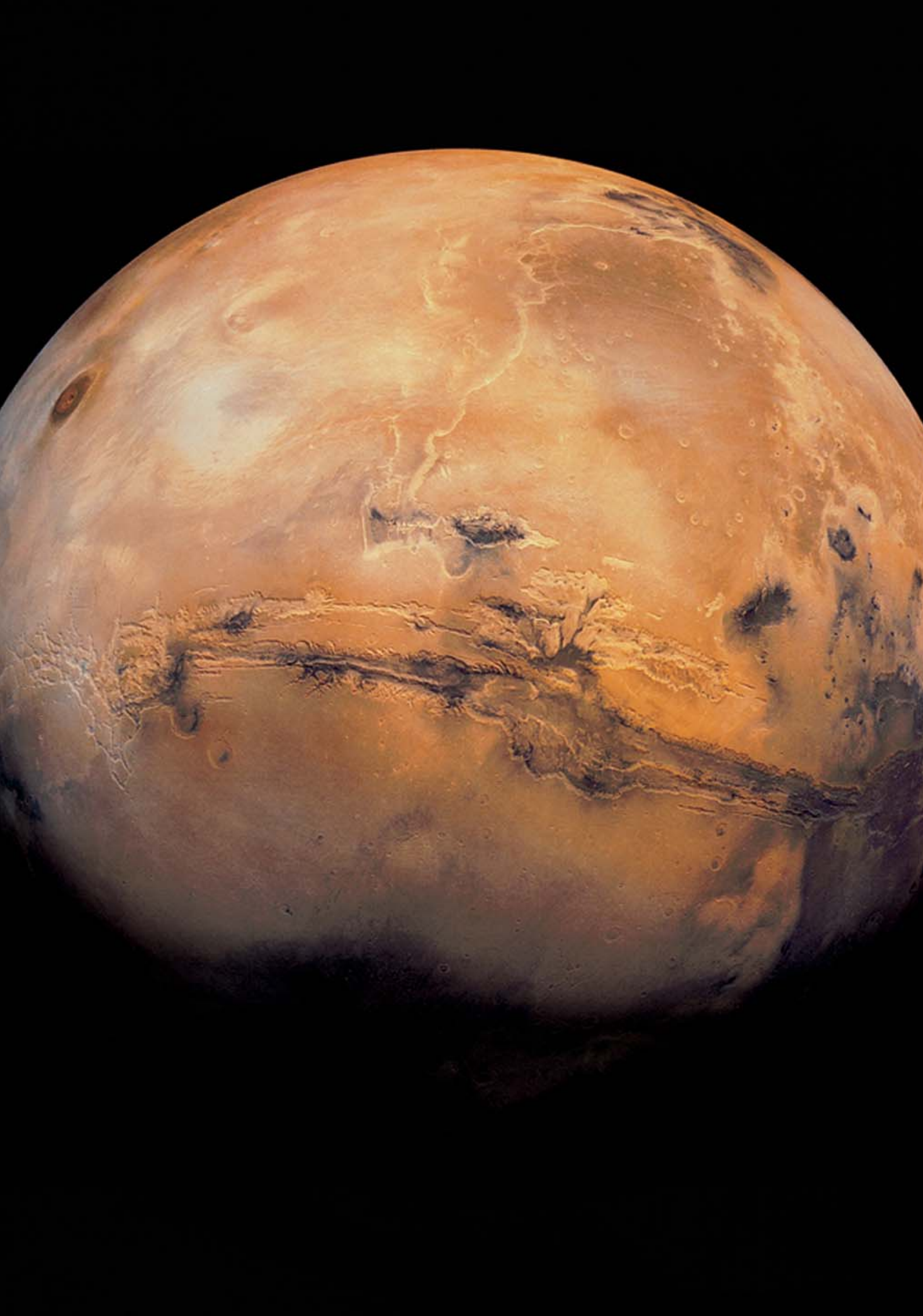

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Mars

FROM MYTH AND MYSTERY TO RECENT DISCOVERIES

Springer

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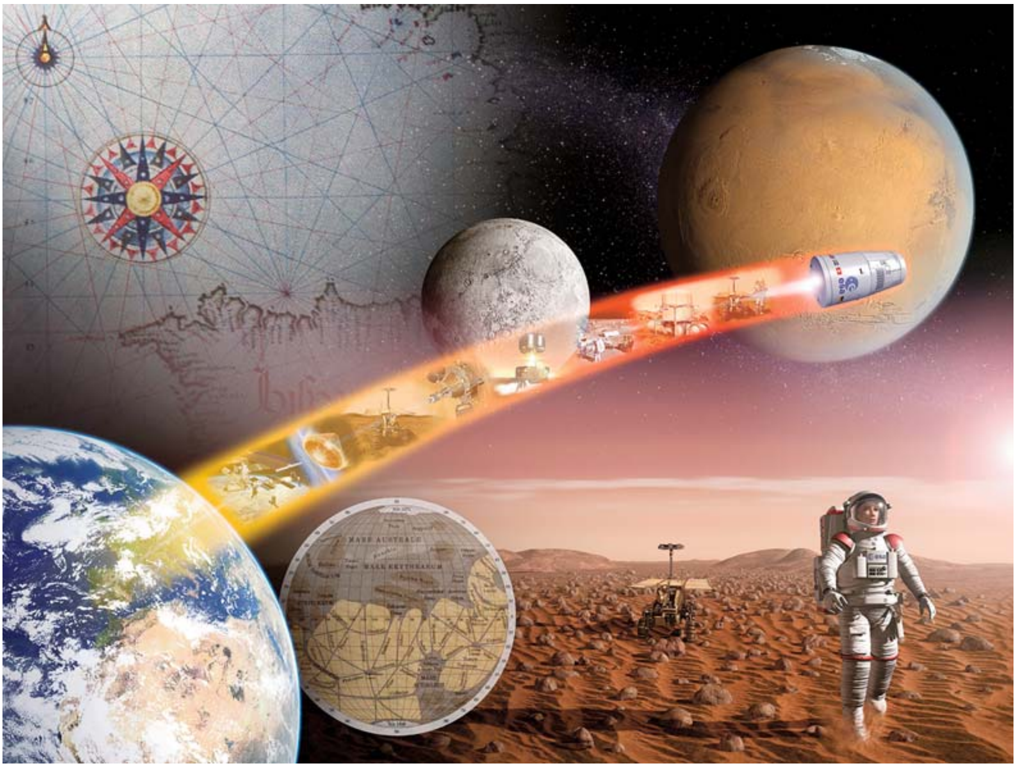

Preface

MARS ON OUR MINDS

No one would have believed in the last years of the nineteenth century that this world was being watched keenly and closely by intelligences greater than man's and yet as mortal as his own . . .

– Herbert George Wells: *War of the Worlds* (1898)

Yes, they would. And they did, actually very firmly. In the last years of the nineteenth century it was almost an established fact that there were intelligences greater than that of humans and that they were residing on our planetary neighbor, Mars. Ever since those days, people have been waiting for the attack of the little green creatures of the Red Planet with fear, even with fear verging on panic. For a long time "Martian" has been synonymous with "extraterrestrial being."

Knowledge about Mars has increased tremendously since the end of the nineteenth century. A mysterious world shrouded in myth was first mapped with the aid of telescopes and then later imaged by planetary probes. Thus, our celestial sibling has become ever more familiar to us and a more everyday part of our culture.

A substantial portion of science fiction is focused on Mars or on our own imaginary voyages to the Red Planet. In the world of movies Mars has symbolized the threat of communism, the fear of everything new and strange, and a future utopia for humanity.

Mars and our strong mental images connected with it have also been exploited in domains such as the comics, music, advertising, and the toy industry.

Even though our knowledge on Mars is constantly increasing, the number of misconceptions and illusions related to it has not diminished. Rather, the contrary is true. The deserted, maybe lifeless, planet photographed by space probes has been claimed to accommodate ruins of ancient civilizations, secret military bases, energy currents from parallel universes, and, according to some allegations, even Elvis, the king of rock 'n' roll – or at least his image in the form of a statue!

In one way or another Mars is part of everyone's consciousness. To most people the other planets of the Solar System are familiar only as names, possibly as points of light visible every now and then in the sky. But everybody considers Mars as a world. It is not just a celestial body; it is a place humans will one day end up going to and maybe living on. We all know about Mars, but do we know exactly what kind of planet it really is?

Foreword

Throughout the history of humankind the Planet Mars has attracted many people's attention, first as a reddish object in the sky with peculiar motion, later as a planet where life might exist in a similar form to Planet Earth. Today, thanks to the intensive research activities directed towards the planet, we are getting more and more acquainted with the real nature of our planetary neighbor in the Solar System.

In 2010 we will celebrate the 400th anniversary of the longest research program ever carried out by humans. Galileo Galilei was the first astronomer to use telescopes for planetary observations. In 1610 he wrote: "I'm not sure I can see the phases of Mars, however, if I'm not mistaken, I believe I see it is not perfectly round." Actually, he had found the varying phases of Mars.

After this dramatic start more and more accurate observations of the rotation period of Mars were made, and gradually in the eighteenth century it was learned that Mars had a tenuous atmosphere, clouds, and seasons that deformed the polar ice caps. The first map of Mars was published in 1840. In 1878 a very detailed map was published by the Italian astronomer G.V. Schiaparelli, who also gave names to several large areas observed on the Martian surface. He started to use word "canali" for the long, straight features on the surface. This Italian word means "channels," but was mistranslated as "canals," which meant artificially produced landforms. This mistranslation had dramatic consequences until the modern times.

On August 27, 1911, the *New York Times* wrote: "Martians build two immense canals in two years. Vast engineering works accomplished in an incredibly short time by our planetary neighbor." These two sentences clearly demonstrate how incorrect the public image of an object can be if no proper scientific tools to find the truth are available. To proceed further and to rectify the pattern of research, the space age had to begin, which occurred in 1957.

Mariner 4 was launched from the United States in 1964 and put an end to the speculations of "vast engineering works." Only desert covered by craters of different sizes was found. Since 1960 over 40 space probes have been launched towards Mars. Russia has built 20, the United States 18, Japan and ESA each one. Although no evidence of life was found on the surface of Mars, the interest in studying the planet further has continued to grow.

Looking at the history of the study of Mars, it is not difficult to understand why Mars has attracted so many authors and artists. Obviously Schiaparelli gave the impetus for discussions about "little green men," and this was strengthened by the reports of the American astronomer Percival Lowell, who believed to the end of his life that an existing intelligent civilization cultivated Mars. Maybe this type of "popularization" was needed to keep the interest in Mars alive during those times.

Today, what interests us about Mars has been completely changed. While waiting for news of finding life on Mars, new discoveries are being announced almost monthly. Subsurface water-ice layers, methane emissions from the ground, possible recent volcanic activity, evidence of past water on the surface, magnetic anomalies found, and so on, are typical of the types of new discoveries made during the past few years. Also, the atmospheric conditions and weather patterns have stirred great interest since Earth's atmosphere seems to have developed in a similar way to how Mars might have developed in the past. Today, Mars seems to be a continuous source of new information about how all the planets in our Solar System developed.

More and more countries are joining the Mars research effort. European countries through ESA are the newcomers, but also China and India are expected to join in the coming decade. Today, many countries have developed their national strategies on how to study Mars. In this context Finland has to be mentioned, since it is one of the smallest nations having an active role in the field. Finland was leading the research and development work on small-size Martian landers for the Russian *Mars 96* mission. The main aim was to start a meteorological network on the Martian surface to create weather forecasts in the future. After the unsuccessful *Mars 96* attempt, weather instruments have been sent onboard NASA's *Mars Polar Lander* and ESA/UK's *Beagle 2* landers, both of which failed. The next attempt, together with the Canadians, is with NASA's *Phoenix* lander. Finland, together with Russia, has developed a completely new generation of landers, the *MetNets*, to be sent to Mars in 2009, according to the present plans.

Thus it is not strange that in Finland the interest in Martian research is high. Since the early 1990s several important books about Mars have been published, this book being the most recent one. The approach of this book is very wide ranging, from fantastic new observations and discoveries to why the public is so determined to know more about Mars, not only scientifically but also as a place of endless fascination. While waiting for humans to take the next great step, which seems to involve sending people to Mars, we can enjoy the excitement this book provides.

Risto Pellinen, Professor
Director of Science in Space Research
Finnish Meteorological Institute

01

FOURTH ROCK FROM THE SUN

I can tell you about Mars.

– Larry Niven: *The Meddler* (1968)

Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune. All it takes is one line to list the larger planets circling the Sun, eight words to name eight whole worlds. One of them is Mars, the Red Planet.

Mars is the fourth planet in the Solar System and at the same time the outermost of the planets known as terrestrial. It is the last outpost before the myriad boulders of the Asteroid Belt and the desolate space opening out beyond them, a realm where the distances between the planets are measured in hundreds and thousands of millions of kilometers instead of mere tens.

The planets circling the Sun divide into two very distinct classes. All of the four innermost terrestrial planets are relatively small. Earth, with a diameter of less than 13,000 km, is the largest of these. They all have a solid surface and a rather thin if not nonexistent atmosphere. The four outermost planets, the gas giants, are in accordance with their name – large. They lack any solid surface, and their atmospheres are dense and thousands of kilometers thick. For more than 75 years Pluto was considered to be the outermost planet, but nowadays it is considered a dwarf planet, or a plutoid, a member of a group of small, faraway objects that circle the Sun in the Kuiper Belt beyond the orbit of Neptune.

Mars as viewed by European Space Agency's Mars Express *probe in December 2003 from a distance of about 5.5 million km.*

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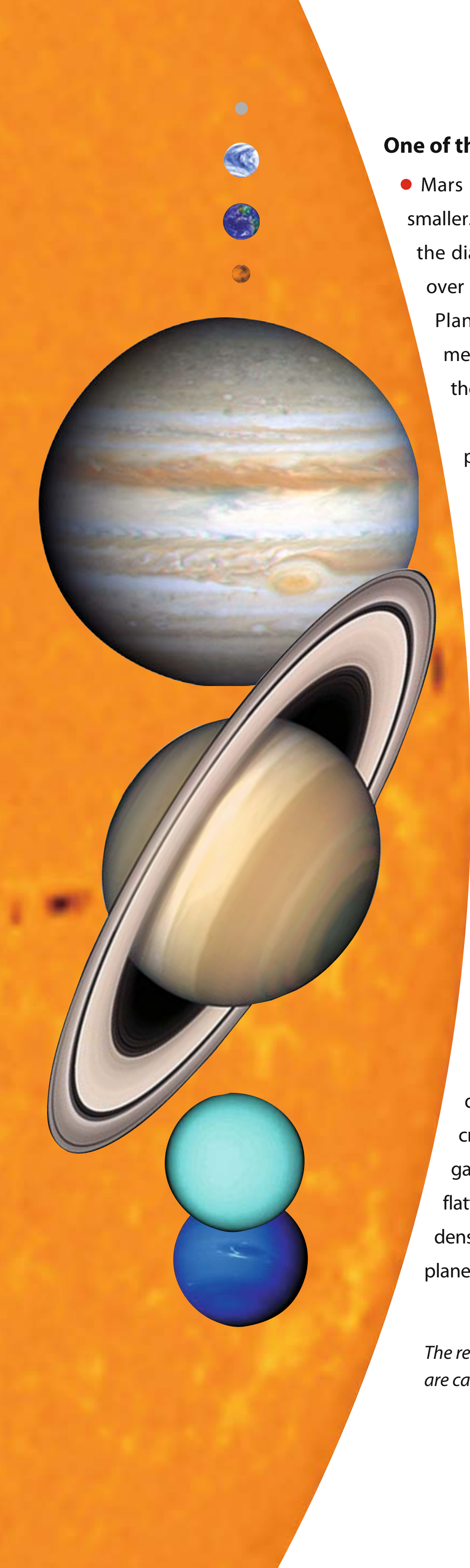


One of the lesser ones

Mars cannot boast of its size. Of all the planets only Mercury is smaller. The diameters of Earth and Venus are approximately double, the diameter of Jupiter about 20 times larger. In volume, Earth is over six times larger, and Jupiter could hold more than 9,000 Red Planets. However, compared to the Sun all the planets are mediocre midgets: it would take more than 8.5 million bodies the size of Planet Mars to fill up the volume of the Sun.

There is an obvious reason for the small size of the terrestrial planets. At the time the planets were forming, the temperature in the inner regions of the Solar System was so high that all the volatile gases, such as hydrogen and helium, maintained their gaseous state so that strong radiation pressure and the solar wind were able to blow them farther from the Sun. All that was left were small lumps of heavier elements and solid material, one of them being our future home planet.

The more distant gas giants are large because they were also able to accumulate light elements around their small, solid cores. But then again, several of the planets found around other stars – the total number of which is well over 200 – are more massive than Jupiter and still closer to their parent star. This simply means that all the details of the birth and evolution of the Solar System or any other planetary system are not yet fully solved.

Broadly speaking the history of our cosmic neighborhood is well known, though, which may be regarded as quite an achievement considering the fact that all we know is the outcome. Some 5 billion years ago an interstellar cloud of gas and dust began to collapse, perhaps due to a passing pressure wave created by the explosion of a nearby star. Before long the process gave birth to the Sun, which was surrounded by a disc of material flattened by swift rotation. Eventually the material in the disc condensed into planets, the orbits of which are more or less in the same plane because of their origins.

The relative sizes of the Sun and the planets. The four innermost planets are called terrestrial, while the four outermost are gas giant planets.

	Diameter	Distance from the Sun	Period
Sun	1,391,000 km	–	–
Mercury	4,880 km	57,910,000 km	87,97 d
Venus	12,104 km	108,210,000 km	224,70 d
Earth	12,756 km	149,600,000 km	365,24 d
Mars	6,792 km	227,940,000 km	686,93 d
Jupiter	142,984 km	778,300,000 km	11,86 a
Saturn	120,536 km	1,429,390,000 km	29,42 a
Uranus	51,118 km	2,875,040,000 km	83,75 a
Neptune	49,532 km	4,504,500,000 km	163,72 a

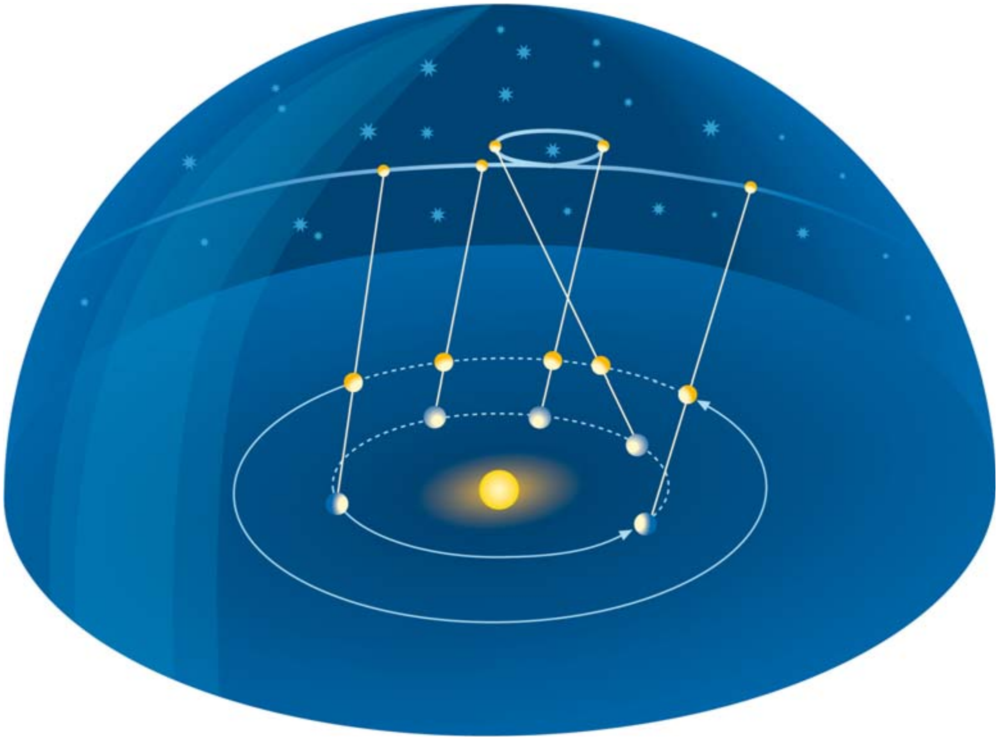
A circle or an ellipse?

● Usually the orbits of the planets are depicted as circles, but in fact they are not circular. The same goes for the orbit of Mars, which is clearly oval – elliptical to be precise. That is why the distance between Mars and the Sun varies by some 20%, or more than 40 million km, almost a third of the distance between Earth and the Sun.

In reality the elliptical orbits of the planets are very close to circles after all. If the orbit of Mars – which, after Mercury, is the most elliptical of all the planets – is drawn on a sheet of paper with a compass the shape of the circle deviates from a true ellipse by only about the width of the line made by the tip of the pencil. The "ellipticality" of the orbit is mainly manifested in its location relative to the Sun, which is not in the center of the orbit but at one of the two foci. Thus the distance of the planet from the Sun is different at different points along the orbit, and this especially affects the visibility of Mars as seen from Earth.

Oppositions of Mars

● A planet is said to be in opposition when it is opposite the Sun in the sky as viewed from Earth. It is the moment a planet is closest to Earth, and its brightness and apparent diameter have their maximum values. While in opposition a planet is also visible all night long; it rises from behind the eastern horizon at sunset, is highest in the southern sky at midnight, and sets in the western horizon only at sunrise.

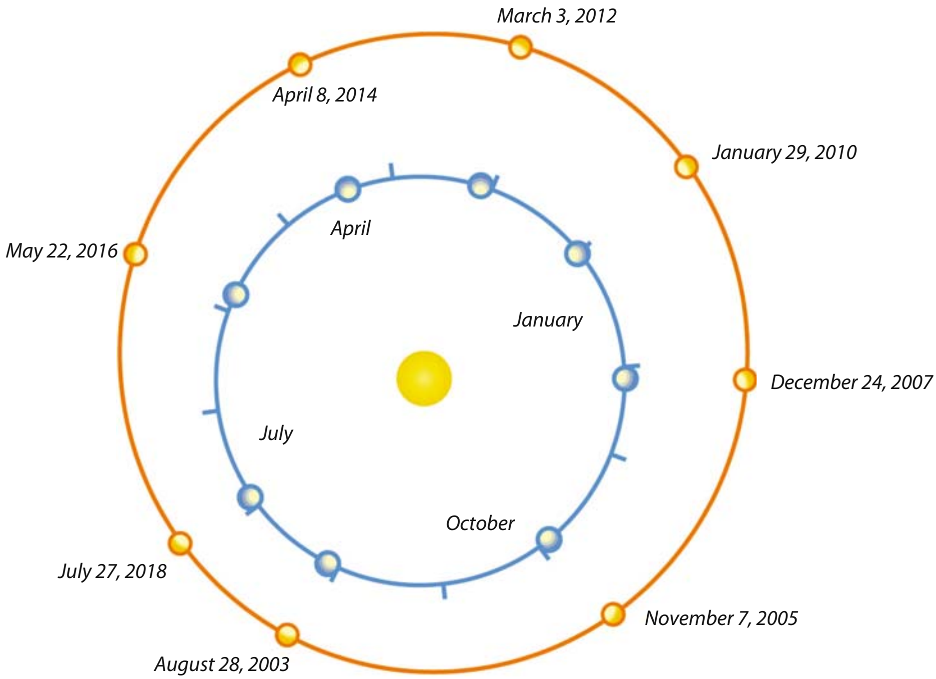


Around opposition the apparent eastward motion of the planet with respect to stars comes to a stop, changes direction, stops anew, and continues eastward once again. This opposition loop is most obvious in the motion of Mars since, being the nearest of the outer planets to Earth, its apparent movement is the fastest of them all.

The term "opposition loop" originates from the fact that Earth passes an outer planet on an inner "track." Around its opposition Mars seems to move for a couple of months backward, or from East to West in respect to stars.

The orbital period of Mars is approximately two Earth years, so after 1 year – one whole revolution of Earth around the Sun – following an opposition Mars has traveled almost half a revolution around the Sun, thus being behind it as seen from Earth. Earth catches up with Mars again only after another year. This is the reason the oppositions of Mars recur every 2 years and 2 months. The next oppositions will be in January 2010, March 2012, and April 2014.

In the case of Mars being at the same time in opposition and closest to the Sun, in perihelion, it is said to be in perihelic opposition. These oppositions occur every 15–17 years. In perihelic



The relative positions of Earth and Mars. The next perihelic opposition will be in July 2018.

opposition, Mars comes closest to Earth having greater brightness and bigger apparent diameter than during other oppositions. The difference is considerable; when Mars is in opposition while being farthest from the Sun in aphelion, its distance from Earth is nearly double, its apparent diameter is about half, and its brightness is approximately one third of the respective values during perihelic opposition.

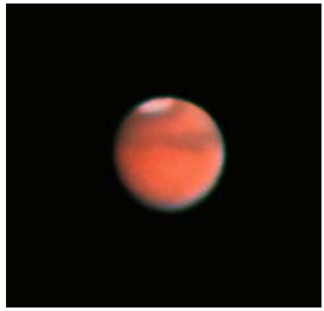
Perihelic oppositions of Mars are always in July or August, when the planet is at its lowest in the sky as viewed from the northern hemisphere. The conditions otherwise being the best possible, at these times Mars lurks on the southern horizon and is easily hidden behind buildings, trees, or other visual obstructions. Even in an open place the atmosphere of Earth constitutes a hindrance, since the light from the low-lying Mars travels a longer than average distance through the restless layers of air. The advantage brought about by its greater brightness and larger apparent diameter is more or less wrecked by bad seeing caused by the turbulent atmosphere.

Warning light on the move

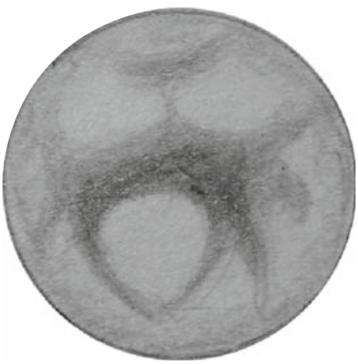
● On August 28, 2003, Mars came closer to Earth than in the past 60,000 years. The distance between Earth and Mars was "merely" 55,758,006 km. The apparent diameter of the planet was 24.7 seconds of arc and the brightness −2.8. In the autumn sky, Mars was brighter than any star or planet except for Venus. In August, Venus happened to be behind the Sun, and the new Moon was on August 27, so for a few days Mars was the brightest object in the night sky. Despite its meager altitude the planet was noticed not only by amateur astronomers but by many nocturnal wanderers.

The red point of light was so conspicuously bright that some people took it for the warning light of a newly erected relay station until they noticed it moving slowly. The opposition of 2003 was not cited as record-breaking for nothing. The last time Mars came closer to Earth was on September 12, 57617 B.C. – though Neanderthals and Cro-Magnons most probably did not have an accurate calendar – at a distance of 55,718,026 km. The next time Mars will be as close or even closer will be on August 27, 2287. At that time the distance will be 55,688,405 km.

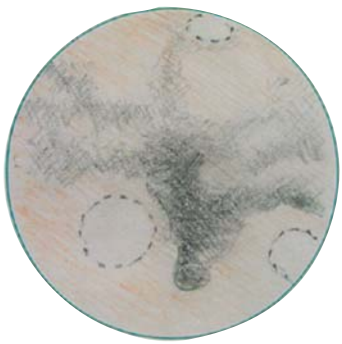
A composition of 22 digital images taken with a 25-cm reflector on August 2, 2003. Photograph by Kimmo Hytti.



The Ursa Astronomical Association has an archive of Mars observations made since the 1950s. Isto Kauhanen drew these sketches during the oppositions of 1956, 1988, and 1995.



September 10, 1956



September 17, 1988

February 28, 1995

Waiting for Godot

● After the sensational opposition of August 2003 things have gotten worse. The opposition of November 2005 was still quite decent, but the one in December 2007 was at best average. The distance between Mars and Earth was almost 90 million km, and the apparent diameter a mere 16 seconds of arc. Nevertheless, for a while it shone brighter than any star high in the winter sky in the constellation of Taurus, the Bull.

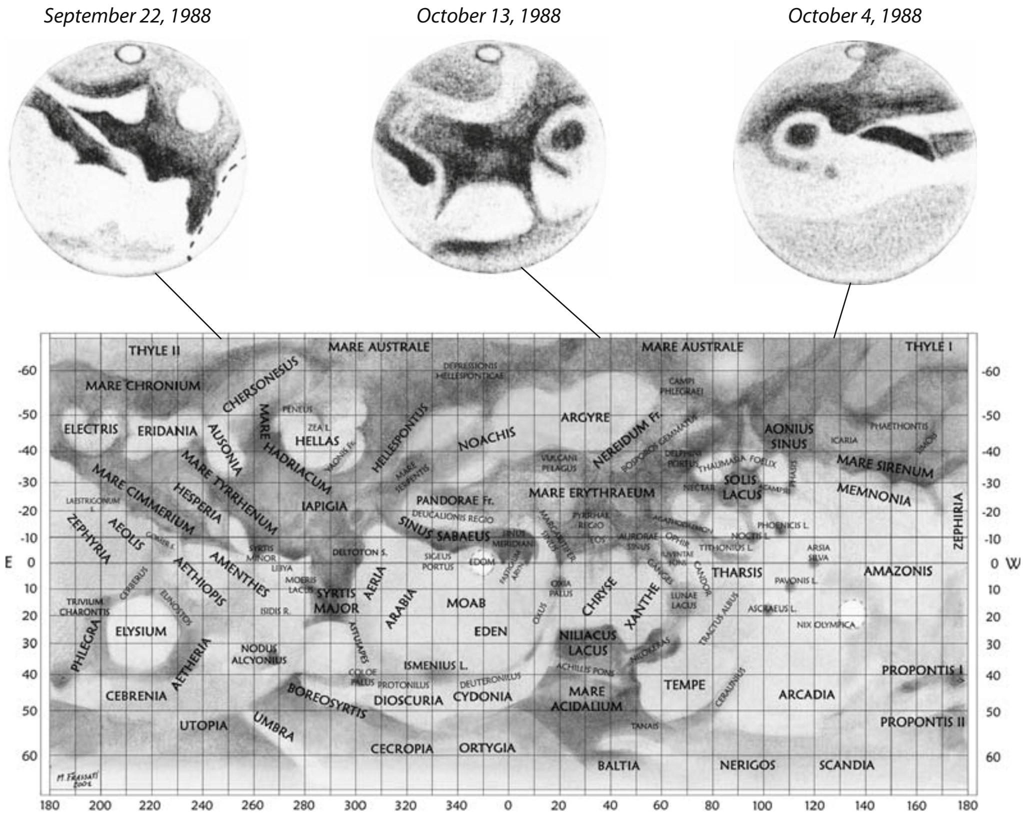
This is still something compared with the next opposition in January 2010. Mars will be nearly 100 million km from Earth, and its apparent diameter will be just 14 seconds of arc. There will be one more, even worse, opposition before things start to get better. But the next perihelic opposition will not be until July 2018, with Mars at a distance of 58 million km and an ample apparent diameter of 24 seconds of arc. That will be something worth waiting for.

Please, meet Mars!

● Despite the meager viewing for years ahead, Mars is an extremely interesting object to observe. It is the only planet in the Solar System whose surface we can see with our own eyes. Mercury is always so close to the Sun that most of the time it is difficult even to find. The surface of Venus is covered by permanent clouds, while Jupiter and Saturn have almost no solid surface. Telescopes show only massive clouds swirling in the upper layers of their thick atmospheres. It is the same with Uranus and Neptune; furthermore, they are so distant that any details are next to impossible to discern with amateur instruments. Trying to find Pluto – not officially a planet anymore – is more or less futile without a telescope with an aperture of 20–30 cm.

How about Mars? What can we expect to see? In case you are looking through a telescope for the very first time, it must be emphasized – to avoid any disappointments – nothing much. The surface features of Mars are so small and the difference between the light and dark areas, the so called albedo features, so slight that you should not be surprised to see at first glance more or less just the color of the red disk. However, the human eye is an extraordinary apparatus with its ability to learn to see, and this can be achieved only by watching.

The most prominent feature on the surface of Mars is the ice cap, glowing white either on the upper or lower edge of the



An albedo map of Mars based on the observations made by Italian amateur astronomers from 1988 to 1999. The individual sketches of Mars were made by the author with a 14 cm refractor during the 1988 opposition. The central meridians of the sketches are marked on the map.

planet. The size of the cap depends on the season and on whether it is the northern or southern cap, and whether the image on the telescope is right side up or upside down, as it usually is in astronomical telescopes. Around the opposition of 2010 it will be spring in the northern hemisphere of Mars and thus the ice cap will be very small, but there will be plenty of other details to be seen, if you care to keep on observing our neighbor. After a while you will start perceiving more and more details with a varying degree of darkness.

Mars' period of rotation – 24 hours 37 minutes – is so close to that of Earth that at the same instant on consecutive nights you will see nearly the same side of Mars, but not quite. The difference of a little more than half an hour in the periods of rotation of the planets results in the apparent rotation of Mars seeming to go slow, like a defective watch. Mars as seen from Earth is at exactly the same

An image of Mars recorded with a 1 m telescope at Pic du Midi observatory in the French Pyrenees on November 18, 2007, exactly 1 month prior to the date of closest approach to Earth with a distance of about 88 million km. The opposition was a few days later, on Christmas Eve.

position after a period of 40 days – supposing you are still looking through a telescope at the same instant to the minute.

The most prominent features on Mars are dark Syrtis Major and bright Hellas just south of it. Westward – that is, to the right in an upside down image of an astronomical telescope – lies oblong Sinus Sabaeus with Sinus Meridiani, the local Greenwich marking the zero meridian of Mars, at the end of it. After Mare Erythraeum starting south of Sinus Meridiani there comes the dark "eye" of Solis Lacus and further to the west two more "seas," Mare Sirenum and Mare Cimmerium. If you manage to see all of these, you have come a long way in the field of areography, the Martian version of geography.

The eye learns to see and the mind to decipher. Nevertheless, it took thousands of years before humans even had a chance to try interpreting Mars as a planet, a world of its own accord. After all, it is just a point of light in the night sky.

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02

GOD OF WAR, HEAVENLY BODY

Both Earth and Mars circle around the Sun.

– Wernher von Braun: *Project Mars – A Technical Tale* (2006)

Nergal, *Har décher*, *Mangala*, *Tyr*, *Ares*. Mars is a planet with a number of names. In the past millennia it has been identified in many languages and cultures with hatred, war, and death. Its blood-red color and capricious movements among the stars of heaven shaped it in the susceptible minds of our ancestors into a messenger of the gods, perhaps a god himself, the behavior of which people tried to decipher to gain hidden knowledge of things to come.

Astronomy – said to be the oldest of the sciences – has a history reaching thousands of years into the past. Surely humans have raised their awed gaze toward the stars at even earlier times, but there are no written records on that. The Egyptians are known to have erected their pyramids according to the positions of the stars, and they were capable of predicting the floods of the Nile based on the heliacal rise of the "Dog Star," Sirius, in the constellation Canis Major, the Greater Dog.

They also noticed that the stars maintained their mutual positions even though they rise and set the same way as the Sun does – which, by the way, they noticed to move with respect to the stars. Five bright points of light were perceived to have similar movements. Nowadays we know them as Mercury, Venus, Mars, Jupiter, and Saturn. The name the Egyptians gave to Mars was very

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Ancient civilizations noticed the erratic movements of the blood-red Mars thousands of years ago.

MARS IN DIFFERENT LANGUAGES

Angkarn	Thai
Ares	Greek
Bahram	Farsi
Ch'ak-ah	Mayan
Fuosing	Cantonese
Har décher	Ancient Egyptian
Huoxing	Mandarin
Hwasung	Korean
Kasei	Japanese
Ma'adim	Hebrew
Mangal	Bengali, Gujarati
Mangala	Sanskrit
Marikh	Malay
Mars	Bulgarian, Croatian, Czech, Danish, Dutch, English, Finnish, French, German, Hungarian, Icelandic, Indonesian, Irish, Latin, Norwegian, Polish, Russian, Serbian, Slovenian, Swedish, Turkish
Marsi	Albanian, Georgian
Marso	Esperanto
Marss	Estonian, Latvian
Mart	Catalan
Marte	Filipino, Galician, Italian, Maltese, Portuguese, Rumanian, Spanish
Martitza	Basque
Maunu-'ura	Tahitian
Mawrth	Cymric
Merrikh	Arabic
Mirrikh	Uzbek
Nergal	Babylonian
Salbatanu	Babylonian
Si-mu-ud	Sumerian
Smrtonos	Ancient Czech
Ti	Ancient Swedish
Tyr	Ancient Norwegian

descriptive: *Har décher*, "The Red One." Another equally illustrative was *Sekded-ef-em-khetkhet*, "The One Moving Backwards." Thus the Egyptians already 5,000 years ago were aware of Mars having a backward or retrograde motion at times.

Death and destruction

● The ancient culture reaching the highest level in the study of the stars were the Babylonians in Mesopotamia. They used a calendar based on Egyptian knowledge, but they developed it further and adopted the concept of the Zodiac to facilitate observing the movements of the planets. Calendars were of utmost importance both for timing agricultural activities and celebrating religious festivities at the right time. Thus Babylonian astronomy – as far as it can yet be characterized as a proper science – was very practical. The local "scientists," the high priests, were not even trying to explain the phenomena they observed. The points of light twinkling in the sky were higher beings needing no explanations, their movements communicating the future course of events. Red Mars was *Nergal*, the Star of Death and the god of the underworld, great hero and king of battles bringing about destruction and devastation. Therefore the connection of Mars with matters bellicose comes from a long past.

The ancient Greeks made great efforts in trying to find the real phenomena behind celestial events, but mythology still constituted an important part of their philosophy. In Greek legends Mars was *Ares*, the God of War. He was a son of Zeus, the supreme god, and his wife Hera. The parents despised their offspring because he was – at least according to the *Iliad,* the poetic work of Homer – bloodthirsty and full of wrath, but still a chicken-hearted coward. Ares was the first god to be sued for his misdemeanors. It was understandable that Mars enjoyed the highest esteem in the warrior state of Sparta, where they built several temples in his honor.

The Greeks called the moving points of light "planetes," wanderers, which is the basis for the word *planets.* On the other hand the cultural heritage of the Romans includes Mars and the names of the other known planets at that time, too. Also, the symbol of Mars, a shield and a spear, comes from ancient times.

In Hindu mythology Mars or Mangala represents Karttikeya, the god of war, who is often accompanied by a peacock.

A statue of the Roman god of war on the roof of a block of flats built in 1929 in Helsinki.

Amidst the bellicose conquerors, Mars was a far more highly respected god in Rome than in the minds of the Greeks who thought him to be a repulsive derelict. In Rome, Mars, the father of Romulus and Remus, was worshipped through human sacrifices. With the Roman conquests the cult of Mars spread amongst other people, such as the Germans.

The warlike nature of Mars is an essential feature also in Hindu mythology, in which it is known as *Mangala*, the symbol of Karttikeya or Skanda, the God of War. Karttikeya sprang from six sparks falling from the eyes of the god Shiva into the lake in the vicinity of Madras. The sparks gave birth to six children tended

by Kartigai, the six ladies represented by the Pleiades. At one time Shiva's wife Parvati embraced the children with such a powerful emotion that they were squeezed into a single being, Karttikeya, "The One of the Pleaides." Usually he is described as a 6-headed and 12-handed deity riding a peacock. It is his duty to beat the archenemy of the gods, the monster demon Taraka and his aid Mahisa. Karttikeya has a sword forged of the shining rays of Surya, the god of the Sun. One of the months – supposedly being especially suitable for fighting – has been given the name *Karttika* after him. In the western calendar it is in October–November.

The Mayans residing in Central America were also eager observers of the sky. Like many other ancient peoples they believed their fate was written in celestial movements. They had a complicated calendar with the names and numbers of the days making a circuit of 260 days called Tzolkin. Instead of Mars they connected war with Venus, the most important planet in their cosmology. In many of their cities the doors and window openings of significant buildings pointed in directions related to the movements of Venus, such as rising and setting. However, in the Dresden Codex, originating from the eleventh century, there is a series of sketches of Mars. It has the form of *Ch'ak-ah*, a long-beaked or long-snouted beast, possibly a wild boar, descending from the sky – symbolized by a snake – to different altitudes above the world. This might reflect the strange movements of Mars also known to Mayans, or perhaps the noticeable variations in its brightness, too.

In the mythical world of the Vikings Mars' counterpart was *Tyr*, the god of war and battle. Tyr was a son of Odin himself, even though some sources give the parents of Tyr as being Frigg, the goddess of fertility, and Hmymr the Giant. Tyr distinguished himself by keeping Fenris the Wolf from terrorizing Asgaard, the legendary dwelling site of the gods. He put his hand in the mouth of the wolf as a bluff so that the other gods were able to tie Fenris up with a magic ribbon woven by the dwarfs. In the scuffle Tyr lost his hand and that is why he is usually depicted as a one-handed god. The sacrifice was not wasted, since Fenris will be tied up until Ragnarök or "The Destruction of the Gods," the very last battle that will destroy the whole world. Most probably the Vikings adopted Tyr from the beliefs of the Germanic people in which the god appears as *Tyz* or *Tiw*, the names being very similar to Tyr. The "t" in the runic alphabet is based on the name Tyr, and in the Icelandic Edda poems it is closely related to Mars. This god of the mythology of northern Europe is still living on in our calendars through his namesake day. Tuesday comes from "Tiw's day." It is *tiistai* in Finnish and *tisdag* in Swedish; in Old Swedish *Tyr* was known as *Ti.*

"The Times They Are a-Changin'"

● Despite the knowledge gained as times went by, people gazed at the skies for millennia without comprehending what they saw, whether it was the Sun, the Moon, the stars or the planets. The illusions concerning the world and the universe began to evolve into realistic concepts only in the sixteenth and seventeenth centuries by giants of science, including Copernicus, Brahe, Kepler, and Galileo.

It was slow, though. A significant obstacle was the Catholic Church. Clergymen appealing to orthodoxy did not see fit to try altering the prevailing concept of the world. They thought it to be just fine and very much in accordance with the Holy Bible – which, in fact, it was not.

Another major obstacle was human nature. Notwithstanding the self-evident notion of the belief in progress, people are very wary of change. And the change about to happen in the seventeenth century was without much doubt the most fundamental ever. This age of transition also starred Planet Mars, perhaps in the leading role.

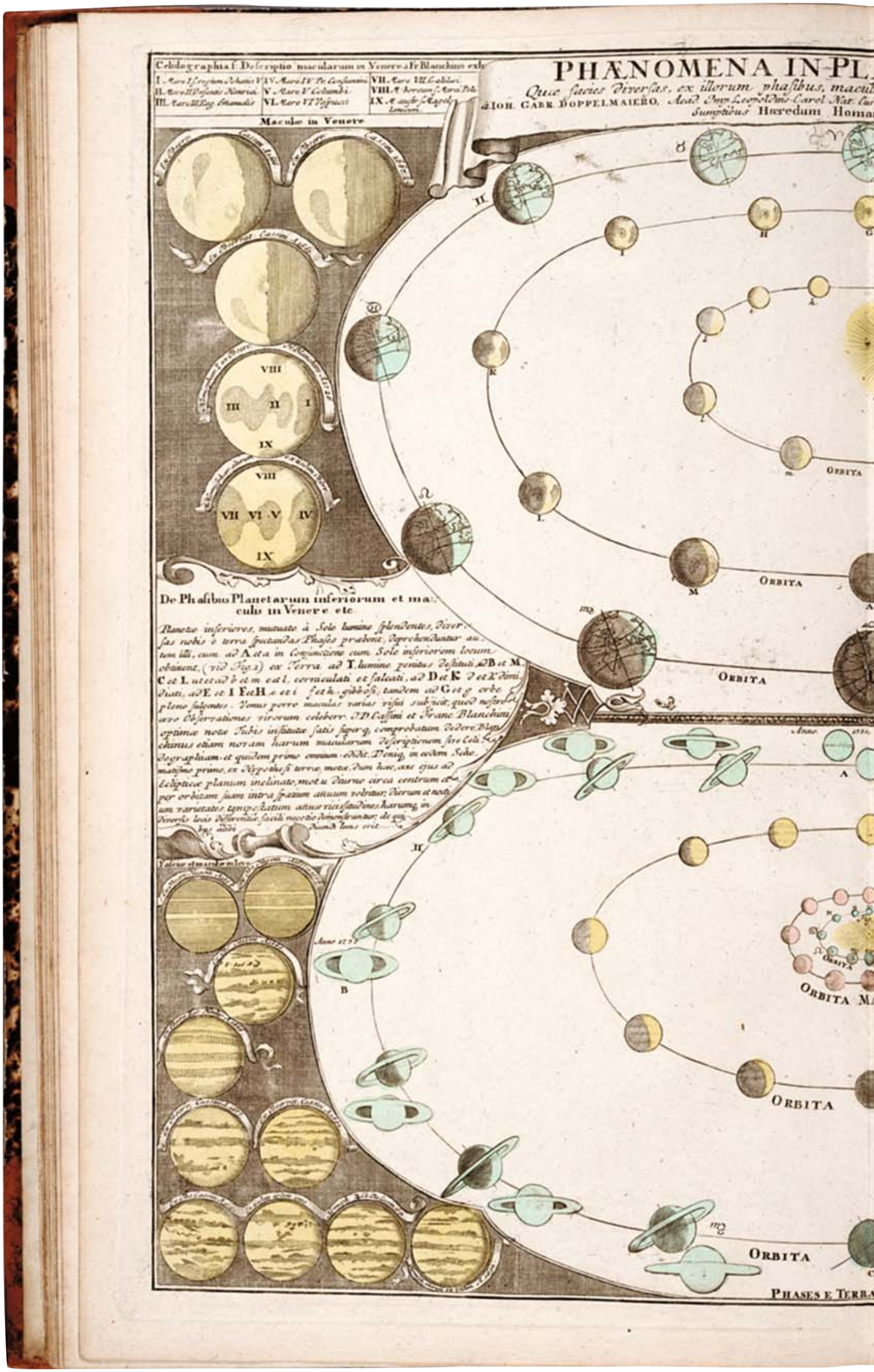
Keplerian diagrams

● In the final years of the sixteenth century faith in the geocentric universe was starting to crumble. Although the observations became ever more accurate, explaining planetary movements demanded ever more complicated explanations. The cosmos was beginning to get crowded with spheres, circles, and shafts moving in respect with each other.

The cosmic revolution started with the book *De Revolutionibus Orbium Coelestium* (On the Revolutions of the Heavenly Spheres) by the Polish Nicolaus Copernicus, published in 1543, the year he died. In his book Copernicus introduced a new heliocentric model of the world, one he had come up with a lot earlier but because of the narrow-mindedness of the time had kept to himself. With the new theory Earth, formerly thought to be the center of the universe, was very rapidly demoted to being a planet among other planets, while the Sun took the place it deserved. Many astronomers – threatened with a strict confinement, if not loss of life – began to ponder matters from a new point of view: how could the movements of the planets be explained if Earth, from the surface of which we make our observations, is actually one of those planets and on the move, too?

The heliocentric system took over the geocentric one during the seventeenth century. Illustration from Specula physico-mathematico-historica notabilium ac mirabilium sciendorum *by Johann Zahn, published in 1696.*

Johannes Kepler, a German astronomer, was inspired by the revolutionary ideas of Copernicus. Kepler was working for his


PHÆNOMENA IN PL
Quæ facies diversas, ex illorum phasibus, macul
Ioh. Gabr. Doppelmaiero,
Sumptibus Hæredum Homan
Maculæ in Venere
De Phasibus Planetarum inferiorum et maculis in Venere etc
ORBITA
ORBITA
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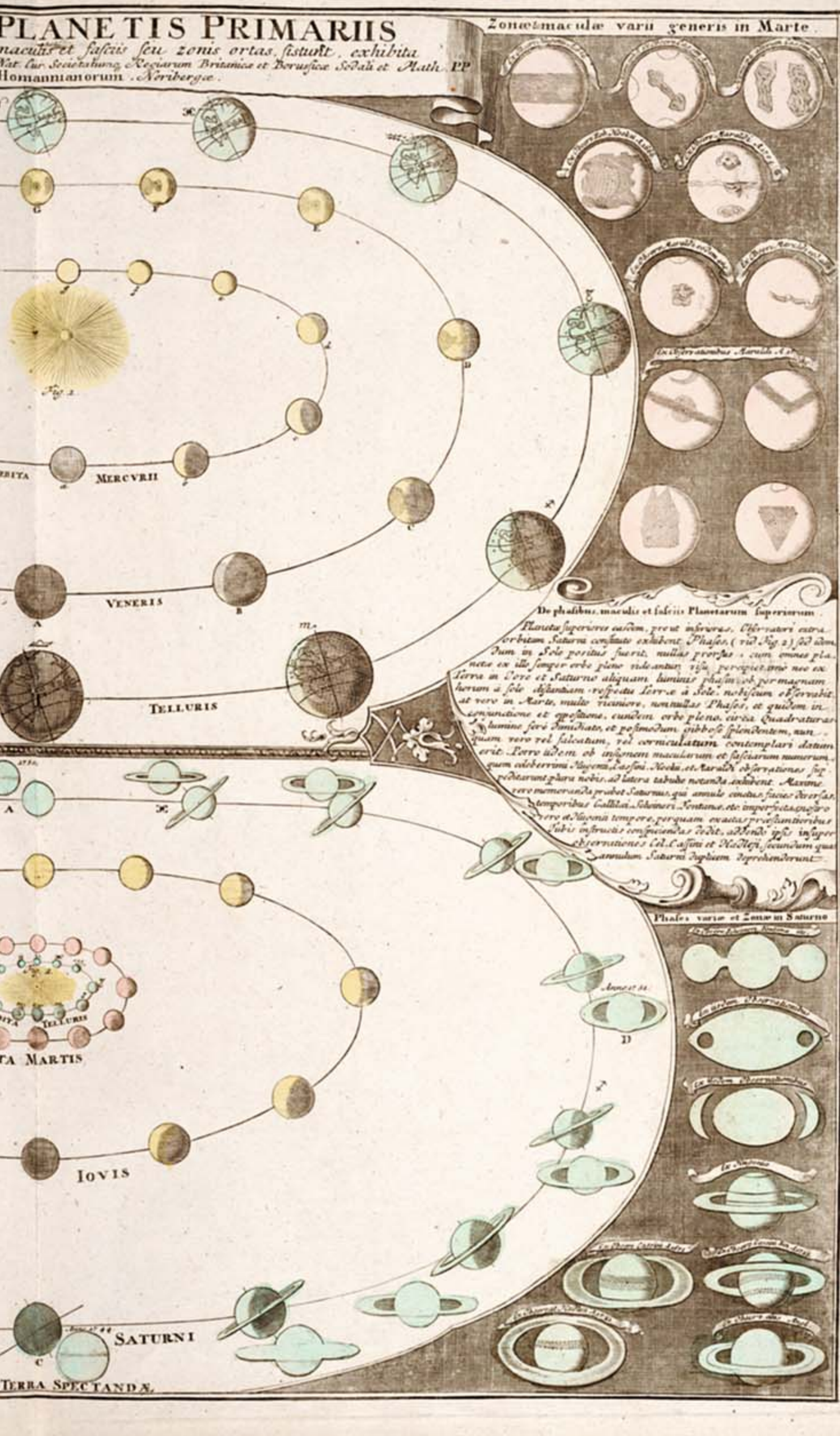
ORBITA
ORBITA MA
PHASES E TERRA


PLANETIS PRIMARIIS
maculis et fasciis seu zonis ortas, sistunt, exhibita
Nat. Cur. Societatum, Regiarum Britannicæ et Borussicæ Sodali et Math. PP
Homannianorum . Norimbergæ .
Zonæ et maculæ varii generis in Marte
Fig. 2.
ORBITA MERCURII
VENERIS
TELLURIS
ORBITA MARTIS
IOVIS
SATURNI
TERRA SPECTANDÆ.
De phasibus, maculis et fasciis Planetarum superiorum
Planetæ superiores easdem, prout inferiores, Observatori extra orbitam Saturni constituto exhibent Phases, (vid. Fig. 2) sed idem, dum in Sole positus fuerit, nullas prorsus, cum omnes planetæ ex illo semper orbe pleno videantur, visui percipiet. Imo nec ex Terra in Iove et Saturno aliquam luminis phasin ob permagnam horum à Sole distantiam respectu Terræ à Sole, nobiscum observabit, at vero in Marte, multo viciniore, nonnullas Phases, et quidem in conjunctione et oppositione, eundem orbe pleno, circa Quadraturas lumine ferè dimidiato, et postmodum gibbosè splendentem, nunquam vero vel falcatum, vel corniculatum contemplari datum erit. Porro iidem ob insignem macularum et fasciarum numerum, quem celeberrimi Hugenii, Cassini, Hookii, et Maraldi observationes suppeditarunt, plura nobis, ad latera tabulæ notanda exhibent. Maxime vero memoranda prebet Saturnus, qui annulo cinctus, facies diversas, temporibus Galilæi, Scheineri, Fontanæ, etc. imperfectas, ast vero et Hugenii tempore, perquam exactas præstantioribus tubis instructis conspiciendas dedit, addendo ipsis insuper observationes Cel. Cassini et Hadleji, secundum quas annulum Saturni duplicem deprehenderunt.
Phases variæ et Zonæ in Saturno

Danish colleague, Tycho Brahe, who was not the most easygoing of persons. Brahe had left his country of origin after falling out with both his superiors and inferiors – and losing half his nose in a duel – and dwelled in Bohemia as a court astronomer of the emperor. He enlisted the help of poor Johannes to tackle the problematic wanderings of Mars, being quite well aware that the movements of the planet, especially the loops it made during opposition, were the most peculiar of all the planets. The task Kepler thought would take a couple of weeks dragged out to several years. For two decades Brahe had made observations of Mars and its position as accurately as possible without the aid of a telescope, but he withheld some of his observations until his death. Only after Brahe had passed away did Kepler get hold of all the observations, and finally the problem started to be resolved.

At that time the new heliocentric cosmology-to-be was still based on "perfect" circular orbits, just the way the former geocentric system used to be. Kepler broke with tradition and started to fit an oval orbit to the movements of Mars instead of a circular one. The calculations began to make sense, and the conclusion was inevitable: Mars – like all the other planets, including Earth – circles the Sun in an elliptical orbit with the Sun at one of the two foci. The strange loops Mars made when in opposition were explained with Earth as an inner planet traveling faster in an orbit of its own, catching up and passing Mars, like all the other outer planets, causing Mars for a while to seem as if it is moving in a retrograde direction in the sky.

If Kepler had used the movements of another planet as the basis for his calculations, the correct conclusion would not necessarily have been inevitable at all. Mars has the second most elliptical orbit of all the planets, so the effects of the shape of the orbit are especially pronounced on its movements. The orbit of Mercury is even more elliptical, but it orbits the Sun closer than Earth and because of that it is always difficult to observe in the glare of the Sun. Kepler himself never even saw the planet.

The concept of the world was changing. It was becoming obvious that in the hierarchy of the Solar System Earth was equal with the other planets. Could this possibly mean that the other planets – among them Mars – were correspondingly similar worlds to Earth?

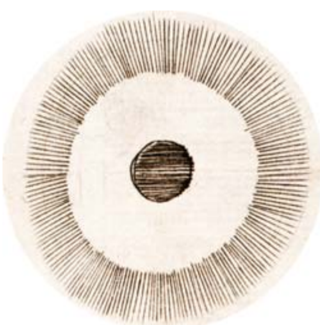
The observations made with the naked eye did not reveal the answer, for Mars is only a tiny point of light, just like the stars.

The rise of technical astronomy

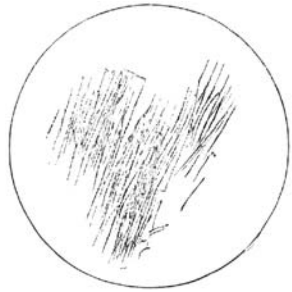
● One of the most important events in the history of science is the invention of the telescope in the early years of the seventeenth century. Despite persistent beliefs, the honor for this achievement does not go to the Italian Galileo Galilei, but what Galileo did do was to think of turning his primitive instrument toward the stars – even though he apparently was not the first one to do this, either. Galileo saw spots on the Sun, mountains on the Moon, the phases of Venus, and the moons of Jupiter. His observations all lent credence to the new order of the world.

Galileo's telescope was not powerful enough to make anything out of Mars, though. The modest objectives of the first telescopes with their chromatic aberrations and other optical deficiencies prevented the tiny details of the Red Planet from showing. However, Galileo managed to make an observation of Mars that strengthened his belief in the heliocentric system developed by Copernicus and adjusted by Kepler – or actually it was the other way around. Supported by his belief, he saw what he wanted to see.

Galileo knew that because Mars circles the Sun outside the orbit of Earth it is not always seen as "full," with the hemisphere facing Earth totally illuminated. At the time the angular distance between Earth and the Sun as seen from Mars is the greatest, Mars as seen from Earth is gibbous, just like the Moon 3 or 4 days before the full Moon or after it. In reality Galileo could not see any phase on Mars – and he knew it. In reporting his observations he used language that seemed to convey embarrassment, which was uncommon for Galileo, who usually was quite boastful in his statements. But he was right: Mars does have phases.


Sketch made by Francesco Fontana in 1636.

With the improvement in telescopes our planetary neighbor began to reveal its details. Francesco Fontana, an Italian lawyer and an amateur astronomer, was watching Mars with his telescope in 1636. He made a sketch of the planet showing – as he wrote – a little "black pill" in the middle of it. Unfortunately it was not a genuine feature on the surface of Mars, but a phenomenon related to the poor optics of the telescope. Fontana managed to see a similar "pill" on Venus. However, 2 years later Fontana managed to confirm Galileo's observation based on his recognition of the phases of Mars.



Sketch made by Christiaan Huygens in 1659.

The shaping of a world

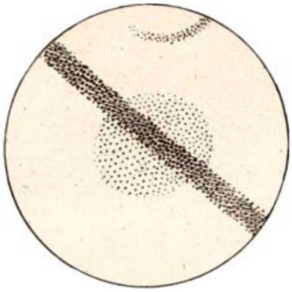
● Since the days of Fontana, a scientist peering at the heavenly bodies who saw varying dark patches on Mars would describe these albedo features verbally or with smudgy outlines. It was only in 1659 that the Dutchman Christiaan Huygens first made a sketch with identifiable details. For example, there is a dark area shaped like the letter *V* in the middle of the round disc of the planet that came to be known as the Hourglass Sea. Later it was renamed Syrtis Major, which is the name still in use today.

With the aid of the spot Huygens was able to follow the rotation of Mars. He determined the period of rotation of the planet to be 24 hours, which is quite close to the correct value of 24 hours 37 minutes and 23 seconds. Consequently the dark area seen was a real feature on the surface of the planet, but the nature of this detail was something the rough sketches could tell nothing about.

Sketch made by Domenico Cassini in 1666.

The Italian-French Giovanni Cassini began his studies of Mars in the 1660s. His sketches were not so much scientific as artistic, and the details on them are not easy to identify with the real features of Mars. Cassini did manage to renew Huygens' feat. He defined the period of rotation of Mars to be 24 hours and 40 minutes, which was still closer to the real value. Huygens had not published his results, so now there were two independent observations of the similarity between Mars and Earth: they rotated at almost the same pace.

In September 1672 Mars was at perihelic opposition, and the list of similarities lengthened. In addition to the familiar Syrtis Major – or Hourglass Sea – Huygens observed a bright spot, the white and shining polar cap, on the southern edge of the planet. About a century later it was realized that it was ice. At the same time Cassini was working on the existence of a possible atmosphere on Mars. He watched a star about to be occulted by the planet and noticed that it disappeared before the planet covered it.



Sketch made by Giacomo Maraldi in 1719.

Sketch made by William Herschel in 1777.

This led Cassini to conclude that Mars has a substantial atmosphere, which caused the dimming of the star.

The pioneering work of Huygens and Cassini was continued by the Frenchman Giacomo Maraldi, who made his most important observations during the perihelic oppositions of 1703 and 1719. Maraldi also saw dark areas on the surface of the planet and white caps at the poles, which he observed to expand and shrink, even disappear at times. Maraldi concluded that the changes in the polar caps were real, but he did not try to guess at their real nature.

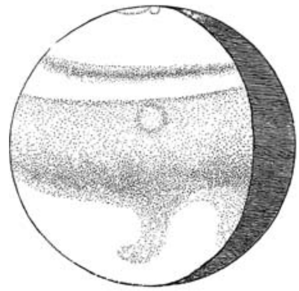
After Huygens, Cassini, and Maraldi, Mars studies entered a hiatus that lasted for several decades. The development of the telescope was slow, and the increase in real knowledge concerning Mars was next to negligible. However, the Red Planet had changed from a mere point of light to a whole world, the surface features of which could be observed if not revealed in their entirety until the latter half of the twentieth century.

Curtain call

● A new stage in Mars studies began during the last decades of the eighteenth century when the German-English William Herschel and the German Johann Schröter started to make accurate observations of the planet – or as accurate as was possible with the telescopes of the time.

Herschel attacked the subject of Mars in 1777, and after two oppositions managed to calculate the most accurate value so far for the period of rotation of the planet: 24 hours 39 minutes and 21.67 seconds. The error had diminished to just a couple of minutes. Herschel also determined the inclination of the axis of rotation, or the obliquity of Mars, to be 28.7° (the true value being 25.2°). In addition to these observations he studied the atmosphere of Mars with the method Cassini had used. However, Herschel did not perceive any changes in the brightness of the two stars he observed until they disappeared behind the limb of the planet. Thus the atmosphere could not be very thick. Nevertheless, Mars apparently did have an atmosphere, since Herschel had seen some changes in the dark areas of the surface he deduced to be due to clouds. According to Herschel the variations in the polar caps were comparable to the seasonal changes on the polar areas of Earth. Based on this assumption he concluded that they were made of snow and ice. All this led Herschel to think that the conditions on Mars were very much like what we have here on Earth.

The baton was passed from Herschel to Schröter – quite literally, since two of the mirrors in his several telescopes were made by Herschel. The details Schröter observed were similar to the ones in Herschel's sketches. However, Schröter stubbornly maintained the view that the dark areas were only atmospheric clouds with changes occurring even by the hour – despite the fact that they were, for the most part, permanent. After Schröter died, his observations were temporarily lost. They were rediscovered only at the end of the nineteenth century, and by that time knowledge concerning Mars had reached completely new levels.



Sketch made by Johann Schröter in 1798.

The age of areography

● Thanks to Herschel and Schröter the details of Mars became more familiar. At the same time many basic features of the planet were revealed – ever more accurate values for the period of rotation and the inclination of the axis of rotation together with the true nature of the seasons, the polar caps, and the atmosphere. However, a consensus on the true nature of the surface features of Mars was not yet reached. Schröter was not the only one to consider them as transient, and several observers thought it futile to try mapping the planet. It would be about as sensible as making maps of the clouds in the sky blowing in the wind.

Sketch made by Wilhelm Beer and Johann von Mädler in 1830.

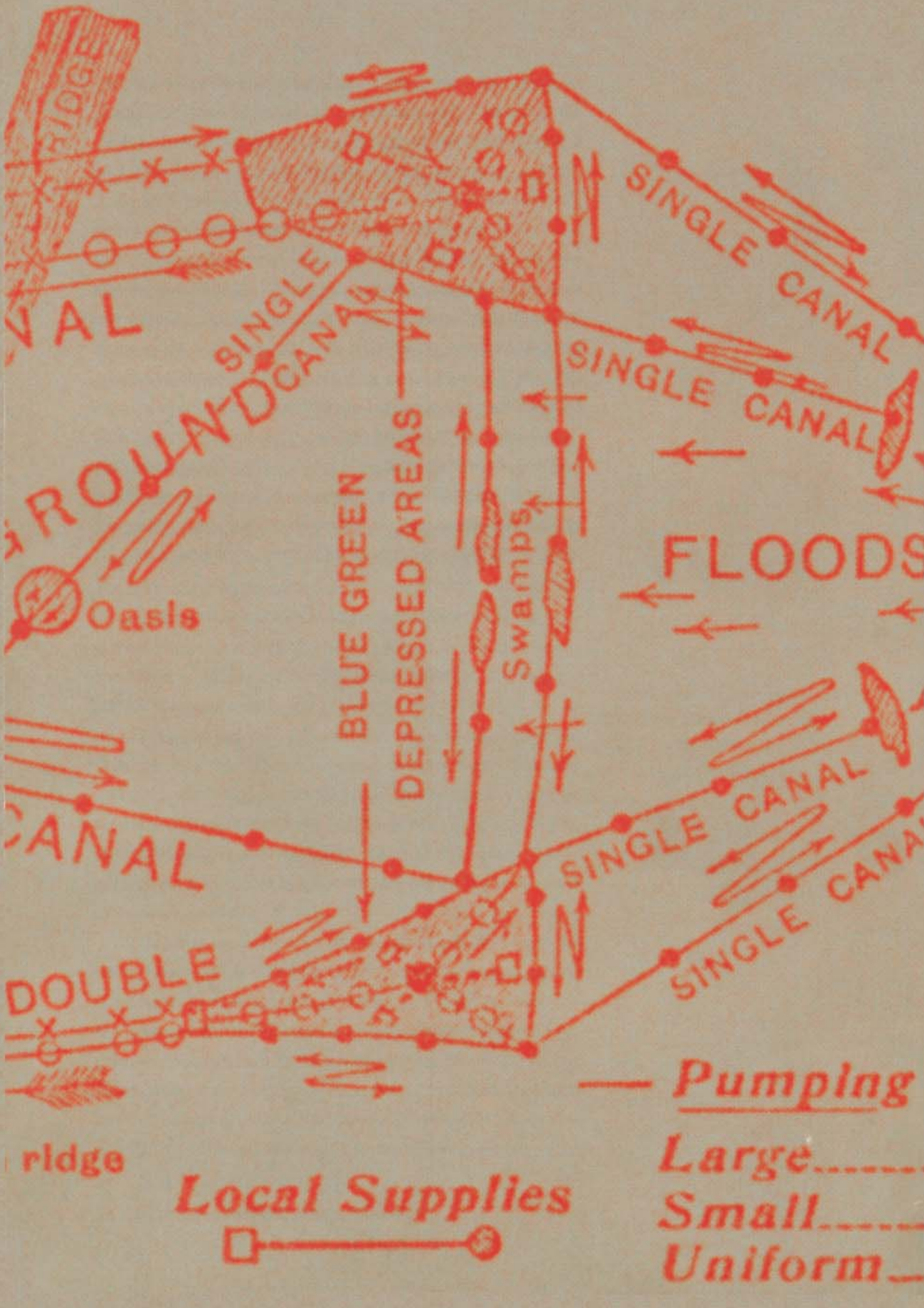
Two Germans, Wilhelm Beer and Johann von Mädler, turned a deaf ear to ideas like this. They had done cartography with the Moon, and in 1830 they decided upon their next target: Mars. Their aim was to solve once and for all the question on the permanence of the surface details. Beer and Mädler did not have to conduct their observations for long and were able to conclude fairly soon that the dark areas on Mars were not clouds but real features on the surface of the planet. They chose one of them – later to be named Sinus Meridiani – as the site for the prime meridian of the planet and began systematic mapping of Mars. They did not give any names for the dark areas they saw, though, but designated

Sketch made by William Dawes in 1864.

them with letters: Sinus Meridiani was simply "a." They observed the planet in opposition after opposition, and finally in 1840 they were able to publish the first-ever map of Mars.

The nineteenth century could very well be called the age of areography, in relation to the mapping of Mars. Telescopes improved, and smaller and smaller details could be discerned on the surface of Mars. An ever growing number of astronomers, headed by the Italian Angelo Secchi, the German Frederik Kaiser, and the Englishmen J. Norman Lockyer and William Dawes, made more and more detailed sketches of the Red Planet. These were used as a basis for maps with the details on them given proper names instead of mere letter insignia. It began to be commonly accepted that the dark areas were seas, the light ones continents. The new nomenclature followed this idea: the features were named after late but also contemporary astronomers. The maps of Mars depicted places such as Cassini Land, Herschel Straight, Maraldi Sea, and Mädler Continent.

Compared with the millennia of myth and mystery concerning Mars, the Red Planet had become a real world practically overnight, a world that could be mapped in much the same way as Earth, though with less accuracy and not in situ, but in principle in the same way. As a result, scientists adopted a view of Mars as a more or less similar world to Earth. Even though the notion of the red hue of the planet as being due to a blazing hot surface was still being espoused as late as 1877, the prevailing ideas were more or less uniform. Mars appeared to have seas and continents like our own planet, as well as polar ice caps expanding and shrinking with the regular rhythm of the seasons. Could it be that Earth and Mars might have something else in common? Perhaps life, maybe even intelligent life . . . ?



RIDGE
SINGLE CANAL
SINGLE CANAL
SINGLE CANAL
SINGLE CANAL
GROUND
NAL
Oasis
BLUE GREEN
DEPRESSED AREAS
Swamps
FLOODS
CANAL
SINGLE CANAL
SINGLE CANA
DOUBLE
Pumping
ridge
Local Supplies
Large
Small
Uniform

03

MARTIAN CANAL ENGINEERS

A dead city upon a dying planet which was the home of a dwindling race.

– John Wyndham: *Sleepers of Mars* (1938)

> It was a dark and stormy night. Giovanni peered through the heavy velvet curtains of his dusky study and screwed up his eyes to see outside. Autumn rain lashed the dark form of the observatory, which was barely discernible against the almost as dark Milanese sky. 'There won't be any stars there tonight,' Giovanni sighed wearily. 'Fortunately.'

The following night there once again were stars, stars and planets. The Italian Giovanni Schiaparelli climbed up the stairs of the observatory, opened up the hatch of the dome and aimed the 22 cm telescope at the heavens. Schiaparelli was to test the telescope through planetary observations. A suitable object was Mars, approaching opposition in September, and thus well situated in the southern sky around midnight. Schiaparelli wanted to see with his own eyes the markings observed – and mapped – on the surface of the Red Planet.

Schiaparelli did not have any plans to start making regular observations of Mars, and his first effort was not much of an encouragement to do so. The details in his sketch were nothing like the

M. Hotakainen, *Mars*, DOI: 10.1007/978-0-387-76507-5_3,
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markings on the maps the earlier observers had drafted. Schiaparelli did not give up, though, but returned to Mars on subsequent nights. Gradually the image in the telescope started to make sense, and Schiaparelli changed his plans with great enthusiasm. He would concentrate on observing Mars and would prepare the most accurate map ever of the features seen on the surface of the planet – the number of which at that time was barely a couple of dozen. It was a decision that would revolutionize the whole future of Martian studies.

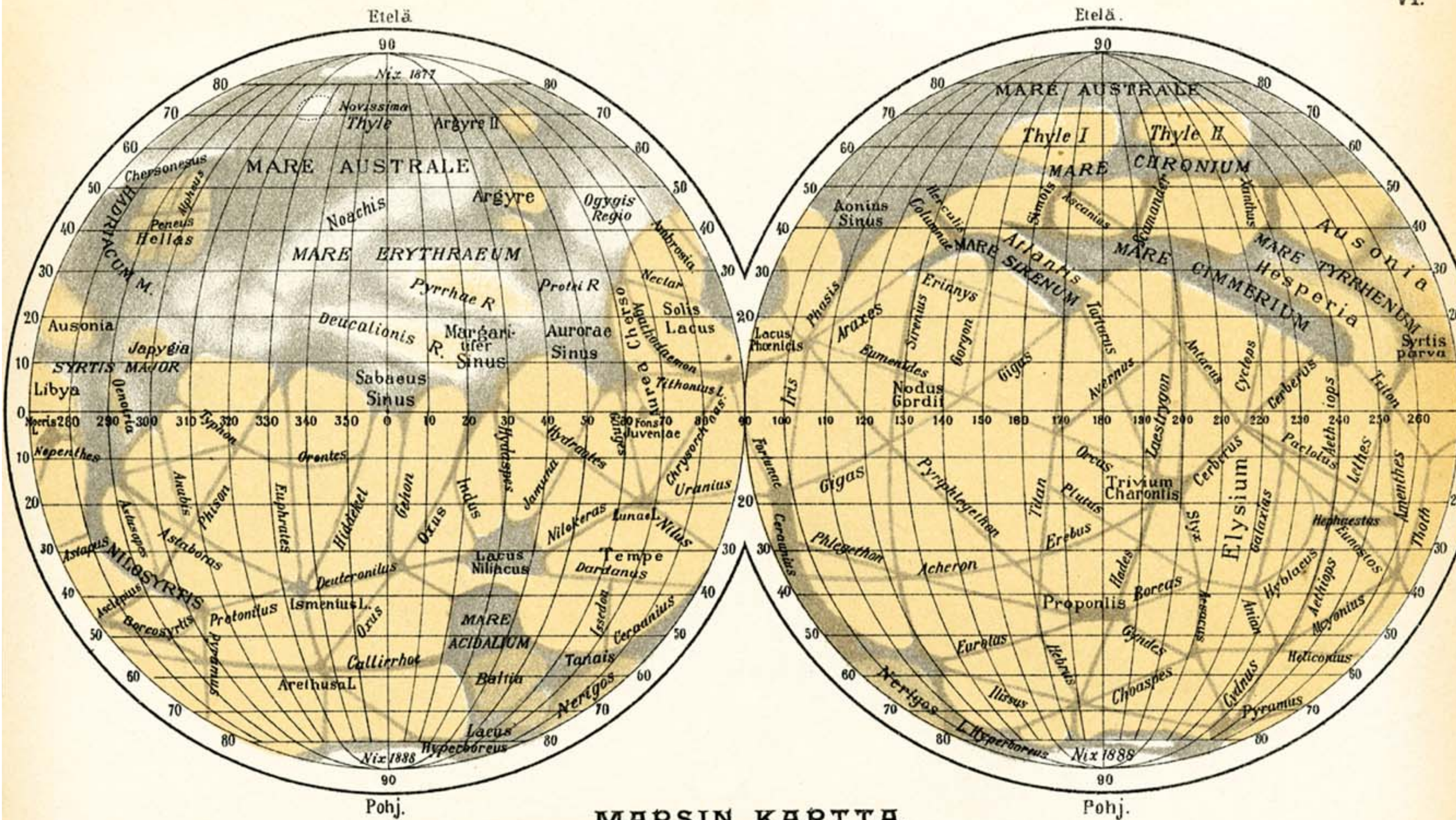
Map of Mars by Giovanni Schiaparelli, showing for the first time a global network of canals.

Lost in translation

● Schiaparelli started his regular observations in September 1877, 1 week after Mars passed opposition, during which time it came closer to Earth than it had been since the 1840s. The first thing Schiaparelli did was abandon the confusing and impractical nomenclature created by earlier mappers of Mars. He decided to give the bright and dark areas of Mars Latin names based on real and Biblical names of the lands and seas of Earth. Schiaparelli did not think that the dark areas were really oceans and the bright ones continents, so he emphasized that the names were symbolic at most, just as in the case of the Lunar "seas," Maria. The new nomenclature was not adopted by everyone at once, but gradually it became accepted, and it is still in use where the details visible in telescopes are concerned.

Schiaparelli's "Martian revolution" was not restricted to nomenclature. His first map, published in 1878, showed in addition to the formerly known features, more or less straight, narrow lines connecting larger dark areas, the "seas," with each other. Schiaparelli called them "canali," an Italian word that can be translated in two ways. It should have been translated into "channel," since Schiaparelli did not think the straight lines to be artificial constructions; sometimes he used the word "fiume," a river. The alternative that became accepted in English was the wrong one: "canal." It immediately brought to mind an artificial waterway, especially around the end of 1870s, less than 10 years after the completion of the Suez Canal, which was considered in those days to be the epitomy of engineering skills.

Giovanni Schiaparelli was not the first observer to see canals on Mars. There were some traces of them already in sketches made by



MARSIN KARTTA.

Osakeyhtiö Weilin & Göös Aktiebolag.

the German Johann Schröter at the end of 1700s and several others all throughout the 1800s. Schiaparelli was not even the first to use the fatal word *canali*. The Italian Angelo Secchi called Syrtis Major an "Atlantic Canal" in 1858, and 11 years later he used the word for the straightish lines he saw on the surface of the planet. But Schiaparelli was the first cartographer of Mars whose map showed the canals – or channels – so clearly and in such great numbers. Not even Schiaparelli had seen at the same time all the canals he had drawn on his map – he saw just a few at a time at most – but due to his systematic study by far the most accurate map of the planet was crisscrossed by a complicated network of several dozens of canals.

Yes. No. Yes! No! YES!!! NO!!!

● After Schiaparelli had published his map several professional astronomers and amateur observers began to report observing seeing the canals on the surface of Mars – or at least they spoke louder than their more skeptical colleagues. Many observers did not see any canals. Soon the canals of Mars became a matter of faith and as usual with matters of faith, a matter of heated dispute.

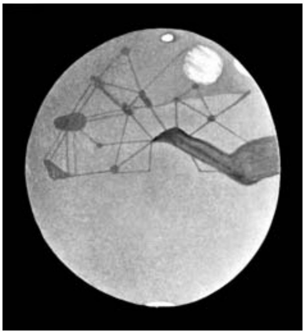
Camille Flammarion, a French astronomer, immediately took in the deeper meaning of Schiaparelli's observations: the canals were artificial and proved Mars to be inhabited. And he was not prudish with his opinions. He came forward with them regularly in articles he wrote for various magazines, especially a publication of his own, *l'Astronomie*. Faithful to his eloquent style Flammarion created fascinating visions of a planet the civilized inhabitants of which, because of a lower gravity compared to Earth, "are by form almost certainly different from us and can fly in its atmosphere."

Not everybody was as unreserved in the enthusiasm for the matter as Flammarion, even though the number of observers seeing the canals grew larger with every passing opposition. Those who where skeptical about the existence of canals tried at first to correctly put forth alternative explanations. At the same time the canalists grew increasingly pronounced in their opinions and unambiguously stated the existence of the canals to be an indisputable fact. Before long the fuse was blown on either side and astronomers

A LONG DISTANCE CALL TO THE RED PLANET

● At the end of the nineteenth century it was a common view that Mars must harbor intelligent life. The spirit of the times is aptly characterized by the case of Pierre Guzman Prize the French mademoiselle Clara Goguet Guzman who died in 1891 stipulated in her will to be created in the memory of her late son. A sum of 100,000 francs was to be given to "the person of whatever nation who will find the means within the next ten years of communicating with a star (planet or otherwise) and of receiving a response." The rules of the prize excluded the communication with the Martians because it was considered to be too easy. Nevertheless, a contact with the inhabitants of Mars were tried to be established in several ways. For example the Finnish mathematician Edvard Engelbert Neovious proposed as early as 1875 a vast system of lamps to be built in the Andes for relaying messages to our neighboring world. At the end of the century the American Serb Nikola Tesla tried to communicate with the Martians with the aid of the new radio technology and in 1899 he even claimed to have received messages from Mars. During the twentieth century observers have seen bright flashes on Mars which some people have claimed to be signals sent by the Martian civilization. In reality they have been reflections of sunlight from the ice crystals on the surface or in the atmosphere of Mars.

began to call each other names in both scientific journals and newspapers. The general public started to get interested in Mars, too, but the uproar on canals would have been confined to an academic wrangle in the long, dusty corridors of universities without the emergence of a man who had so much wealth that he could do whatever he wanted to do. And that is exactly what he did.



Sketch made by Percival Lowell in 1910.

Boston rules!

● Percival Lowell was the offspring of a wealthy Bostonian family. His father had plans for him to take over managing their textile business, but as so often happens in fairy tales, movies, and real life, the prince did not want to become king.

Lowell found a new object of interest after traveling widely in the Far East, especially in Japan, which he wrote several books about. In Christmas 1893 his aunt gave him *La Planète Mars,* a book by Flammarion. It awoke in Lowell a dormant interest in astronomy from his youth and particularly in Mars. He was excited about the observations made by Schiaparelli and had not a single doubt over the existence of the canals. Next spring Lowell was already busy building an observatory in Flagstaff, Arizona. In the observatory named after him, the opposition of 1894 launched a period of Martian research unprecedented in intensity.

Lowell succeeded in seeing with his own eyes what he had expected to see: Martian canals. According to him they could signify only one thing:

> The amazing blue network of Mars tells us that another planet beyond our own is inhabited.

Based on his observations Lowell developed a romantic theory of a civilization dying of thirst on an arid planet. In those days the Solar System was thought to have been born by the accretion of a rotating cloud of gas and dust according to a "nebular hypothesis" proposed by the German Immanuel Kant and developed further by the Frenchman Pierre Simon de Laplace. The main difference with the current theory is that the cloud was thought to have condensed and cooled down starting from the outer edge so that the outer planets are older than the inner ones and thus evolved further.

Mars would already have evolved into a lifeless desert with the dark areas being not seas but dry land, just like the bright areas. The dark, greenish color was that of vegetation, and the changes in hue were due to the changes in the seasonal cycle. With tremendous effort the inhabitants of the planet, advanced well beyond us, had constructed a global irrigation system with which they led the waters from the melting ice caps to the dry equatorial regions. For the waterways to be visible from Earth they should have been tens of kilometers wide, but what actually was seen were the cultivated lands lining the canals like the lush valley of the Nile, that great African river.

Lowell defended his ideas until the very end of his life, even after it was evident that the conditions on Mars were too harsh even for the existence of a dying civilization. In his public lectures and the popular books he had started to publish in 1895 he presented the evidence for his opinions. However, this was all in vain since the hopes for the existence of another, albeit doomed, civilization in the Solar System dwindled fast with more and more detailed and varied observations on various aspects of the planet. There was no water on Mars, not even water vapor. Its atmosphere turned out to be very thin and its composition unsuitable for life, and the surface temperature way too low for the kind of life we know.

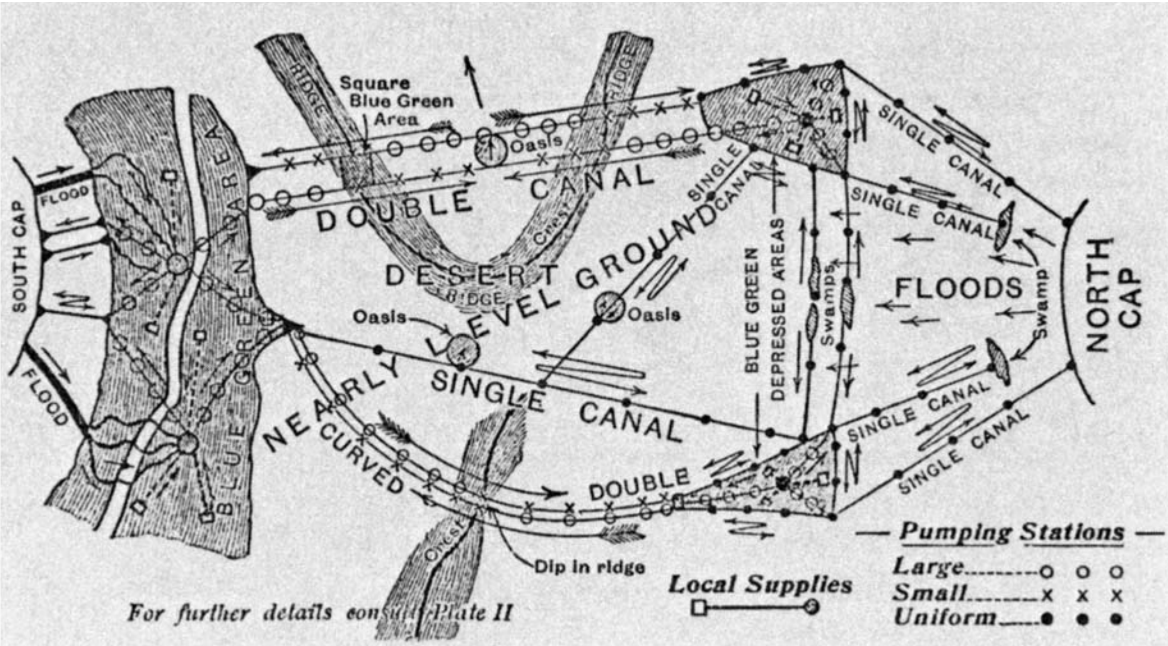
Mental mansion

● The idea of Lowell and his fellows of the canals as a massive construction project of an advanced civilization was not the most imaginative explanation for the network of straight lines. Charles Housden, a British engineer, was still somewhat sensible in drafting a detailed presentation of the canal system with pumping stations, etc. E. H. Hankin, also British, had a completely novel approach to the matter. He wrote in the prestigious science journal *Nature* that instead of a civilization there was only a single living organism, a kind of giant vegetable, on Mars. The "canals" were the creature's tentacles, with which it absorbed the melting waters of the polar caps.

The German Ludwig Kann proposed that Mars was almost completely covered by seaweed, and the canals were in reality ocean currents that were visible because the seaweed had been swept

LIAR, LIAR!

● Percival Lowell's theory was promoted also by the Austrian Spiridion Gopcevic, whose support was not necessarily favorable for the case. Gopcevic titled himself as being "doctor, professor Leo Brenner" – a statement transmitting as much mendacity as can be conveyed with only four words. Brenner founded an observatory concentrating on planetary research on the island of Lussinpiccolo (nowadays Losinj) on the Adriatic Sea, which was even visited by Lowell in 1895. Brenner's reports were fanciful, to say the least. According to them in 1896–97 he managed to see not only all the channels observed by Schiaparelli and Lowell but also 68 new, previously unknown channels, 12 seas and 4 bridges. After the respected scientific magazines refused to publish the sensational reports of this makeshift professor, Brenner founded a magazine of his own titled *Astronomische Rundschau* ("Astronomical Survey") and kept publishing it until 1909. In the very last issue he revealed his true identity – nevertheless still maintaining that he was a count – and solemnly declared that he would give up astronomy altogether. Most probably the world of science did not miss much.



The true nature of the Martian canal system was no riddle to Charles Housden.

free from their paths. Adrian Baumann, another German, claimed that the dark areas on the surface of Mars were dry land bearing both vegetation and animals, and the bright areas glaciers covered by volcanic ash. According to him the "canals" were crevasses in the glaciers caused by volcanoes. The glacial theory was also supported by his fellow countrymen Philip Fauth and Hanns Hörbiger, but they thought the thickness of the cracked mantle of ice covering Mars was 1,000 km. Like Lowell, they all were wrong.

Double canals

● As early as 1881 Schiaparelli first observed a phenomenon, which undermined the credence of the canal reports. He saw some of the canals to be doubled, or "geminated." Sometimes a new canal appeared alongside an older one, and sometimes in the exact location of one canal there suddenly were two canals. Soon this gemination was observed by others, too. The process of gemination could take a couple of days, at times a mere couple of hours. The inventive observers of the 1800s came up with perfectly natural explanations for this phenomenon.

Schiaparelli, for example, who had started to regard the canals as artificial, thought the gemination to be a consequence of the proper functioning of the alleged irrigation system. According to Schiaparelli the water from the melting ice caps needed so sorely by the Martians flooded the arid areas of the planet in springtime. At first they led the waters to valleys, which could preserve the moisture for a somewhat prolonged period of time. The trifling amount of water at the bottom of the valleys was not of much help in the long run, and – in Schiaparelli's own words –

> Therefore the inhabitants have dug canals on the slopes of the valley like the picture depicts. When the snows start to melt in the polar area, the flood is withheld until it has risen to the margin of the upper canals aa. After flooding over, the margin water covers the

> nearby areas ab making them fertile. At that time these areas look like a double canal.

In the end the dwindling water would cover only the bottom of the valley and make that green, and the canal would again be seen as a single line.

It was a clever explanation, but it had one major flaw: it had nothing to do with reality. Ernst Bonsdorff, a Finnish astronomer, wrote as early as 1899 about it in his book *Tähtitiede* ("Astronomy") with a more than justified doubt:

> It is difficult to understand how the gemination of a canal in just a couple of hours in some cases would be possible. Considering the fact that sometimes the original canal seems to be transferred too, one is compelled to assume that the phenomenon is caused by the atmosphere of Mars and thereby not real.

Consequently it had to be an optical illusion. And it was that, but not one caused by the Martian atmosphere.

Brainwork

The canals had not been seen by everybody in the first place, and gradually it became obvious that the sketches of those who had seen them were based more on faith than on knowledge and reality. Later on it was concluded that the canals were an illusion caused by several factors.

One strong motive was, of course, faith in the existence of the canals on the surface of the planet – after all, others had seen them, too. Another important factor is linked with the physiology of seeing: the human eye tends to connect separate details into continuous lines. This effect was proposed as an explanation for the canals immediately after the opposition of 1877, when news of Schiaparelli's revolutionary observations began to spread. This theory can be tested very easily; if the page of a book is looked at from far enough so that the individual letters and words are no longer discernible, the spaces between them form sinuous lines.

The simplest explanation for the canals of Mars is human eye's tendency to connect separate details into continuous lines.

Faith could not have affected Schiaparelli's observations, because he did not have any expectations of seeing canals. In the case of Schiaparelli, the explanation could very well have been his color blindness, the effects of which had already been speculated on by the end of the 1870s. Because of the simultaneous contrast known in color theory, the darker areas on the surface of red, or rather orange, Mars look greenish blue. An observer with color blindness is unable to see the areas as being of different colors but only darker and lighter shades. If there is only a slight difference in brightness between them – as is usually the case with Mars – he is only able to distinguish the borderlines between the areas as narrow lines – "canals."

According to a more contemporary theory the solution to the riddle of straight lines crisscrossing the surface of the planet could be closer than expected, much closer. William Sheehan and Thomas Dobbins, historians of Solar System exploration and experienced observers themselves examined a few years ago not only the sketches made by Lowell of Mars but also of Mercury and Venus. Lowell had seen straight lines on the surfaces of all these planets, though to a lesser degree on Mercury and Venus. Sheehan and Dobbins came to think of comparing the network of lines with the blood vessels of the retina of the human eye and – touchdown!

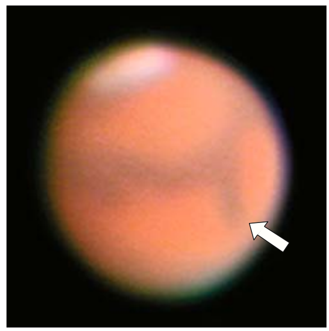
The canals of Mars might have been just a reflection of Lowell's retinal blood vessels in the eyepiece. Strictly speaking this explains only the observations made by Lowell himself, as he saw canals on other planets, too. On the other hand the location and appearance of the Martian canals according to different observers was somewhat dissimilar – just like the retinal vascular systems of different individuals. However, the mystery of the canals is not yet definitively solved, and it might very well stay that way.

Size does matter

● There was one especially weird feature of the canals: the smaller the telescope, the better they could be seen. In the beginning of the 1900s, when belief in the canals was already rapidly dwindling, a French canalist, F. Jonckheere, inquired of Edwin Frost, the director of Yerkes Observatory, whether the canals could be seen with their giant telescope. Frost was clipped in his reply; he told Jonckheere their 40-in. refractor was too large for that.

Lowell limited the 60-cm aperture of the largest telescope of his observatory to 30 cm with a mask, and he recommended this procedure to others, too. This way the effects of Earth's atmosphere would be as small as possible. The canals were often observed with reflectors with an aperture of 20–30 cm, even with refractors with lenses of 10 cm or less. Notwithstanding their size they showed dozens of canals whereas astronomers working with large telescopes usually managed to not see a single canal.

In a way, the advocates of tiny telescopes might have had it right. The restlessness of Earth's atmosphere is mainly caused by "air cells" of differing densities and thus with differing refracting indices. As a result the image in a telescope seems to "boil." The size of the cells is such that with telescopes larger than 30 cm in aperture their effects begin to be more and more obvious – though many astronomers, both professional and amateur, disagree about this. Nevertheless it was folly to claim that small telescopes could clearly show something completely invisible with large telescopes. With increasing aperture and resolution such details will not disappear entirely.

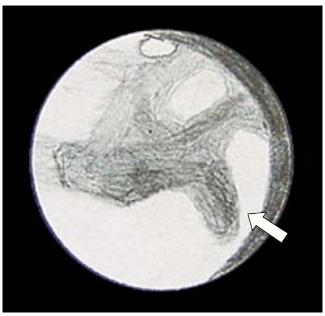


The same side of Mars in a digital image and in a sketch. Kimmo Hytti took the photograph with a 25-cm reflector on July 26, 2003, more than a month before the opposition; the polar cap was still rather large. Veikko Mäkelä made the sketch with a 14-cm refractor on October 3, 2003; the polar cap had shrunk considerably.

Technology not always the answer

● Why not solve the dispute on the existence of canals by means of photography? That way the expectations, beliefs and preconceptions of an observer could not affect the results. Photography was invented in the beginning of the 1800s, and the first ever photograph of a celestial object – the Moon – was taken by the American John Draper in 1840.

Many objects, like the mystical "nebulae," the true nature of which were definitively determined only in the 1920s to be extragalactic entities, revealed in photographs details that could not have been anticipated by visual observations. Would it not be the same with planets and especially with Mars? Wouldn't photographs have revealed Martian details the same way and solved the existing puzzles? The answer – unfortunately – is no.



It is not that this wasn't attempted, though. Mars was photographed industriously, for example, at Lowell Observatory in 1905 and on an expedition Percival Lowell financed in 1907 to the extremely arid Atacama Desert in Chile. The expedition was led either by the American David Peck Todd, professor of astronomy at Amherst College in Massachusetts, or his fellow countryman Earl C. Slipher, staff astronomer of Lowell Observatory, depending on who you asked. Nevertheless, as a result of this expedition the canalists had some 13,000 photographs of Mars taken under excellent conditions through a superb 18-in. refractor. Lowell himself – along with several supporters of his ideas – claimed the photos proved the existence of the canals without a doubt, but actually they did not.

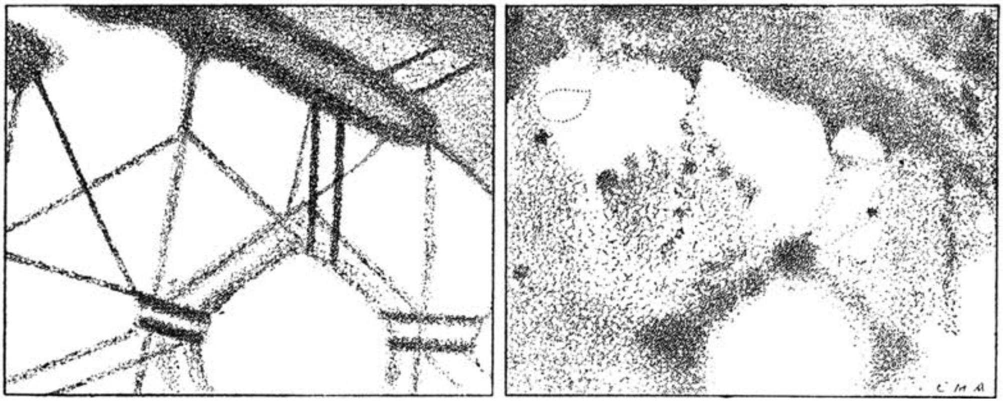
Again, the problem was not Mars but the atmosphere of Earth. The fuzziness caused by the differences in density and air currents distorted the images of all the celestial objects in the same way when registered on photographic plates, but the details on the surface of Mars are so tiny and dim that even the most insignificant blur made them completely unresolvable. At the end of the 1800s and the beginning of the 1900s the sensitivity of photographic materials was rather poor, so the times of exposure tended to be so long that the movements of Earth's atmosphere blurred the image completely. However, the human eye is able to exploit the shortest moments of calm during which the blurry image "freezes" into sharp view.

A sinking ship

● With the 1800s coming to a close the situation of the canalists grew ever more dire. Simon Newcomb, an English astronomer and one of the sturdiest opponents of Lowell, argued one of the most weighty cases against the existence of the Martian canals. At first he pondered what would be the preconditions for the canals to be seen from Earth: what would their width have to be? Newcomb assumed the canals would reflect half the light the rest of the surface did and arrived at a minimum width of 40 miles. Next he took into account the minimum number of canals reported by Lowell (400) and their average length (2,000 miles). It gave him a percentage of 60 for the total coverage of canals on the Martian surface. However, most of the planet is made up of something other than canals, even according to their advocates. Thus – in Newcomb's own words –"the objective nature of the canal system is not nearly proved."

For any canals to exist on Mars – whether carved by nature or constructed by intelligent civilization – there should also be water, some of it inevitably in the atmosphere in the form of water vapor. A spectrograph, a new instrument invented in the 1800s, would reveal the spectrum of any celestial object from which its atmospheric composition could be deduced. When the sunlight reflected from its surface passes through the atmosphere of Mars the potential water vapor would absorb certain wavelengths, leaving dark lines in the spectrum.

In studying the spectra of Mars or any other celestial object the problem is – once again – the atmosphere of Earth. The light has to pass through it before reaching the telescope and the instruments attached to it. There is water vapor in the atmosphere of Earth, and the spectral signature induced by it has to be eliminated. There is an ingenious solution to the problem: the spectra of both the Moon and Mars are registered at the same time. The Moon has no atmosphere, so any signs of water vapor in the lunar spectrum originate in the atmosphere of Earth. If there is a difference in this



Martian canals in a sketch made by Giovanni Schiaparelli with 19- and 22-cm refractors and the same area in a sketch made by Eugène Antoniadi with an 83-cm refractor.

respect between the spectra of the Moon and Mars, it is caused by the water vapor in the Martian atmosphere.

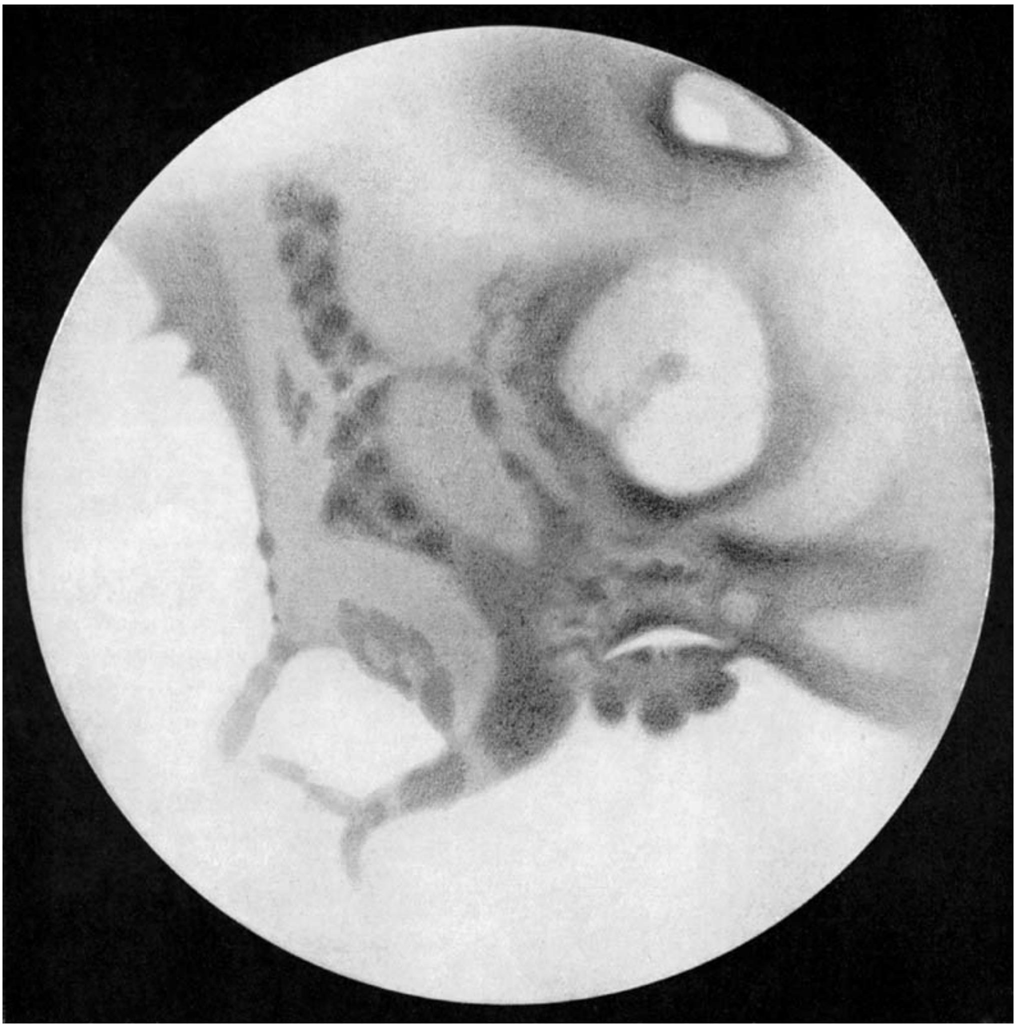
As early as 1867 some observations suggested that there was water vapor in the atmosphere of Mars. This result satisfied the scientists for a long time, since it was in harmony with the other beliefs about Mars, that there were seas and polar ice caps on the planet. However, the observations pointed in the direction of the atmosphere of Mars being much thinner, the atmospheric pressure being much smaller, and the surface temperature being much lower, which cast doubts on the existence of water vapor. And the doubt was more than justified; with increasingly accurate observations it became more and more evident that the atmosphere of Mars did not contain water vapor. (Actually it does, but in such small amounts that its existence was verified only years later.)

Final countdown

● One of the most radical weathercocks in the history of astronomy was the Turkish-Greek Eugène Antoniadi, who entered the arena at the beginning of 1890s. He left for France in 1893 after being appointed to a post at the observatory of Flammarion, a renowned canalist. As a young man susceptible to influence, Antoniadi managed to observe more than 40 canals on the surface of Mars during opposition the following year. After being nominated the leader of the Mars section of the British Astronomical Association 2 years later he began to change his mind.

After each opposition Antoniadi compiled a comprehensive report on the observations of Mars by the members of the section. This gave him an exceptionally thorough idea of the whole range of observations. Gradually, Antoniadi became convinced that the canals were an illusion which could be caused by perhaps eye fatigue; an observer might have to stay at the telescope for hours waiting for the fleeting moments of calm atmosphere. According to Antoniadi another explanation could be the tendency of the human

A sketch made by Antoniadi on September 20, 1909. There is no trace of the canals in this sketch.

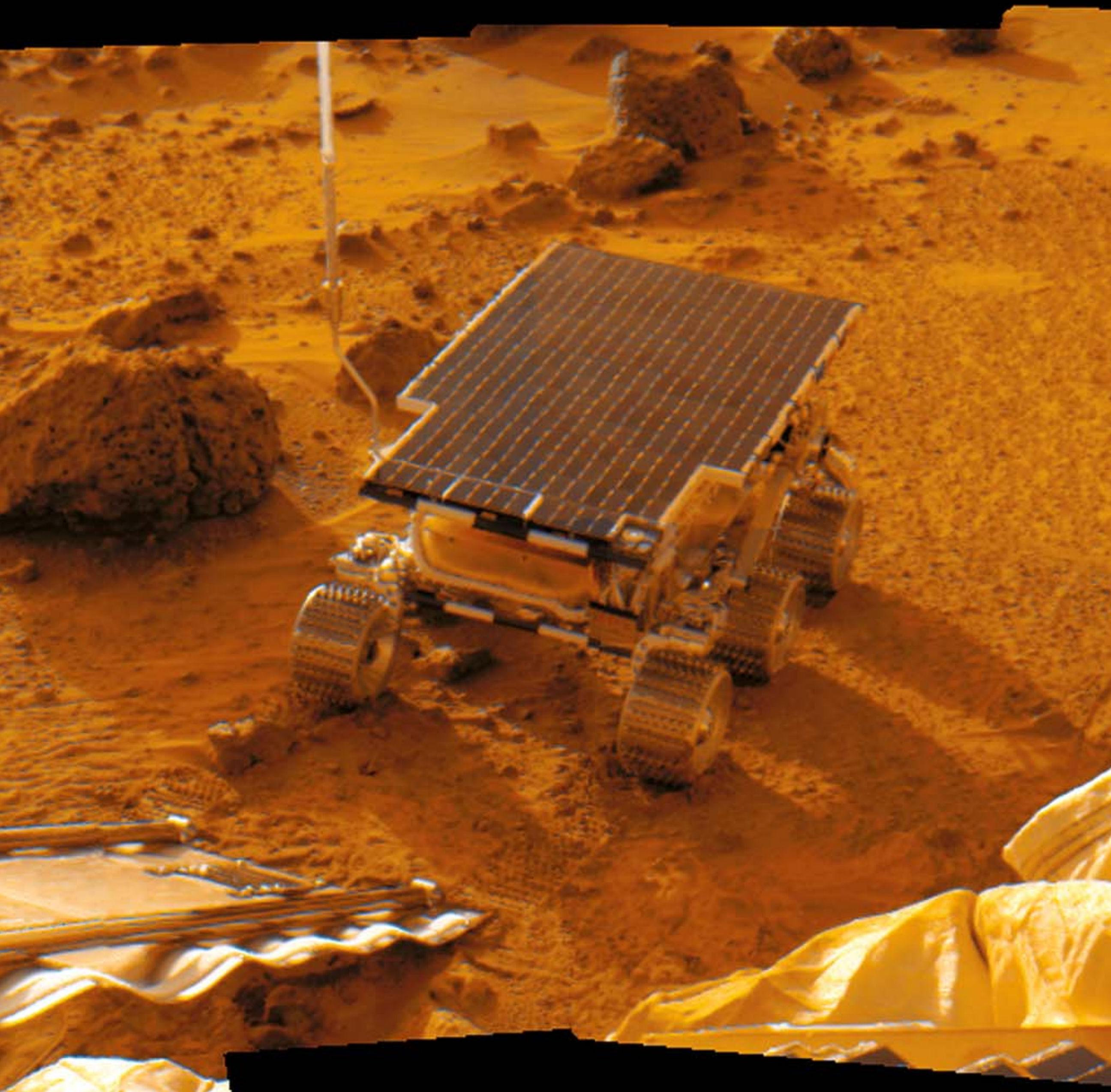


eye to connect separate details proposed earlier. Antoniadi was finally so certain in his opinions that while preparing a map after the 1901 opposition based on sketches made by several observers he decided to omit the canals altogether. For the first time in a quarter of a century it was the first map showing no canals.

The decisive blow was delivered by the perihelic opposition of 1909. Antoniadi had already established that he was as uncompromising in opposition to the canals as Lowell was in defending them. He had access to the 83-cm refractor of Meudon Observatory – the biggest in Europe – and the consequences were devastating. The observing session that later turned out to be the most crucial was on September 20, Antoniadi's first night at the telescope, when the atmosphere was more tranquil than at any other time during his entire career before or after.

The image of Mars was rock steady, and the darker and lighter areas resolved into irregular patterns of increasingly small detail. There was no trace of anything artificial, no straight lines, no regular patterns, nothing at all reminiscent of the geometric sketches made by Schiaparelli, Lowell, and many others.

After the fatal year of 1909 canals were no longer discussed, at least not with any real credibility. This was taken care of by celestial mechanics and mundane politics. The distance between Earth and Mars at the time of opposition grew ever larger, and not until 1924 would the Red Planet be observed again under favorable conditions. In between there was World War I raging on this planet of our own, and it made people concentrate on more down-to-earth matters. Percival Lowell had plans for future oppositions, but they were never realized. Lowell died of cerebral hemorrhage in November 1916, and with him the whole civilization of Mars perished. Actually its fate was even more tragic: it had never existed in the first place.



04

PLANETARY UPS AND DOWNS

What happened?

– Eric Idle: *The Road to Mars* (1999)

As a result of the "crazy years" at the end of the nineteenth and beginning of the twentieth century almost everything that was possible to make out of Mars with terrestrial telescopes was made out. Observations, for example, on the composition of the atmosphere did get more accurate with the increase in sensitivity of instruments, but the most essential aspect, the true nature of the surface of Mars, was unknown and stayed that way.

All of the actual surface features, except the polar caps and albedo features, were practically unidentifiable, if not indiscernible, in telescopes. Only few observers, most notably the American astronomer Edward Emerson Barnard and his fellow countryman, amateur astronomer John Edward Mellish, reported seeing craters on the surface of Mars, but these observations – those of Mellish already lost – have always been a matter of controversy because the alleged craters do not coincide with any known formations.

The veil of mystery created by the great distance involved began to lift only with the development of space technology in the 1960s, but it was not a painless process . . .

M. Hotakainen, *Mars*, DOI: 10.1007/978-0-387-76507-5_4,
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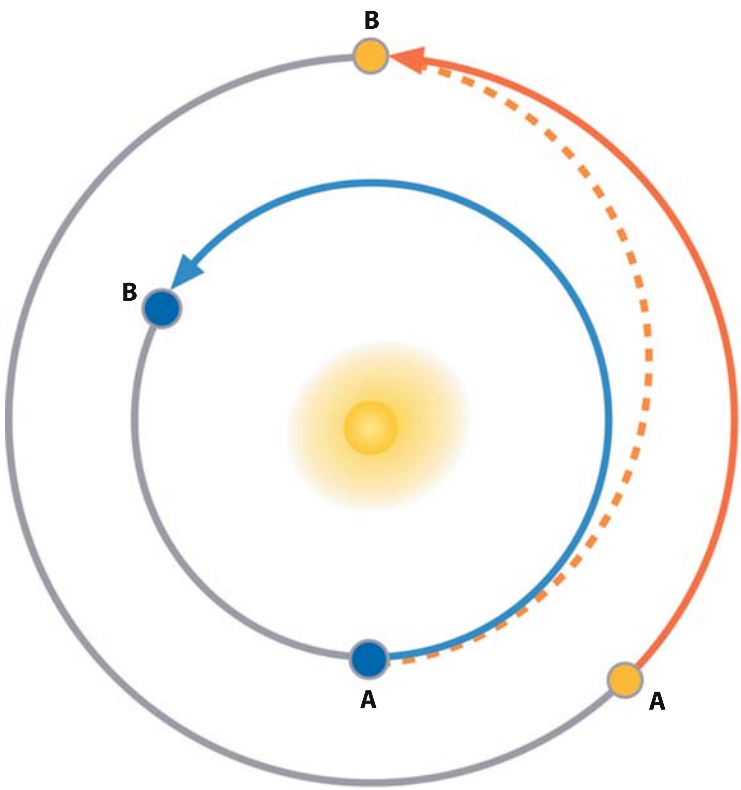
Great Galactic Ghoul

● It is not easy to get to Mars, at least not in one piece. Ever since the Soviets' *Marsnik 1* and *2* launched in 1960 were destroyed without even reaching Earth orbit, the history of Martian research has been infected with failures caused by technical problems, embarrassing mistakes, and sheer bad luck. Adding up all the flybys, satellites, and landers there have been over 40 attempts of sending a spacecraft to Mars. Less than one-third have been successful. If the triumphs of the past 10 years were omitted, the number of successes would be cut down to half. People in the field of space research have a long-standing joke about a Great Galactic Ghoul, a cosmic rascal residing somewhere between Earth and Mars eating up planetary probes sent by poor uninformed humans.

A more scientific approach to the problems of Martian research with space probes reveals two facts about why the

Probes sent to Mars travel along an elliptical path called Hohmann's Transfer Orbit. During the flight Earth and Mars move along in their orbits from points A to points B.



trip to Mars is so difficult: it is a long way to Mars, and Mars is far away. These may sound like the same thing, but the problems caused by them differ from each other. Even though Mars is at its closest "only" 55 million km from Earth, a probe sent to Mars has to travel hundreds of millions of kilometers to get there. The launch vehicles used today are not nearly powerful enough to send a probe directly to Mars or any other planet, for that matter.

Present technology requires a trajectory, or orbit, with the shape of half an ellipse, a so-called Hohmann transfer, with one end at Earth and the other at Mars. A probe traveling in an orbit like this has to follow a large curve around the Sun to reach its destination. The benefit of this kind of trajectory is that you only need to accelerate at the beginning of the flight and Newton's mechanics takes you there with just minor course corrections – and the obvious deceleration in the end.

Maneuvering Mars probes from Earth is difficult because of the radio delay of up to an hour.

That is why Earth and Mars have to be in a suitable position in relation to each other at the time of launching a probe. This makes life difficult for the designers and builders of the probes. On the wall of the Jet Propulsion Laboratory (JPL), which is responsible for most of the space research projects of NASA, there hangs a plaque with a saying adapted from the rear-view mirror of American cars: "Objects in calendar are closer than they appear." This aptly symbolizes the problems with schedules in working with planetary probes. They are emphasized in the case of Mars, since it is in a suitable position rather seldom, only once in about 2 years. A launch window for sending a probe opens up just for 1 minute each day for a period of 4 weeks. If this window is missed, the project is delayed for more than 2 years or, in the worst case, canceled altogether.

The long flight of a probe through space creates some special problems. One of the biggest is that the electronics of the probe are a target for particle bombardment for months, with possibly fatal consequences. In Spring 2003 the Japanese *Nozomi* ("Hope") probe was hit by a particle storm from the Sun, destroying electronics and crippling the craft. After that the only thing scientists could do was to hope that *Nozomi* would miss the planet – as it did – and not crash onto the surface, leaving microbes from Earth polluting Mars. In that case there certainly would have been life on Mars.

The great distance to Mars causes trouble especially on arrival after the long journey. The radio signal from Earth to Mars travels at the speed of light, which is fast, but still finite. At the time of closest approach it takes just about 3 minutes for a signal to cross the distance between the planets, but when the planets are on opposite sides of the Sun, a signal sent from Earth to Mars reaches the probe more than half an hour later. A probe is completely on its own whether it is getting into orbit around the planet, landing on the surface, or avoiding a rock in its path. All flight controllers can do is to follow the unfolding of events with a delay of at least several minutes, at worst over an hour; the probe has to perform all the necessary maneuvers automatically. If it fails to do so, the game is over and probably no one will ever know what went wrong.

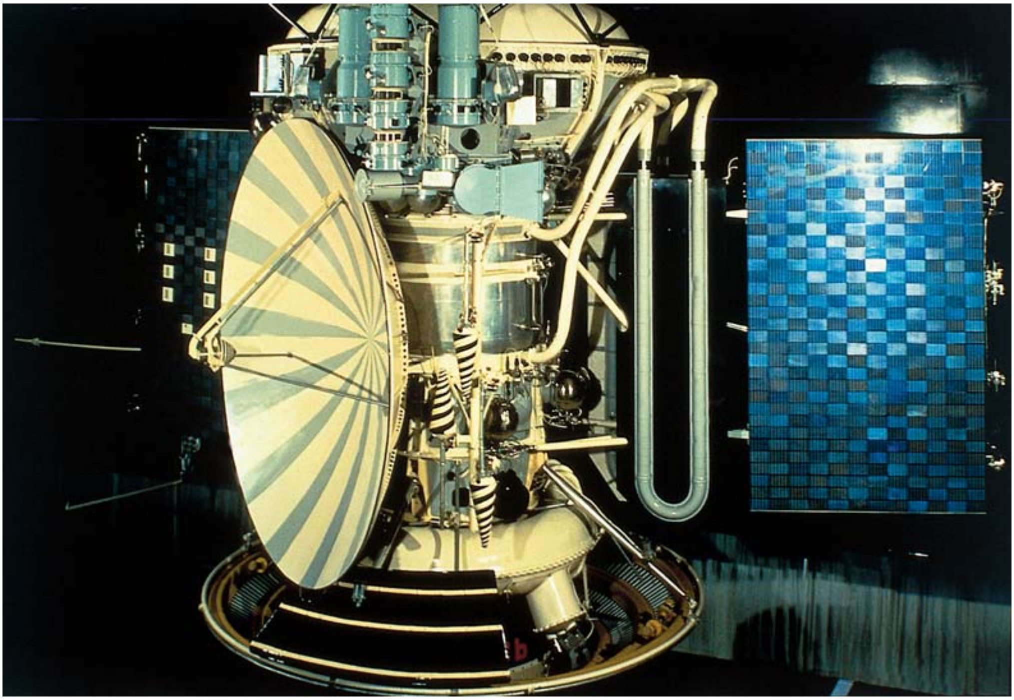
Probe cemetery

● One obvious reason for many failures with space probes is that there have been so many attempts. Mars is the most thoroughly studied planet in the Solar System – after Earth, of course. It is the first planet a probe flew by at close range, the first planet a probe has studied from orbit, the first planet a probe has landed on, and the first planet a robotic rover has traveled on.

The poor score of the first Mars probes can in large part be explained through inexperience. Because of lack of knowledge the designing and building of the probes had to be based on enlightened guesses – which were not always good ones. In the 1960s the still-new technology of launch vehicles was also rather unreliable, and often malfunctioning rockets caused a probe to miss the planned orbit or even to be destroyed.

In the early years of the Space Age the Soviet Union had a head start over the United States. The Soviets fussed with Mars for many years before the Americans even got started. But unlike the race for the Moon, which the United States won only in the homestretch (despite the fact that the early triumphs of the Soviets in space were in part just "smoke and mirrors"), in Mars studies the Soviet Union dragged behind almost all the time. It had powerful rockets to send large payloads into space, so they did not have to skimp on the size of the probes: the first Soviet Mars probe weighed almost twice as much as the first American probe. The problem was the technology of the probes, which could best be described as scrappy. Especially in the field of electronics the Americans were far ahead, and this was particularly important for long planetary flights.

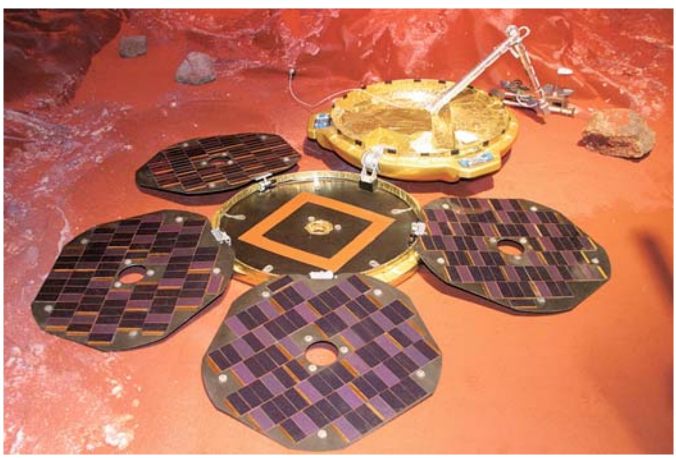
A good example was the trio of probes arriving at Mars at the end of 1971: the Soviet *Mars 2* and *Mars 3,* and the American *Mariner 9.* They all performed flawlessly and went into orbit around the planet according to plans. Unfortunately, at that time, Mars was experiencing the biggest dust storm ever observed, and there was nothing to be seen of the surface. *Mariner 9* was reprogrammed to wait for the dust to disperse, but the programs of the Soviet probes were loaded prior to the launch and they could not be altered. *Mars 2* and *Mars 3* took mainly photographs of a planet wrapped in dust and sent the doomed landers straight into the eye of the storm.



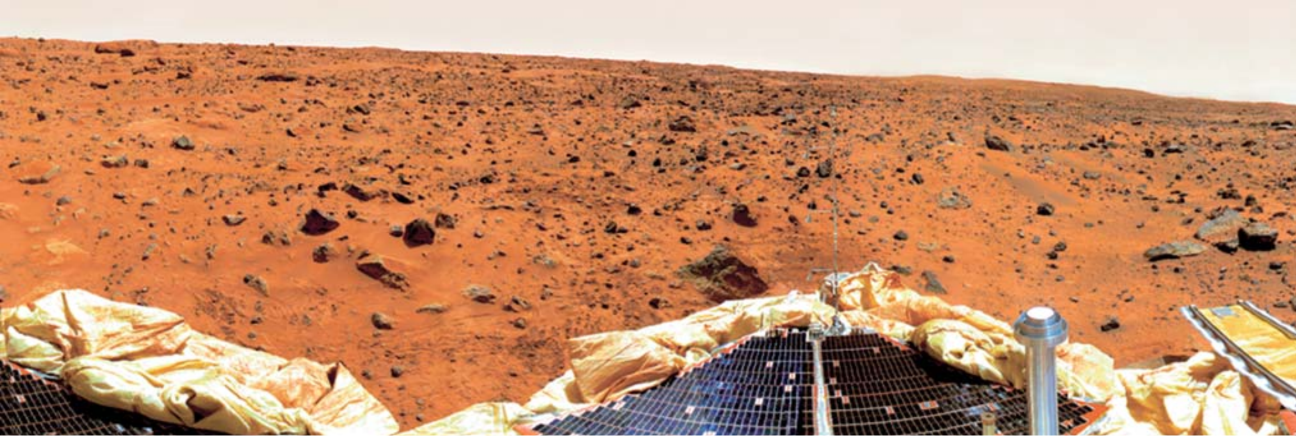
Mars 3, *one of the unlucky probes of the Soviet Union. Upon arrival Mars was experiencing one of the largest dust storms ever. Despite that, the probe managed to take photos showing the Red Planet both during (left) and after the storm.*

In the 1970s and 1980s there was a hiatus of almost 10 years on both sides of the Iron Curtain in sending probes to Mars, but bad luck was more or less a permanent state of affairs even after that. The Soviets' *Phobos 1*, launched in 1988, was lost on the way to Mars, and its sister ship *Phobos 2* fell silent after circling the Red Planet for about a month. The *Mars Observer,* the first American probe in 17 years, was also lost on the way, when the fuel tanks exploded while they were pressurized. *Mars 96,* a Soviet heritage mission, the first and to date the only Russian Mars probe, plummeted into the Pacific in 1996 after a malfunction of the launch vehicle. In 1999 the American *Mars Climate Orbiter* was incinerated in the Martian atmosphere: it got too close to the planet because of a mix-up in units of measurement while calculating the orbit. Later that year the *Mars Polar Lander* was destroyed while attempting a landing in the southern polar area of Mars. The retro rockets were shut off when the probe was still at an altitude of dozens of meters, and it fell like a rock. The *Deep Space 2* miniprobes, which were supposed to hit the surface at a somewhat diminished speed and to send information from below the ground, were lost in the mishap, too.

The most recent failure was the destruction of *Beagle 2,* a lander piggybacking on the European Space Agency ESA's *Mars Express.* (This craft was named after the famous HMS *Beagle*, the second voyage of which, in 1831–36, enabled Charles Darwin to make observations that later led him to develop the theory of evolution by natural selection.) *Beagle 2* was supposed to land on Christmas Day 2003 on Isidis Planitia to study the geology of the region and search for signs of water and possible life. Everything went according to plans until the lander was supposed to play a melody of nine notes commissioned from the British pop band Blur as the sign for a successful landing. Not a beep was heard, not to mention any music. *Beagle 2* was lost. The real reason for the



Beagle 2 *was nicknamed "The Pill" after its British chief designer Colin Pillinger.*



The solar panels and the ramps of the Pathfinder *lander, with the Sojourner rover studying a rock named "Yogi."*

cause of the failure is still unknown, but one possibility is that the atmosphere of Mars was thinner than expected, and it did not slow the probe down enough. Another possibility was that the air bags supposed to cushion the impact ruptured. After all, this had happened in the tests.

First Internet probe

● July 1996 marked a new era in Martian research – in more ways than one. The American *Pathfinder* probe carrying with it the tiny Sojourner rover landed successfully on the Red Planet. A couple of months later the *Mars Global Surveyor* reached orbit around Mars and started its operations, which were destined to continue for almost 10 years. For the first time in more than 20 years up-to-date information of unprecedented detail was available from Mars. The *Mars Global Surveyor* was capable of measuring the topography of the planet with a resolution of 20 cm. And what was most important, for the first time scientists had an instrument capable of moving around on the surface of another planet. In 1967 the Americans did test moving around on another celestial object when *Surveyor 6* landed on the Moon, but all the spidery probe did was to make a single jump of a couple of meters with its rocket engines.

Another novelty was the way *Pathfinder* landed: it went straight down onto the surface of the planet without first going into orbit around Mars. The probe was slowed down at first by a heat shield protecting it from the atmospheric friction and then with a huge parachute. The impact was cushioned with large air bags that protected the probe while it was bouncing on the surface before it

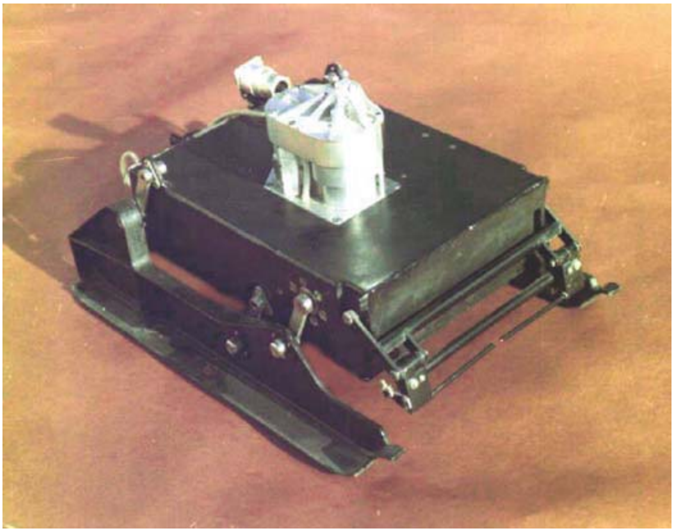
came to rest. After that the tight package opened up like a flower and let the rover drive on the surface.

Pathfinder/Sojourner was also the biggest Internet event ever. A home page with rapid updating was set up for the probe, and during the first month it got more than 560 million hits; the record for 1 day was 47 million hits. Never before had a planetary probe attained so much publicity so fast. The images sent by the probe were on the Internet almost in real time. True space replaced virtual space; in principle humankind had set its feet on the surface of Mars.

Originally, *Pathfinder*/Sojourner was planned to just be a technical test flight. It was to be used to test new solutions that could be applied to future scientific probes. Planetary scientists did not settle for that, though, but very quickly developed an ambitious but successful research program for the mission. The operation period – well over 3 months – of the lander and the rover was triple of that planned. *Pathfinder* sent information on Martian weather, such as temperature, atmospheric pressure, winds, and clouds. Sojourner, a kind of midget geologist, studied the composition and structure of the soil and rocks in an area of about 200 m^2. The observations validated the earlier assumption that the landing site, Ares Vallis, was an ancient flood plain.

The red pioneers

● In spite of its achievements, Sojourner was not the first rover to be sent to Mars. Its predecessors, the Soviet PROP-Ms, were launched about a quarter of a century earlier. They traveled with



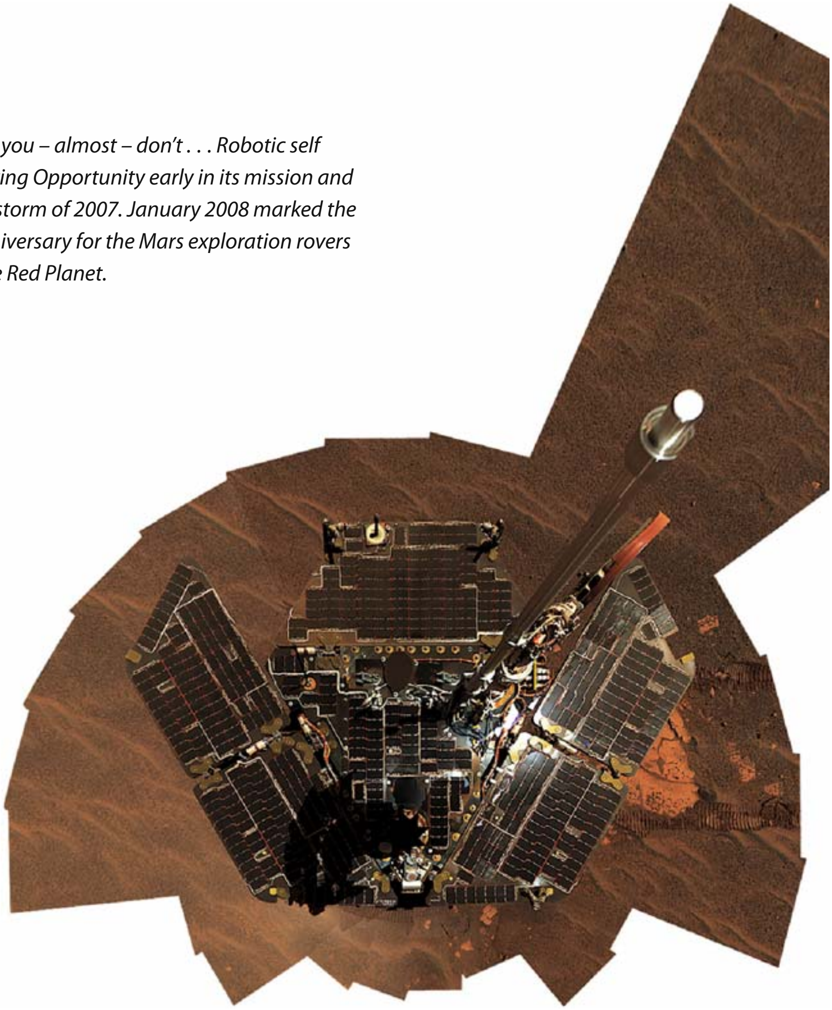
the ill-fated *Mars 2* and *Mars 3* probes. The idea of sending a vehicle to the surface of another celestial body did not come out of the blue, and it was not as absurd as it might have seemed. The Soviet Union had successfully sent the Lunahod 1 rover to the surface of the Moon in 1970 and Lunahod 2 three years later.

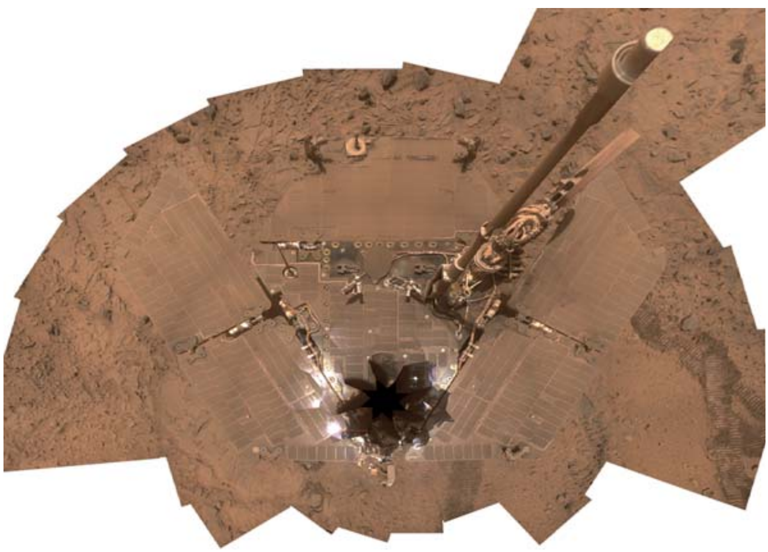
A model of PROP-M rovers taken to the Red Planet by Soviet Mars 2 *and* 3*, and later on by* Mars 6 *and* 7 *– with no luck*.

However, there are rovers and there are rovers. While the Lunahods on the Moon could be remotely controlled from Earth, a rover sent to Mars had to operate independently. There is an inevitable time delay in sending a radio signal to Mars, and it is that which makes direct remote control impossible. By the time an image of a possible danger sent by a camera reaches Earth the rover will have already fallen down a crater or been crushed at the bottom of a ravine. Mars rovers had to have versatile computers that could be programmed to perform complex maneuvers and automatic systems based on artificial intelligence capable of recognizing unexpected emergencies and avoiding them.

Typically for the Soviet era nothing was revealed of the pioneering rovers, either before flight or after. Actually, it will never be known how they would have performed, since the problems were with the mother ships and the rovers never did have a chance of showing their capabilities.

Now you see it, now you – almost – don't . . . Robotic self portraits with glittering Opportunity early in its mission and Spirit after the dust storm of 2007. January 2008 marked the amazing fourth anniversary for the Mars exploration rovers on the surface of the Red Planet.





A 90-day warranty

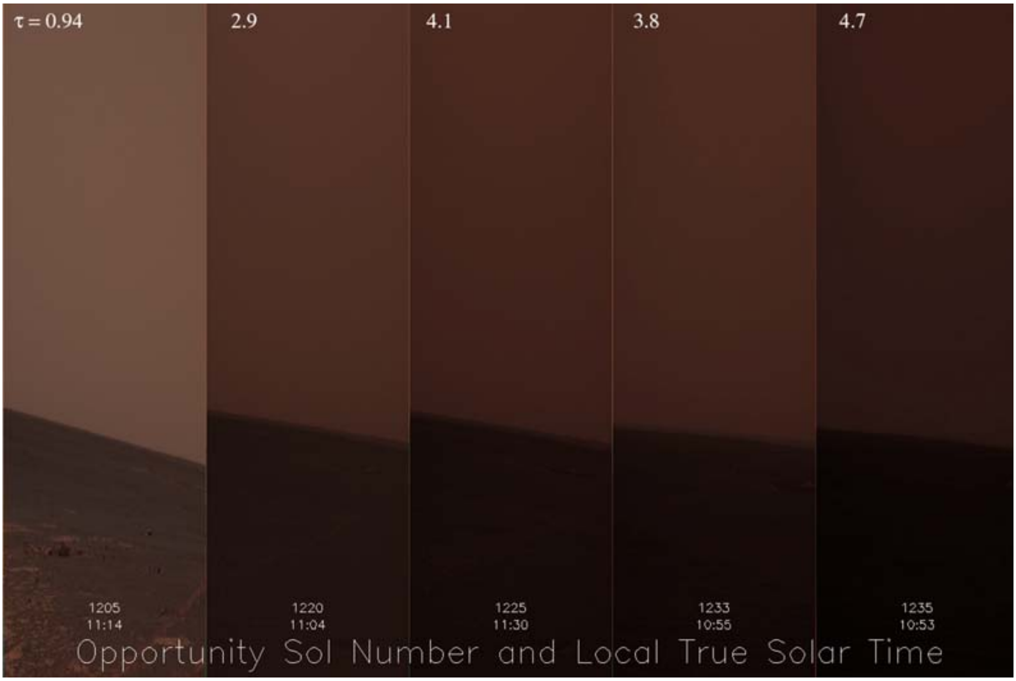
● In January 2004 both hemispheres of Mars received a bouncing rover using the same proven landing method – with the bonus of retro rockets – as *Pathfinder*/Sojourner had used. However, that is the end of the similarities. The size of Sojourner is often demonstrated by comparing it with a microwave oven, while the twin rovers – Spirit and Opportunity – are comparable to a dining room table.

While Sojourner managed to potter for a total of 100 m in 3 months, Spirit and Opportunity can do the same and then some in a day – even though a speed of about 5 m a minute does not exactly take your breath away. By their first anniversary on Mars Spirit had traveled 4 km and Opportunity more than 2. A "warranty" given for the rovers was 90 days, but they have outlived their warranty more than 10-fold.

In addition to instruments studying the composition and structure of the Martian soil and rocks the rovers are equipped with cameras pointing in almost every direction. The images sent by Spirit and Opportunity have become familiar to people surfing the Internet; the home page of the rovers had 9 billion hits during the first year of operation. The most impressing imagery are the wide-angle panoramas assembled of images taken with the stereo cameras, first tested on *Pathfinder,* standing atop the high mast on each of the rovers. Through these "eyes" the scenery can be viewed as if one were standing on the surface of Mars.

The viewpoints of Spirit, Opportunity, and Sojourner can be compared with each other by a very simple test. To see Sojourner's view of the surrounding landscape, you can lie on the ground and look around. Spirit and Opportunity observe their surroundings from the same level as a person 160 cm tall standing up.

In December 2007 the rovers had been operating for more than 1,300 days, two Martian years. They had endured Martian winters with little sunlight for the solar cells, boggy sands, steep slopes, dust devils, a stuck wheel, and a severe dust storm impairing the visibility and obscuring the Sun. Nevertheless,



The lighting conditions changed dramatically while the dust clouds gradually engulfed Mars in 2007. The numbers at the top, denoted with the Greek letter tau, are the values of atmospheric opacity: the lower the number, the clearer the sky. At worst the airborne dust blocked almost 99% of the sunlight, which is the only source of energy for the rovers. Thus, they had to cease most of their activities until the skies cleared. The sol numbers at the bottom correspond (left to right) to June 14, June 30, July 5, July 13, and July 15, 2007.

Opportunity had managed to travel 11.6 km and to take some 90,000 images, while the distance covered by Spirit was 7.3 km and the number of images taken in excess of 100,000. The mission of the rovers has been extended – once again – until the end of 2009.

The main goal of Spirit and Opportunity was to find signs of water in the terrain, soil, and rocks around their landing sites. And they have indeed found them, in more abundance than expected.

The campaign continues . . .

At the moment, Mars and Martian water are studied by more probes than most planets have been visited in total. In addition to the twin rovers still roaming the surface, the planet is orbited and scrutinized by the veteran probes *Mars Express, 2001 Mars Odyssey,* and the *Mars Reconnaissance Orbiter.*

Mars Express – unlike *Beagle 2,* which it carried with it – is operating as planned, mapping the topography of the planet

Viking 1 *Chryse Planitia 22.48°N 49.97°W*

Viking 2 *Utopia Planitia 47.97°N 225.74°W*

Pathfinder/*Sojourner Ares Vallis 19.33°N 35.55°W*

Spirit Gusev 14.57°S 184.53°W

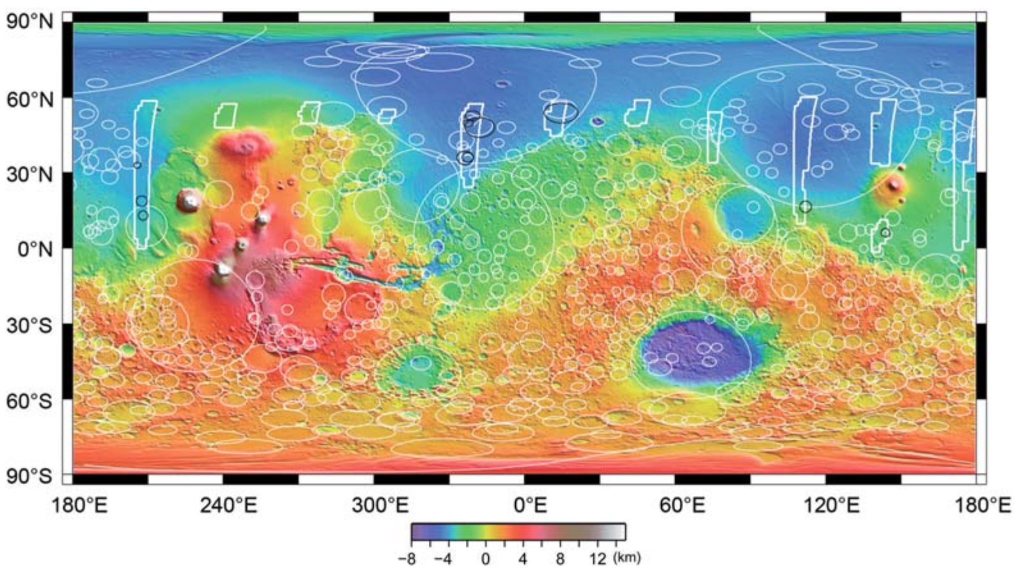
Opportunity Meridiani Planum 1.95°S 5.53°W



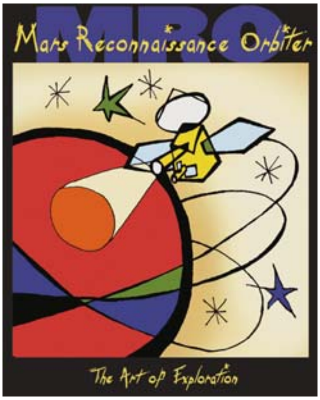


with a high-resolution stereo camera. In November 2007 it reached a remarkable milestone by completing 5,000 orbits of Mars, and about a month later, on Christmas Day, it started its fifth year of research in the vicinity of the Red Planet. The only major problem encountered thus far has been with the MARSIS (Mars Advanced Radar for Subsurface and Ionospheric Sounding), the radar used for the study of underground ice deposits and the properties of subsurface layers. Opening the antenna was somewhat postponed because of the fear that the movement of the 20-m-long booms might damage the other instruments on the probe. However, the concern was unnecessary, and the radar has provided a wealth of remarkable findings both on the extent of ice and the buried landscapes of Mars, which included – one could say – another multitude of impact craters.

The objective of the *Mars Odyssey* – in addition to studying the composition of the surface – is to map water and ice. By measuring the amount of hydrogen in the topmost layers of the ground the probe is capable of determining the real amount of water on Mars whether in solid or liquid form.



MARSIS radar system of ESA's Mars Express *is capable of penetrating the surface layers and has revealed the innards of the Red Planet. Beneath the myriads of craters there is a wealth of buried formations given birth by even more ancient impacts.*



The Mars Reconnaissance Orbiter *has been studying Mars since March, 2006, with its HiRISE camera and a number of other instruments.*

After the failures of the *Mars Climate Orbiter* and the *Mars Polar Lander,* NASA's Mars program was built anew at the beginning of the twenty-first century. The main goals stayed the same: to get a better understanding of the planet's past and to find ways to look for possible signs of life. An early plan was to send both a lander and an orbiter during every launch window, or every 26 months. In the revised program the number of probes was cut down to half and consecutive windows will be used to launch an orbiter and a lander, respectively. This makes it possible to have more margin in designing and building the probes and to make use of the experience gained in the earlier missions.

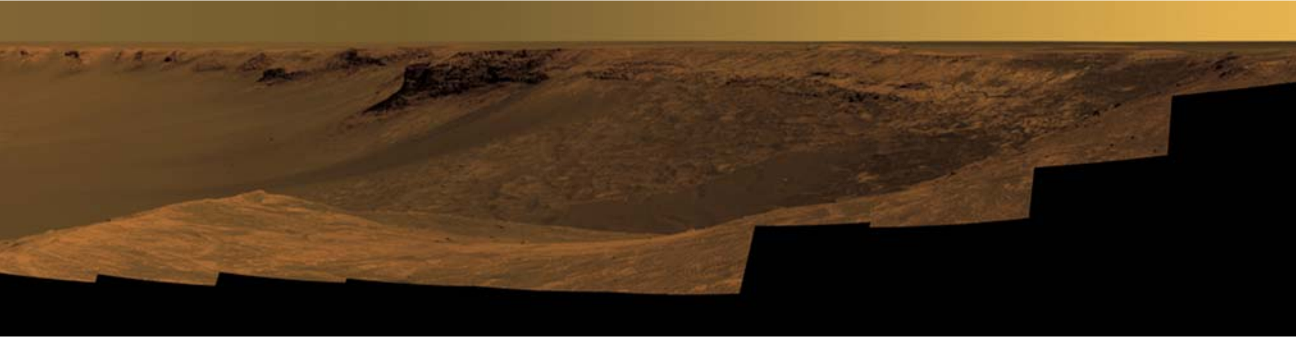
The program is proceeding at a good, if not breathless, pace. *Mars Odyssey,* Spirit, and Opportunity are already part of it. The *Mars Reconnaissance Orbiter* launched in August 2005 is capable of

With the current arsenal of probes studying Mars it is possible to examine the Red Planet from different viewpoints. Victoria crater was photographed from the orbit by Mars Reconnaissance Orbiter *and from the surface by the Opportunity over (next two pages) about to enter this 800 meters wide crater. According to orbital observations the sulfate-rich layers visible on the crater wall might hide clay minerals beneath them. This could indicate a past transition from wetter climate with rainfall to more arid conditions with only groundwater rising at times to surface. As the water evaporated, it left sulfate minerals behind.*

imaging the surface with a resolution of 20 cm. In July 2007 *Phoenix,* the first probe in the smaller and cheaper "Scout" class, was launched. It successfully landed at the northern polar latitudes in May 2008 and began working on the riddles of the Martian arctic. *Phoenix* will be capable of digging trenches about 50 cm deep with its robotic arm so that it can study the underground ice and – perhaps – the sign of ancient life with its miniature laboratories, gauges, microscopes, and cameras.

The Mars Science Laboratory, a revised edition of the rovers operating on Mars at this very moment, will be launched in 2009. With a size about double its predecessors it will accommodate a selection of instruments with which scientists will be able to research the geology of the surface, the distribution of water, and the meteorology of the atmosphere. And its operations will not depend on the Sun being visible in the sky: Mars Science Laboratory will be powered by a radioisotope thermoelectric generator instead of solar cells.

On June 1, 2008, or sol 7, the seventh Martian day of the mission, the Phoenix *lander made its first practice dig with the Robotic Arm into the soil of the Red Planet. The green band is due to a loss of imaging data taken through one of the filters.*



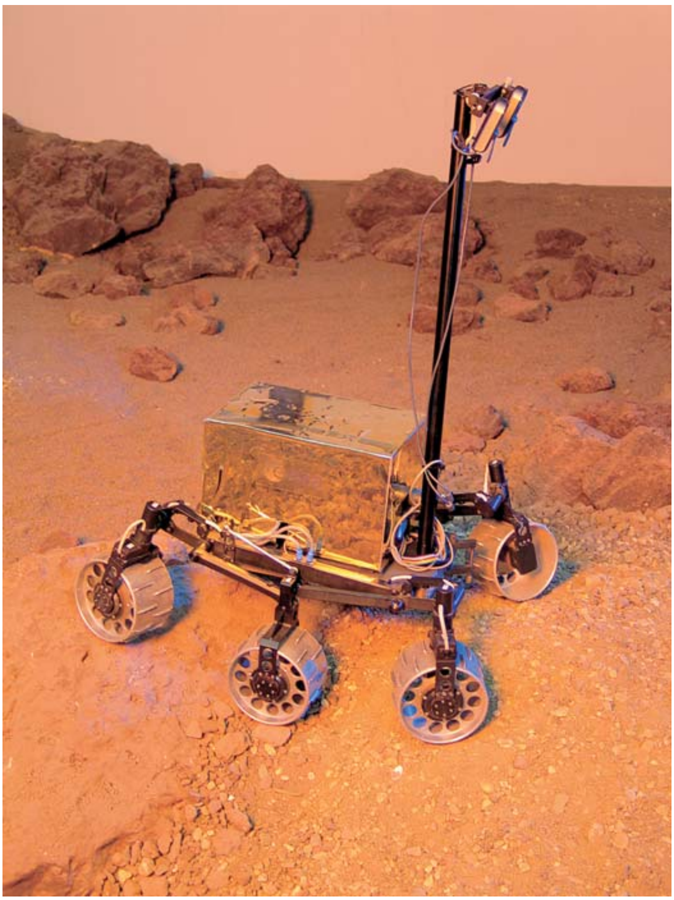
At the end of 2007 the candidates for the rover's landing site were narrowed to six: Marwth Vallis, Nili Fossae Trough, Holden Crater, Eberswalde Delta, Miyamoto Crater, and Northern Meridiani. All of these have one common denominator: past water. The final landing site with its backup will be selected in late 2008.

The Scout program will be continued in 2011 with the possible launch of an airplane or a balloon with an operating range much wider than that of a rover on the surface. One of the proposed Mars planes is ARES (Aerial Regional-scale Environmental Survey of Mars), which would practically be a "flying wing." It would fly at an altitude of approximately 1 km at a speed of about

One of the next steps in Martian research could be an autonomous plane such as ARES.

500 km/hour that is required – just like the vast wings – by the low pressure of the thin atmosphere. The payload would consist of instruments studying the Martian atmosphere plus the composition and magnetism of the surface. The examination of the isotopic ratios of carbon dioxide, oxygen, and nitrogen in the atmosphere would give information on the past climactic evolution of the Red Planet.

Year 2011 would also see the launch of an ESA probe consisting of an orbiter and a lander with a robotic rover, ExoMars. The probe will concentrate on exobiology, which is the search for and study of extraterrestrial life. The rover will be equipped with a



A model of ExoMars, the next Mars probe of the European Space Agency, in technical tests in ESTEC, the European Space Research and Technology Centre, in the Netherlands.

small laboratory that will be used to look for signs of life in soil samples. Before a possible manned flight there will be at least three sample return missions – two American and one European – to be launched in 2013 and 2015. If everything goes according to the master plan, Mars may not have one single moment of peace ever again.

05

UNIDENTICAL TWINS

The blue world was far luckier than its red companion.

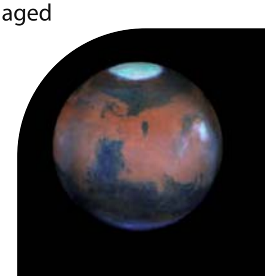
– Ben Bova: *Mars* (1992)

"The analogy between Mars and Earth is, perhaps, by far the greatest in the whole Solar System." This sentence could be found in any modern textbook on astronomy or planetology. However, these words were written by the German-born Englishman William Herschel in 1783. At that time Mars was in favorable opposition, and the anglicized German musician and astronomer observed the planet with his self-made 6-m telescope with a 47-cm mirror.

Herschel made several sketches of Mars and concluded that the white cap glowing in the southern hemisphere was made of ice. On the basis of the position of the cap Herschel estimated the axis of rotation of Mars to be tilted like Earth's and, what is more important, by about the same amount. A natural and above all correct conclusion was that the Red Planet has seasons like ours.

The fact that Herschel's reasoning was solid was no big wonder. He was not blessed with any special gift of prophesy that his colleagues who made correct – and false – deductions lacked. Herschel was a talented scientist who made careful observations and drew conclusions based on them. These conclusions were also affected by the general, albeit at that time, rather scanty, knowledge of the world and the universe. In the case of Mars Herschel had it just right, but due to meager information he managed

A Martian flip-movie. Starting from page 65 the consecutive images on the bottom right-hand corner depict Mars in slightly different positions so that leafing quickly through the pages creates an illusion of a rotating planet.



M. Hotakainen, *Mars*, DOI: 10.1007/978-0-387-76507-5_5,
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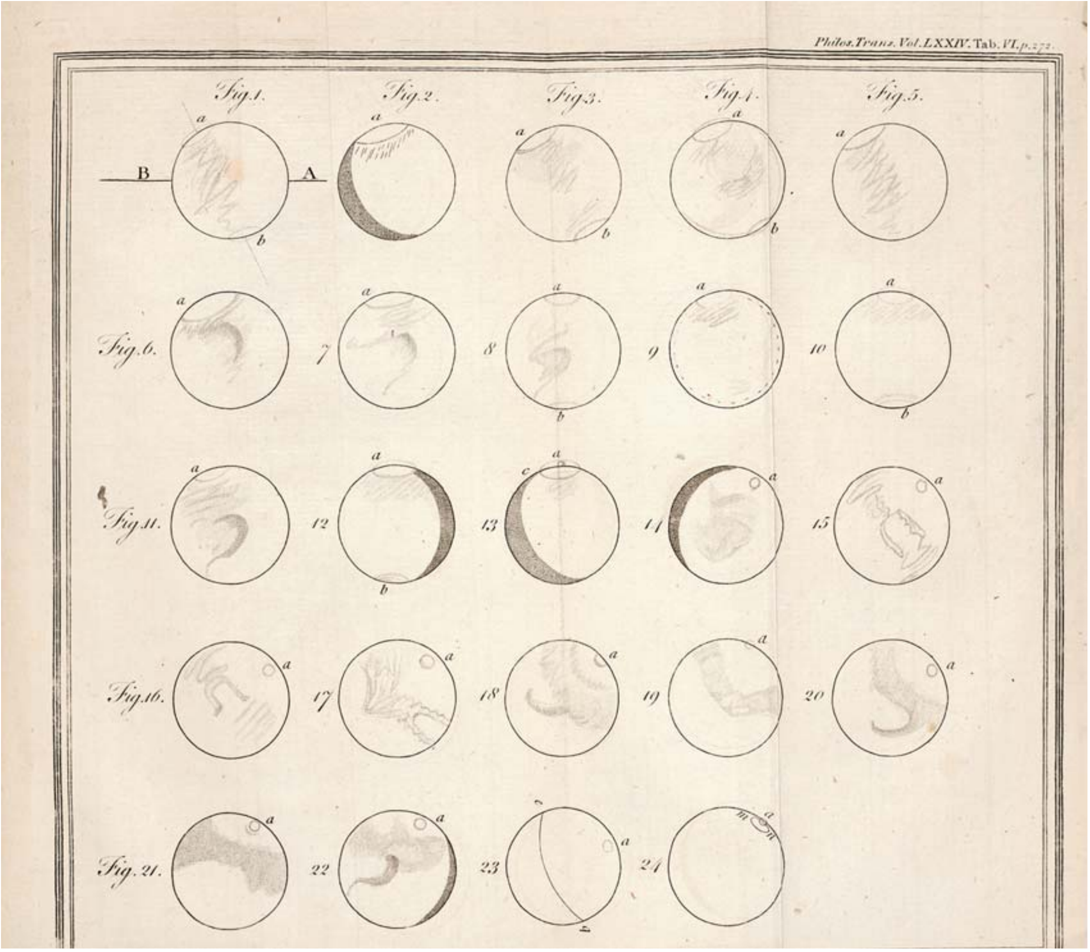


Based on his observations William Herschel could deduce that Mars is very similar to Earth. Illustration from the article On the remarkable appearances at the polar regions of the planet Mars, *published by Herschel in 1784.*

to make wrong assumptions, too. He thought, for example, that in addition to all the planets there could very well be inhabitants in the Sun, under its fiery surface. But in this respect Herschel's ideas were just echoing the pluralistic view of the time: in the eighteenth century all the bodies of the Solar System were supposedly inhabited. Johann Schröter wrote that he was

> fully convinced that every celestial body may be so arranged physically by the Almighty as to be filled with living creatures.

Perhaps this was a kind of overreaction to the religious bigotry of the seventeenth century. Although it used to be forbidden to even speculate on the existence of any extraterrestrial beings, the more liberal climate brought forth the idea of them residing everywhere.

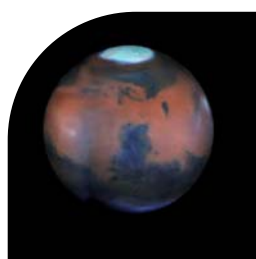
Long, long summer – and winter

● If the axis of a planet's rotation is inclined with respect to its orbital plane, there are seasons on the planet. At times the northern end of Earth's axis is tilted toward the Sun, and there is summer in the northern hemisphere; at other times – separated by half a year from the aforementioned situation – it is tilted away from it, which causes winter in the northern hemisphere. This is the case with both Earth and Mars. They both have an axis inclined by more than 20°, so they both have distinct seasonal variations.

Another thing affecting the seasons is the shape of the planet's orbit (actually, it is the position of the Sun with respect to the planet's orbit, but to keep it simple we'll talk about its shape), whether it deviates from a circle or not. Because the orbit of Earth is nearly circular, our seasons are nearly equal in length both with each other and on both hemispheres. The differences are just few days. Furthermore the distance of Earth from the Sun varies by so little that practically it does not affect the seasons at all. Actually Earth is at its closest to the Sun in January, when the winter in the northern hemisphere is coldest.

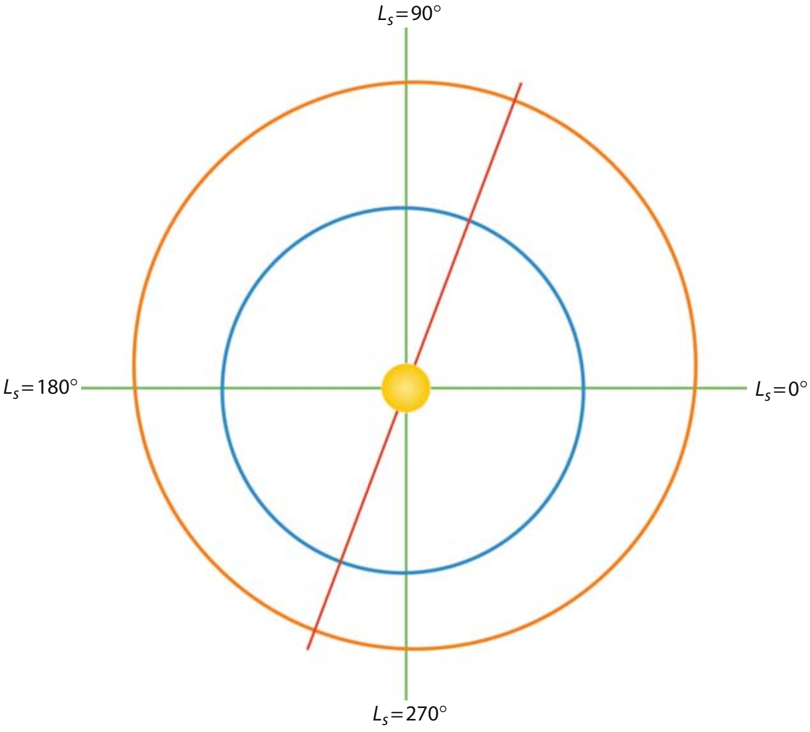
In the case of Mars the situation is completely different. To fix the Martian seasons with respect the direction to the Sun it is helpful to use L_s, the areocentric longitude of the Sun. This is defined as the angle between the imaginary line of equinoxes and the imaginary line connecting Mars and the Sun. For the Martian (northern) spring equinox, $L_s = 0°$; for the summer solstice, $L_s = 90°$; for the autumn equinox, $L_s = 180°$; and for the winter solstice, $L_s = 270°$. The perihelion of Mars occurs at approximately $L_s = 250°$, and the aphelion at $L_s = 70°$.

The lengths of the seasons and the weather conditions during them depend heavily on the distance between the planet and the Sun, as it varies so radically from the perihelion to the aphelion. The northern hemisphere summer and the southern hemisphere winter on Mars last more than 180 sols (Martian days), while the length of the northern hemisphere winter and the southern hemisphere summer is just over 160 sols. The difference between the spring and autumn is larger still, more than 50 sols. A critical factor,



the amount of solar energy Mars receives – the solar constant or the solar insolation at the top of the atmosphere – is at perihelion about 35% larger than at aphelion. All this makes the northern hemisphere winter short and mild, provided that a temperature of some −100°C can be characterized as mild, and the summer long and cool, while in the southern hemisphere winter is correspondingly long and freezing cold and the summer short but relatively temperate.

The areocentric longitude of the Sun, L_s, defines the seasons of Mars. The perihelion occurs at $L_s = 250°$, so it is always late winter in the southern hemisphere of Mars.



Earth or Mars? The left image is of Morocco, in the western Sahara, the right one, taken by the Spirit rover, is at Gusev crater. Or was it the other way around . . . ?

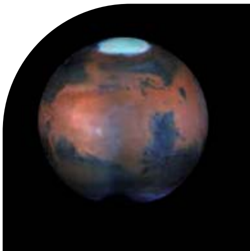
The seasons of Mars are also affected in the long run by the strong variations in the inclination of the axis of rotation, or the obliquity. The stability of Earth's axis is controlled by its large Moon, but the tiny satellites of Mars are incapable of doing anything like that. That is why the inclination of the axis of Mars's rotation alternates possibly tens of degrees between its extreme values.

Mars vs. Earth

Herschel's statement quoted at the beginning of this chapter has been repeated over and over again since he wrote it, but is it really justifiable? At first the claim may seem to be an exaggeration; despite the similarity between the inclinations of the axes of the two planets the seasons on Mars are very different from the ones on Earth. Perhaps, instead of being most similar to Earth of all the planets, Mars should be said to be the least different from Earth.

One reason for the present view on the similarity between Mars and Earth is the imagery acquired from the surface of the planet. In the images sent by the *Vikings, Pathfinder,* Spirit, and Opportunity the scenery on Mars looks deceptively like almost any desert on

	Earth	Mars
Diameter	12,756 km	6,792 km
Period of rotation	23 h 56 m 4.2 s	24 h 37 m 22.7 s
Inclination of axis	23.45°	25.19°
Mean density	5.52 g/cm^3	3.91 g/cm^3
Atmospheric composition	N_2 77%, O_2 21%, H_2O 1%, Ar 0.93%, CO_2 0.03%	CO_2 95%, N_2 2.7%, Ar 1.6%, H_2O 0.006%

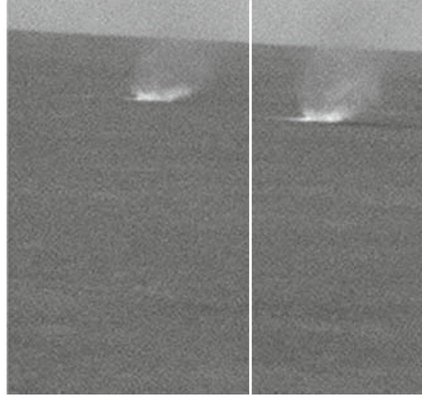


Earth. The only obvious differences are the complete lack of vegetation and the reddish hue of the scene, including the sky. The problem is that the images do not convey the essential conditions of the Martian environment – the atmospheric pressure and composition, or the temperature.

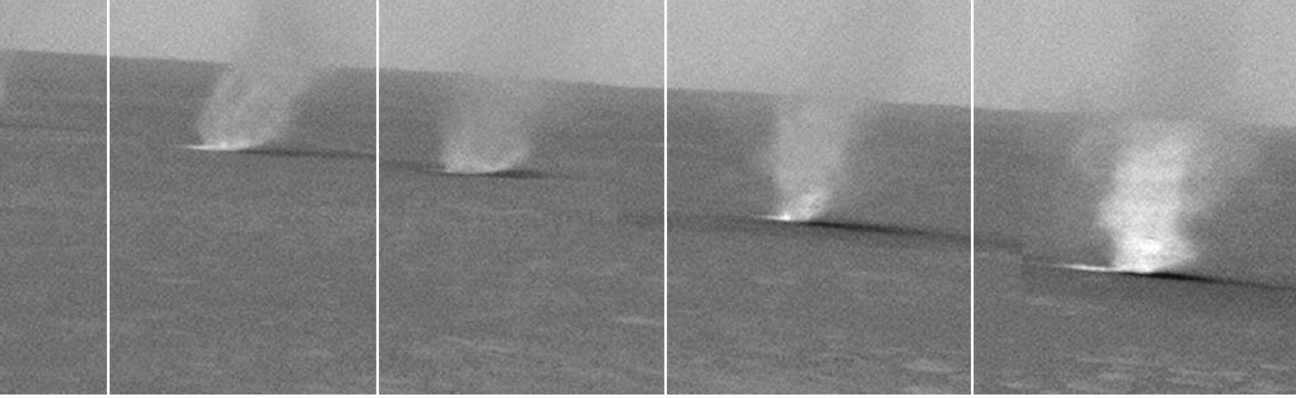
Even though Mars has an atmosphere, its density is just a fraction of the density of Earth's atmosphere, and the atmospheric pressure on the surface is a mere 1/200 of the pressure at sea level on Earth. Furthermore the atmospheric pressure on Mars varies some 30% with the seasons. A comparison often expressed is that the pressure on the surface of Mars is approximately the same as the pressure at an altitude of 35 km on Earth. In a way this is misleading since Earth's atmosphere contains a remarkable amount of oxygen – not enough to breathe, though – even at those altitudes – but the thin atmosphere of Mars consists mostly of carbon dioxide, its percentage being 95, which constitutes only a few hundredth parts of a percent of Earth's atmosphere.

Notwithstanding the sunshine it is extremely cold on the surface of the Red Planet. Even the hottest weather in midsummer gives potential Mars dwellers little chance to enjoy temperatures above zero, and in midwinter the temperature drops below −100°C. A telltale sign of the low temperatures is the sublimation of carbon dioxide from the atmosphere into the polar caps; this requires a temperature of −120°C.

Whether the images are taken on the surface or from orbit they also lack the scale of time. Even though there are abundant signs of water on Mars – dry riverbeds, floodplains, lakes, perhaps even ocean shores – it possibly has been billions of years since water flowed on the surface. While the dry riverbeds on Earth are filled up with water at the beginning of the rainy season, there is no rain to be had on Mars maybe ever again. And if we go underground, Mars has or at least has had volcanic activity – the multitude of volcanoes give their testimony concerning that with their sheer massiveness – but the planet lacks the tectonic activity so essential in the evolution of Earth. The Red Planet probably does not have a viscous mantle or a partly liquid core generating a magnetic field to protect the planet from cosmic rays or the lethal particle bombardment from the Sun.



In addition to dust storms there are lots of dust devils on Mars. In May 2005 Spirit photographed a dust devil with a diameter of about 34 m. It traversed the terrain with a speed of some 20 km/hour over a distance of 1 km. The image is composed of individual photographs taken in a time span of 10 minutes.



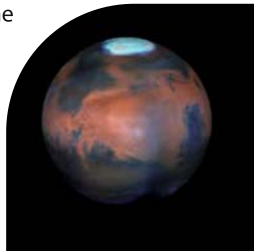
The similarity between Mars and Earth is also relative. Compared with the other terrestrial planets – hot Mercury and even hotter Venus – Mars seems nearly a "human" place, not to mention the gas giants with no solid surface at all. But this is not enough to say that Mars is a planet "like Earth."

Martian meteorology

● The analogy between Mars and Earth has a foundation going much deeper. Actually it culminates in the observation made by Herschel of the nearly identical inclinations of the axes of rotation of Mars and Earth. Both planets have strong seasonal variations at mid and high latitudes. Both Mars and Earth have large polar areas with perpetual sunshine during summer and almost complete darkness in wintertime.

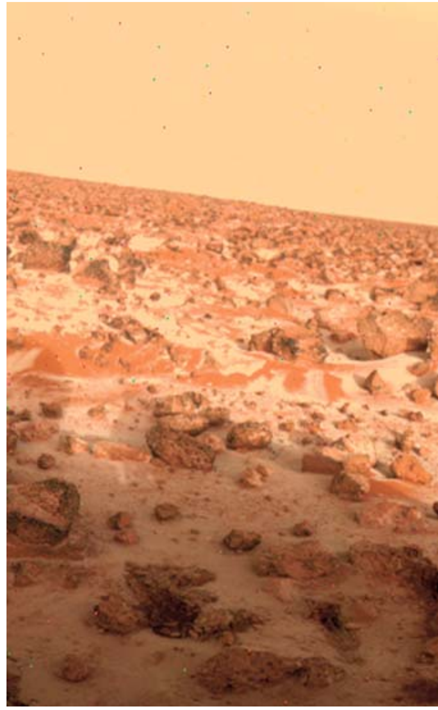
Just like on Earth, the climate on Mars is regulated by the atmospheric currents generated by the differences in the solar energy received from the Sun at the equator and in the polar areas – despite the continuous day in summertime at high latitudes. The second principle of thermodynamics dictates that heat is always transferred from warm areas to cold, in this case from the equator to the poles. The air heated at the equator will rise up and flow toward the polar areas, where it will cool down, sink and start to flow back to the equator. The result is continuous circulation in the atmosphere.

Both Mars and Earth experience relatively rapid rotation, which partly affects the atmospheric currents between the equator and the poles. The air does not flow directly toward the poles, but it is shifted to the side by the Coriolis effect: to the right in the northern hemisphere, to the left in the southern hemisphere. Because the periods of rotation of Mars and Earth are very similar – the



Martian day, sol, is only 37 minutes or 2.5% longer than a day on Earth – they both have strong cyclones, moving areas of low pressure stretching thousands of kilometers, originating in the mid latitudes.

The biggest difference between these weather systems is water – or the lack of it. There are no autumn and winter storms on Mars such as those we frequently have because the atmosphere of Mars is practically bone dry. If all the water vapor in the atmosphere of Mars could be condensed into water, it would form a layer only some 15 μm or a few hundredths of a millimeter thick on the surface. On top of this all the atmospheric pressure on Mars is below the triple point of water, a combination of pressure and temperature at which water, ice, and water vapor can coexist in a state of stable equilibrium. That is why ice would not melt into water, but sublime directly into water vapor even if the temperature at times and in places would rise above zero. This works both ways: the only visible signs of the nearly negligible humidity in the atmosphere of Mars are the thin clouds high in the sky and the frost forming on the surface in winter time. To be honest, this frost is not the same kind of sublimated water vapor like we have here on Earth, but clathrate, a mixture of carbon dioxide and water.

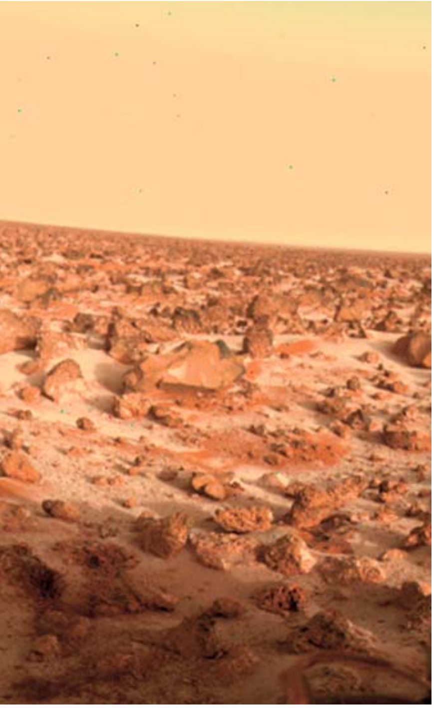


A wintry morning on Utopia Planitia. Viking 2 *photographed the Martian surface covered by a thin layer of frost in 1979.*

1 day = 0.9732469726 sol

● On the other hand the almost identical periods of rotation of Mars and Earth are a real thing. The day on Mars, 1 sol (derived from the Latin name of the Sun), is just about 40 minutes longer than a day on Earth. If – and one day, inevitably, when – people will land on the Red Planet, a slightly longer day is something that can quite easily be adjusted to. The long flight to Mars could be used for the adaptation. All it would take on a journey of 6 months long is to stretch each "day" by about 10 seconds, and at the time of arrival the crew would be living to a Martian rhythm. And even without a procedure like this the problem would not be more serious than the one we all have with daylight-saving time: for a few days there is the vague feeling that time is not what the clocks are telling us.

The sidereal period of Earth, the period of rotation with respect to the stars, is some 4 minutes shorter than the synodic one, the



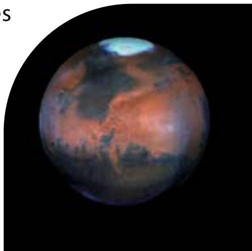
period of rotation of Earth with respect to the Sun. The difference is caused by the fact that while Earth is traveling along its orbit, the Sun seems to move to the east with respect to the stars. That is why Earth has to rotate a little bit more with respect to the Sun than to the stars to have exactly the same side toward the Sun again. Mars is farther away from the Sun and thus orbits it more slowly than Earth, so the sidereal period of Mars is just 2 minutes shorter than the synodic period.

The rotation of Earth is slowing down, though, because of the tides caused by the gravity of the Sun and especially of the Moon which create friction in the oceans and in the crust, consuming the rotational energy of Earth. The rotation of Mars is slowing down, too, but the rate is only about a third of that of Earth. The reason is the fact that even Phobos, the larger of the Martian satellites, is so small that it has practically no effect at all, so only the Sun is to be taken into account. And because Mars is farther away, the effect of the Sun is less than half of what it is in the case of Earth. This means that the difference between the periods of rotation of Mars and Earth is slowly but steadily diminishing, and in the far future the neighbors will rotate in rhythm for a while until the more rapid retardation of Earth's rotation will make our day longer than the one on Mars.

A night on the Red Planet

● The constellations in the Martian night sky would look very familiar to us – in fact, exactly the same as they look from Earth. The distances between the planets are so small compared to the void between the stars that the night sky could be looked upon from wherever in the Solar System and the constellations would still look the same.

However, the night sky as seen from Mars is not identical with the firmament we are familiar with. Although the axis of Mars's rotation is inclined by about the same amount as the axis of Earth, it points in a different direction. Thus it does not point to Polaris, but at a point some 10° from Deneb, the brightest star in the constellation of Cygnus, the Swan. Some of the brightest areas of the Milky Way are in Cygnus, so it would always be visible at night on Mars. As a matter of fact, the Milky Way goes



The Martian night sky would look familiar, but its north pole is near Deneb, the brightest star of Cygnus, the Swan.

through the celestial poles of Mars, so in the course of a night it would seem to sweep across the entire sky from east to west.

In the southern sky the axis of Mars's rotation points a couple of degrees away from Kappa Vela, a star just a little dimmer than Polaris. Thus the Red Planet has a southern pole star, unlike Earth, which has only dim stars in the vicinity of the southern celestial pole.

Because of the difference in the positions of the celestial poles, the rotation of the night sky would look different on Mars. The constellations would rise and set in different positions and with respect to each other at different times than on Earth. Cygnus and the constellations nearby would be visible at all times in the same way that Ursa Major, the Greater Bear, and Ursa Minor, the Lesser Bear with their close companions are in our northern sky. The cross of Cygnus could be used as a "celestial clock" much the same way as the Big Dipper of Ursa Major was used by our ancestors.

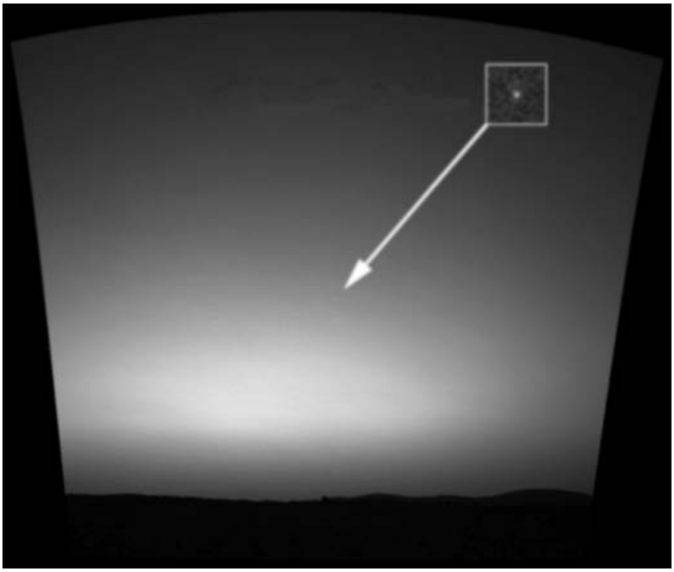
The Martian zodiac, or the zone the Sun and the rest of the planets seem to be moving on in the sky, is almost the same as ours, since the orbital planes of Mars and Earth are very close to each other: the inclinations differ by less than 2°. The main difference is that while passing the constellation Pisces, the Fish, the Sun drops into Cetus, the Sea Monster, for a few days. Also, the equinoxes are situated in different constellations than in our sky. The vernal equinox of Mars is in Ophiuchus, the Serpent Holder, while our vernal equinox is in Pisces, about 85° eastward. At the time the Sun passes the vernal equinox during its annual wandering it moves from the southern celestial hemisphere to the northern one, and the length of the day in the northern hemisphere begins to get ahead of the length of the night.

The axis of Earth's rotation does not permanently point toward Polaris, but the celestial pole travels along a great circle, making one round every 26,000 years. In 12,000 years the northern pole star will be Vega of the constellation Lyra, the Lyre, the second brightest star in the northern sky and the fifth brightest star in the entire sky. The reason for the movement of the celestial poles is precession, a slow swaying of the axis of Earth's rotation resembling the wobbling of a spinning top but being much, much more leisure. The axis of Mars's rotation sways in the same way, but even more slowly: the axis points in the same direction every 175,000 years. This wobble does not affect the positions of the stars with respect to each other, but in a couple of hundred thousand years the proper motions of the stars will begin to change the appearance of the constellations.

Earth and the Moon transit the Sun on November 10, 2084.

View to the Solar System

● The night sky from Mars will not be that different from ours, but the other members of the Solar System would look a bit different. Because of Mars' larger distance from the Sun the apparent diameter of the Sun is smaller by about a third to what it is as seen from Earth. In addition to Mercury and Venus, Earth would be visible only in the evening or morning sky. Mercury



would be very difficult to see, since the largest elongation of the planet as seen from Mars is less than 15° – about equal to a span with an arm stretched out – so it would disappear in the glare of the Sun in a Martian sky reddened by dust.

In the Martian sky Earth is visible only as a morning or an evening "star."

The greatest elongation of Venus would be about the same (approximately 27°) as the one of Mercury in our sky and the greatest elongation of Earth a little less than the one of Venus in our sky. At times the inferior planets would cross the face of the Sun just like they do as seen from Earth. In the case of Earth its transit would be very fascinating with the Moon visible as a tiny black dot next to Earth against the bright surface of the Sun.

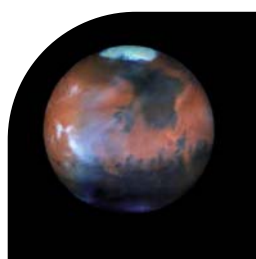
The outer planets are at distances so great that they would be visible in much the same way, in oppositions just a trifle brighter than as seen from Earth. However, the oppositions would occur more rarely, because the orbital period of Mars is nearly twice that of Earth.

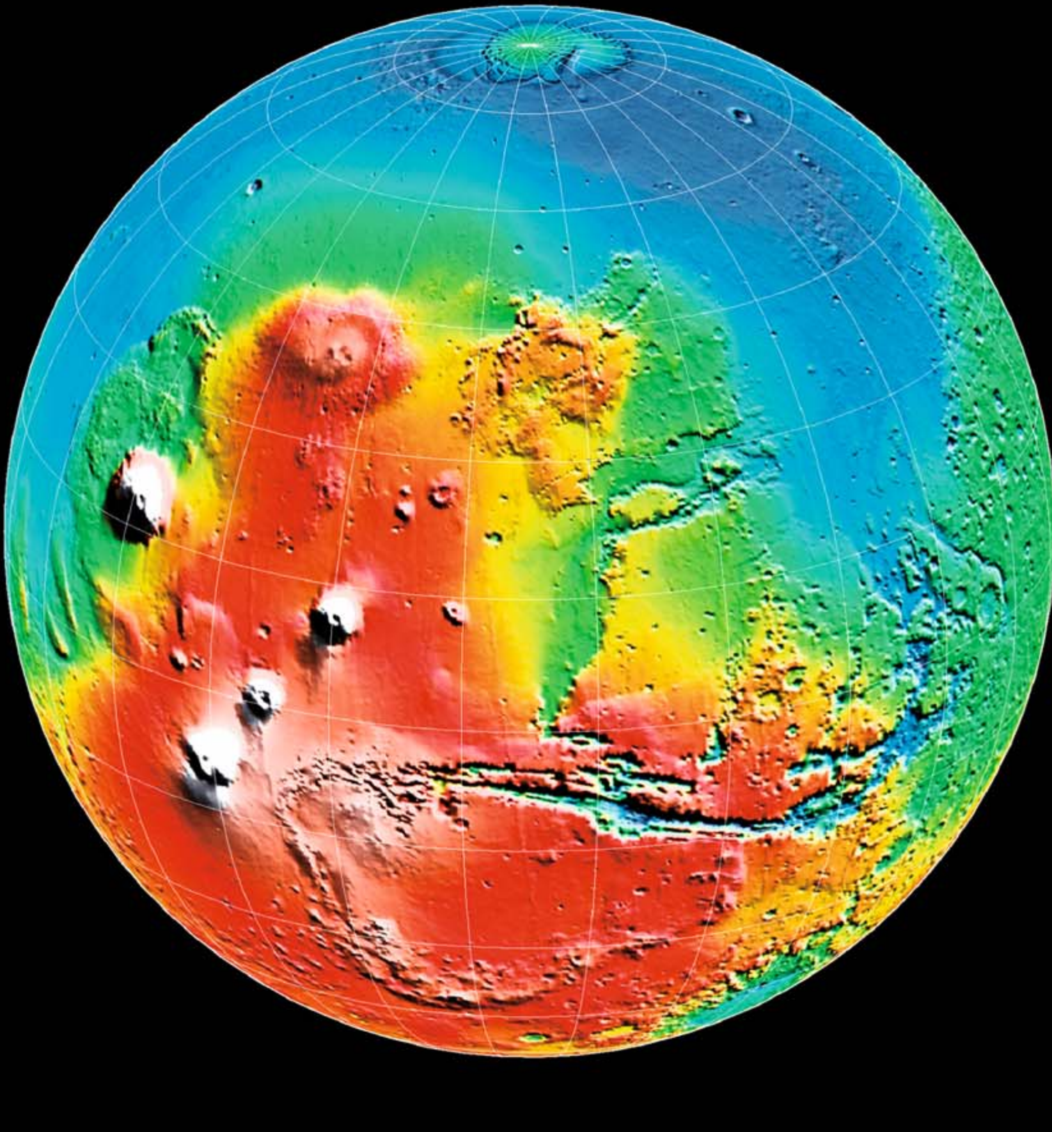
There would be meteors to see on Mars, even meteor showers, just like here on Earth. The Martian atmosphere is thin, but still significant enough to make the tiny meteoroids coming from space burn up. However, the showers visible on Mars would not be the same as those we can – weather permitting – observe. Mars and Earth travel in different regions of space, so the meteoroid streams

Mars encounters are different. Actually, some of them could be the same, but the showers caused by them would not occur at the same time.

Despite efforts to record them with cameras on the rovers, no meteors have been imaged, at least none that could be confirmed. Fortunately, meteoroids entering the Martian atmosphere – in addition to giving off light – ionize the air along their tracks. This plasma reflects radio waves, so it can be "seen" with the instruments on the orbiting probes. So far a total of 10 meteor showers have been identified on the basis of the ionospheric data.

All in all, despite the differences in the visibility of some of the celestial objects, it would probably mostly feel like home on the dusty surface of the Red Planet at night.





06

THE NEW MARS

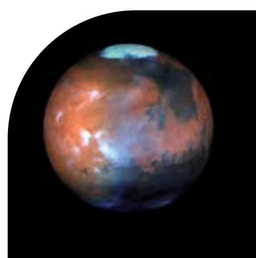
But Mars had become another world entirely.

– John Barnes: *In the Hall of the Martian King* (2003)

The information gained on Mars in the past 10 years is more abundant than all the knowledge accumulated during the preceding millennia. However, this does not mean that we know Mars through and through. With just a hint of exaggeration it can be said to be typical for research made with space probes that the information sent by a craft launched to solve one question stirs up ten new questions. The Red Planet still harbors lots of secrets and riddles on both large and small scales. However, in the beginning of the twenty-first century we already have quite a comprehensive general view of the world next to our own.

Benumbed planet

● The temperature on the surface of Mars is at places well below –100°C, but it is not that warm in the bowels of the planet, either. Right after the birth of the Solar System all the larger bodies were in a molten state. The heat for melting came from the shrinkage of the primordial gas and dust cloud, impacts of smaller bodies, and the decay of short-lived radioactive elements. Just as in the case of Earth the heavy elements sank to the center of Mars to form a iron–nickel core, and the light ones rose to the surface to form a thin crust.



Topographic map of Mars based on measurements made with the MOLA instrument onboard Mars Global Surveyor. *White areas are the highest, purple the lowest.*

M. Hotakainen, *Mars*, DOI: 10.1007/978-0-387-76507-5_6,
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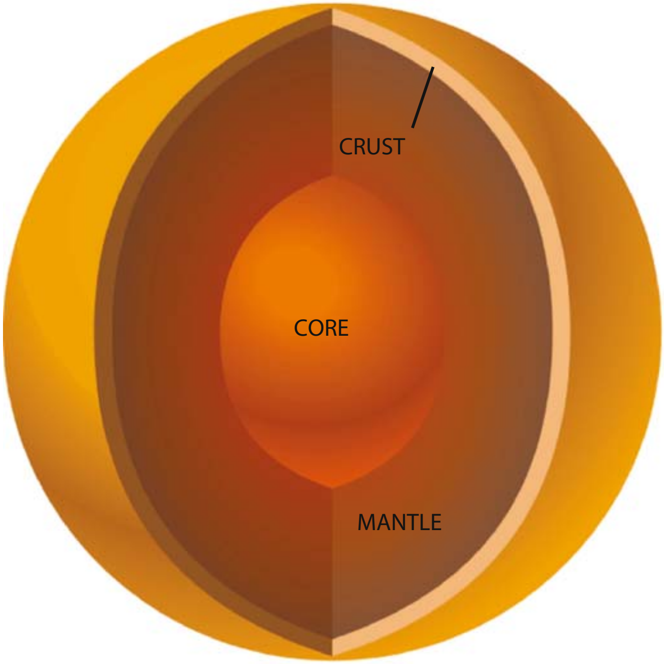


Mars has a thick crust and an iron–nickel core, the diameter of which is about half of the diameter of Mars.

The radius of Mars's core is 1,300–2,300 km or 40–65% of the radius and 15–30% of the total mass of the planet. Mars does not have a global magnetic field anymore, so the core is supposedly completely solidified. Based on studies of Martian meteorites and measurements made by space probes it has been deduced that earlier it did have a magnetic field, which was created by the rotating solid inner core whisking the material in the molten outer core. There is still some remnant left on the surface as a distant memory of the magnetic field long gone. The existence of the magnetic field is also proved by aurorae observed by *Mars Express*. However, because of the weakness of the field these are much dimmer and only local, restricted to smaller areas than the magnificent northern and southern lights around the polar regions of Earth.

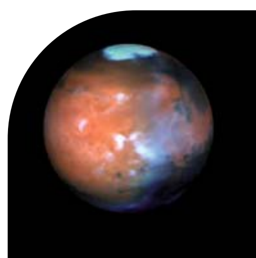
Mars must have cooled down rather quickly for the solid crust to form. The early bombardment of meteorites abated rapidly some 3.8 billion years ago, and there are still clear signs of the ancient events on the surface of Mars. The landscape was shaped by meteorite impacts peppering the entire surface with craters of different sizes. In addition to asteroids and smaller rocks, Mars was hit by innumerable icy comets. These were supposedly the source of most of the planet's water, which originally might have been even more abundant than on Earth.

The end of the meteorite bombardment also marked the end of the Noachian era, the oldest of the three Martian eras begun at the time of the birth of the Solar System. The eras – Noachian, Hesperian, and Amazonian – have been named after certain terrains formed during those periods: Noachis Terra, Hesperia Planum, and Amazonia Planitia.

Gradually the crust of Mars has thickened so that nowadays it is tens, according to some estimates maybe even hundreds, of kilometers thick. The crust did not have time to break into separate plates like the crust of Earth, and therefore Mars is said to be a "one-plate planet." The interrupted tectonic evolution of Mars is manifested by all kinds of bulges, ruptures, and wrinkles on the surface of the planet.

There was still some heat left underneath the solid crust created by the decay of long-lived radioactive elements. For the next couple of billions of years Mars was a very volcanic world. Eruptions spewed not only lava but all kinds of gases that helped create the atmosphere of the planet. During those times the large scale terrains of Mars such as lava plains, highlands, and depressions were also born. This era, the Hesperian, was a very long period, ending only 1.8 billion years ago. Since then the Red Planet has gone through the Amazonian period during which formations like Olympus Mons, the Tharsis volcanoes, and the vast dune fields in the polar areas were born.

By about a billion years ago Mars had cooled considerably. Because of its small size the planet could not maintain internal heat, like Earth. The furnace inside Mars died down, and the planet began to fall into a long, icy sleep. The core solidified, which made the magnetic field disappear so that the solar wind was able to strip the atmosphere off into space. The large variations in the orbit and in the inclination of the axis of rotation made the situation all the worse. The atmosphere became thinner, the climate got colder, water disappeared, and Mars turned into a freezing cold world. Time was stopped – almost.



A bissected world

● On a large scale, Mars is divided into two very different hemispheres. The southern and part of the northern hemisphere is ancient, rugged terrain covered with countless craters. The rest of the planet, the northern polar areas and their surroundings, are very smooth. There are only a few craters here and there, in places none at all, and the elevation could vary by only some tens of meters across distances of hundreds of kilometers. Furthermore the northern hemisphere is “lower” than the southern one. In approaching the equator from the south the terrain slopes continuously down on the large scale. The southern hemisphere is on average a couple of kilometers higher than the “zero level.” Because of the lack of any sea on Mars to use for determining heights, the zero level is an artificial “plane” defined by atmospheric pressure. North of the equator, inclined by about 30°, there is a border line with a distinct drop to the northern plains, which completely lie below the zero level.

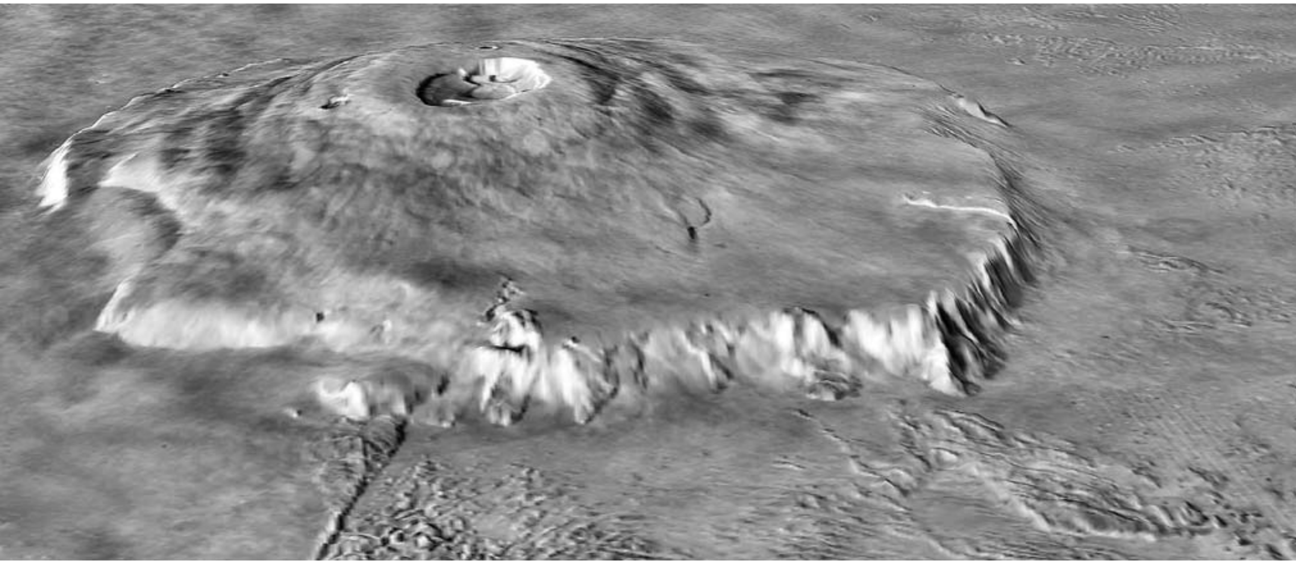
The great depression of the northern hemisphere may be the result of a huge impact that created a crater almost half a planet wide. If the theory holds, this event occurred very early in the history of Mars, possibly around the same time as the cosmic collision that gave birth to the Moon, the satellite of Earth. Even though the origins of the depression could be explained by an external factor, the reason for the smoothness of the surface has to be found on Mars itself. The only equally smooth regions on Earth are the deserts and ocean bottoms with deposited layers of material leveling off the terrain with time. Some scientists consider the conclusion inevitable: there was a heaving ocean on the northern hemisphere of Mars. Then again the smoothness might have originated in ancient lava flows. The roughness left behind was later smoothed by the dust and sand blown around by winds.

With its MARSIS radar system ESA’s *Mars Express* has studied the area of Medusa Fossae lying near the equator, exactly on the borderline between the highlands and lowlands. There are few craters in the area, so the formation must be very young, perhaps among the youngest on the surface of the Red Planet. The Medusa Fossae

The Medusa Fossae Formation, which is found near the equator, might be among the youngest deposits on the surface of the Red Planet. It is practically devoid of impact craters, a telltale sign of young age.

formation also exhibits some of the most mysterious deposits on Mars. Previously it was thought that these deposits might be ash originating from catastrophic eruptions differing from those that created the huge volcanoes on Mars. Previously, it was also thought that the deposits composed of easily eroded materials might be rather thin, but the results of *Mars Express* reveal that there is a thick layer of more than 2.5 km covering the solid rock.

In addition to measuring the thickness of the deposits MARSIS has also determined their electrical properties, which gives us clues to the composition and structure of the material. The data suggest that the layers are made of porous, low-density stuff. This would be difficult to explain if they consisted of volcanic ash or wind-blown dust, both of which would have been compressed under their own weight. However, if there is water ice mixed into the soil, it could explain the curious properties.



An image of Olympus Mons based on laser measurements made by Mars Global Surveyor. *The vertical scale is tenfold.*

There should not be much ice in the equatorial regions of present-day Mars, but if it were buried deep below the surface, it could have been preserved there, since in the past the inclination of the axis of Mars was larger than it is now, making the equatorial regions much colder. If this really were the case, the future studies of the buried ice could yield information on the climate and atmospheric conditions over the past 3–4 billion years, as well as whether there was life in the distant past.

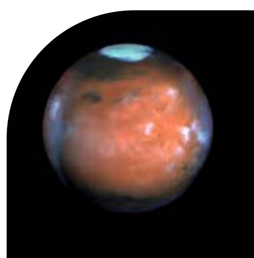
A realm of giants

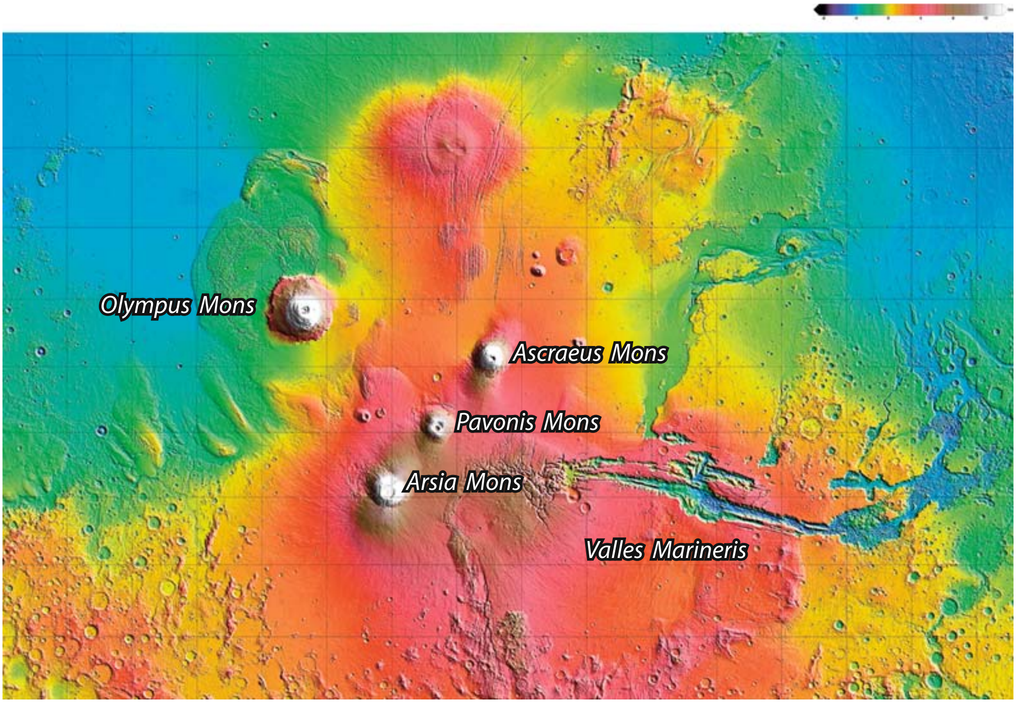
● The diameter of Mars is only half that of Earth, but regarding many Martian formations it is a kind of an XXL version of our planet. The highest mountain on Mars – and in all of the Solar System – is Olympus Mons, which rises some 27 km above the surrounding plains and has a diameter of about 600 km. This makes the mountain about three times higher than the highest peak on Earth, Mount Everest. However, despite its height Olympus Mons is – apart from the steep precipice along the edge of the mountain, with a height of about 7 km in places – very gentle. The rise of the slope is so gradual that any potential climber would have difficulty noticing the land going up.

The giant volcano was formed of lava welling up from the innards of the planet at a "hot spot" residing on a weak point of the crust. Lava poured down the gentle slopes, and the mountain gained height layer by layer. This is the way Mauna Loa on Hawaii, the biggest volcano on Earth, with a height of 9 km measured from the ocean bottom and a diameter of 120 km, was born. Unlike Mars, the plate tectonics on Earth make the hot spots move (or actually it is the other way around: the hot spots stay put, the plates are moving), so shield volcanoes such as Mauna Loa do not have enough time to grow that big. Mars lacks plate tectonics, so once a mountain begins to grow it gains height perhaps for hundreds of millions of years, so long as there is a source of lava. The smaller gravity and thicker crust of Mars also make the existence of high mountains possible; on Earth a mountain over 20 km high would have started to sink back into the mantle a long time ago.

The total area of Olympus Mons is more than 80% that of Finland.

The caldera on top of Olympus Mons, created when the emptied lava chamber collapsed, is 90 km long and 60 km wide.





The height of the Tharsis region and its gigantic volcanoes shows on a map based on measurements made with the MOLA instrument of the Mars Global Surveyor. *In 1879 Giovanni Schiaparelli gave Olympus Mons the name Nix Olympica, "Snows of Olympus," because telescopes showed it at times as a white spot. While Mariner 9 photographed Mars in 1972 the dust storm covering the planet began gradually to settle, so the mountains began to loom through the dust as four dark spots. At first they were called Groucho, Chico, Harpo, and Zeppo, after the Marx brothers.*

In fact there are several calderas overlapping each other. They were born at different times over a period of a few hundred million years. In case a future Mars explorer were to stand on the edge of the caldera on some distant day, he or she would not even be able to see the opposite edge, since it would be below the horizon. The same goes for the mountain itself. It is so vast that it is impossible to perceive it from the surface of the planet at all. If you are situated at such a distance from the mountain that you could see it all, the mountain would be beyond the horizon.

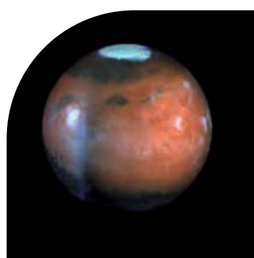
East of Olympus Mons there are three somewhat smaller volcanoes, Ascraeus Mons, Pavonis Mons, and Arsia Mons, in a straight line. They have heights of "only" 15 km. Nevertheless, the summits of the trio rise nearly as high as the summit of their gigantic neighbor, because they are in the Tharsis region, which is at a height of some 10 km. This region, covering nearly one sixth of the total area of Mars, is in reality a bulge on the planet with a diameter of 4,000 km formed as early as 3–4 billion years ago. It might have been born as a result of several consecutive eruptions distributing vast amounts of lava on the surface layer by layer, but more probably it was raised by molten rock accumulating under the crust. One clue in favor of this theory is the network of cracks surrounding the region. The whole planet was about to split up along those clefts. On the other side of Mars there is a similar bulge, Elysium, with apparently the same kind of origins, but it has a diameter of only 2,500 km and a height of about 3 km.

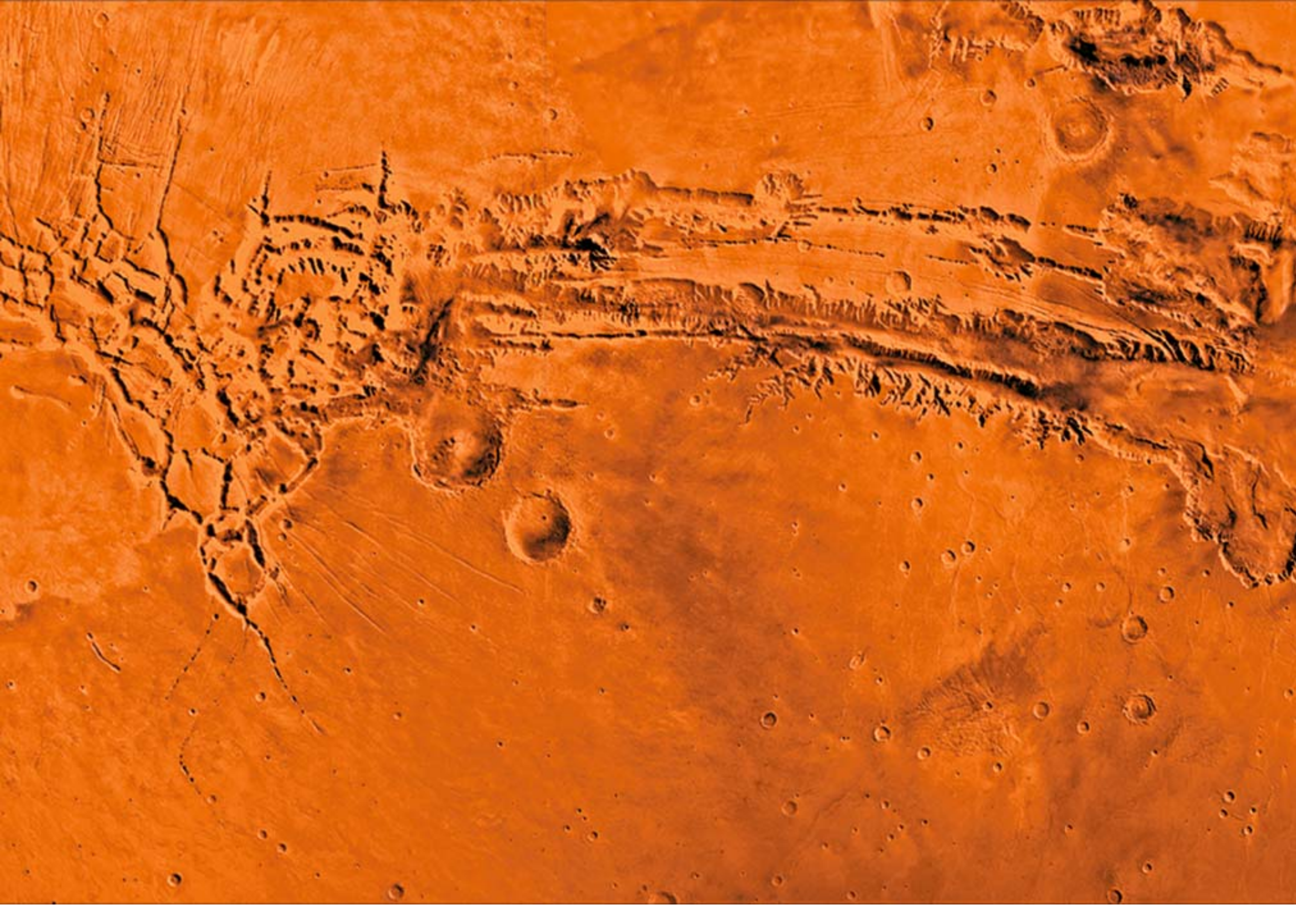
The Tharsis volcanoes are lined up for the same reason the Hawaiian islands are. Both were born on a hot spot, but unlike Olympus Mons, the spot beneath the Tharsis mountains has been slowly moving. The reason for this is not known, since there are no plate tectonics on Mars. The volcanoes are much younger than the region all around them. Arsia Mons, the most southerly of them, had its last eruption 700 million years ago, Pavonis Mons 300 million years ago, and Ascraeus Mons 100 million years ago. The latest lava flows on Olympus Mons are younger still; they are at most only 30 million years old, possibly just a few million years old. Thus Mars has been volcanically active through most of its history, so it might still be.

A planetary scar

● The eastern edge of the Tharsis region marks the starting point of Valles Marineris, a huge valley system, stretching across nearly one fifth of the circumference of the planet. The same volcanic activity swelling out of one side of the planet has torn the other side up. Valles Marineris is 4,000 km long, more than 600 km wide, and 7 km deep. Seen from one edge the opposite side would be below the horizon. It has often been compared with the Grand Canyon, which has a length and width of about one tenth, and a depth of about one fourth of those of Valles Marineris, but the Grand Canyon was carved by water. Based on size and origins a better analogy would be to the East African Rift Valley, which is a huge crack in the crust, just like Valles Marineris.

Valles Marineris has been modified by water since its formation. The water has carved branching tributaries leading to the large



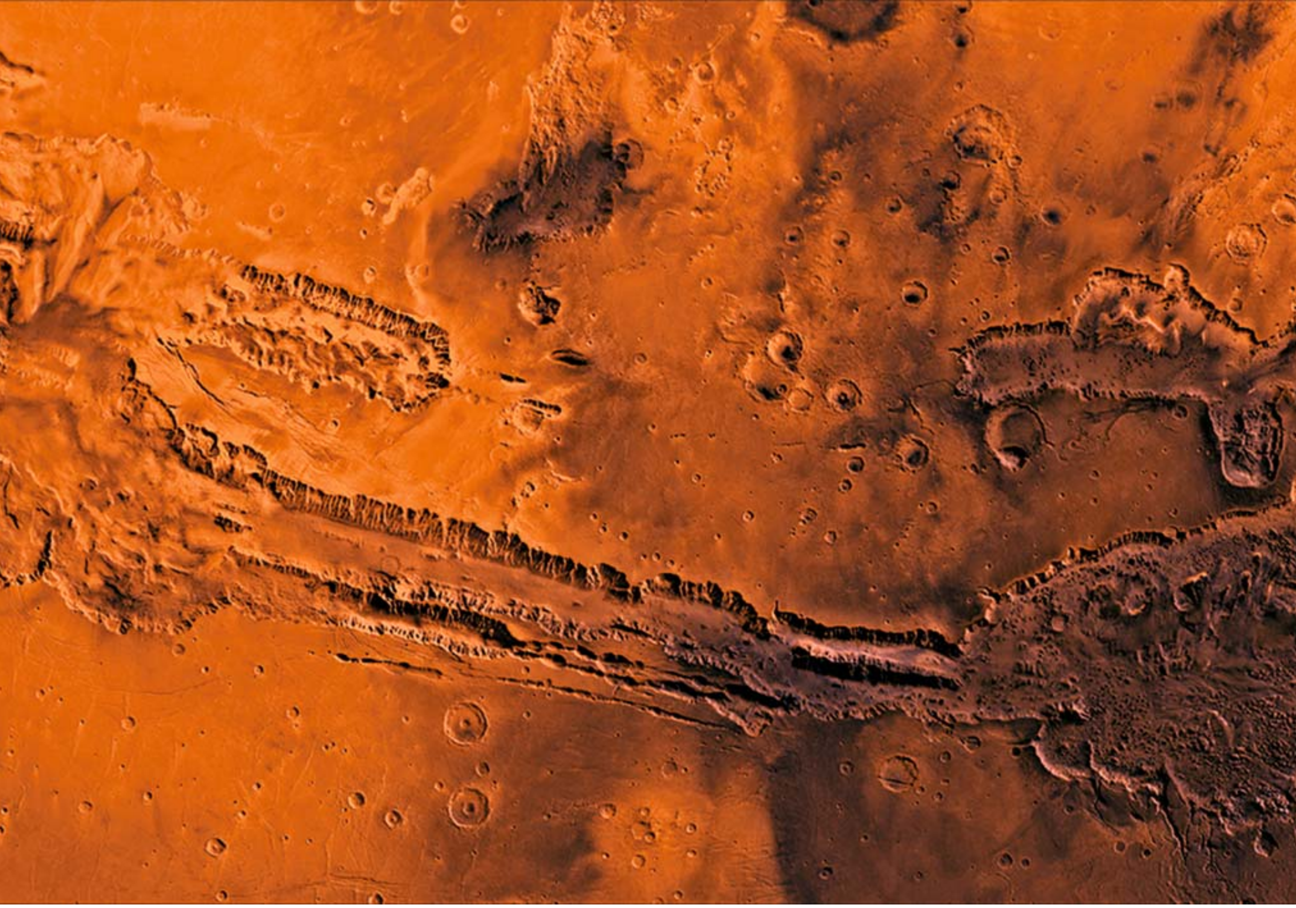


gorges. Landslides and depressions have also eaten up the canyon walls, giving birth to new, smaller ravines. There are thick sediments at the bottom of Valles Marineris, supposedly formed in standing water. At some stage the valley system may have been a huge lake or rather a sea, which has contributed to the present appearance of Valles Marineris.

Valles Marineris on the equator of Mars. The western end is dominated by Noctic Labyrinthus, the Labyrinths of the Night, and the eastern end by "chaotic terrain," which is a starting point for riverbeds ending up at Chryse Planitia.

Lost keys?

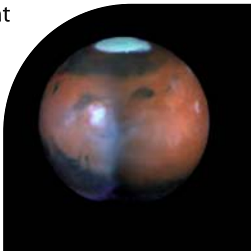
● It is a proven geologic principle that the present is a key to the past. The processes observed today are similar to what they used to be in the earlier days. But what if the lock has been changed? During its millions and billions of years of history Mars has changed much more radically than Earth. Even though the physical processes might have generally been the same, the factors affecting them could have been very different from what they are nowadays. Based on phenomena observed at present it might not be possible

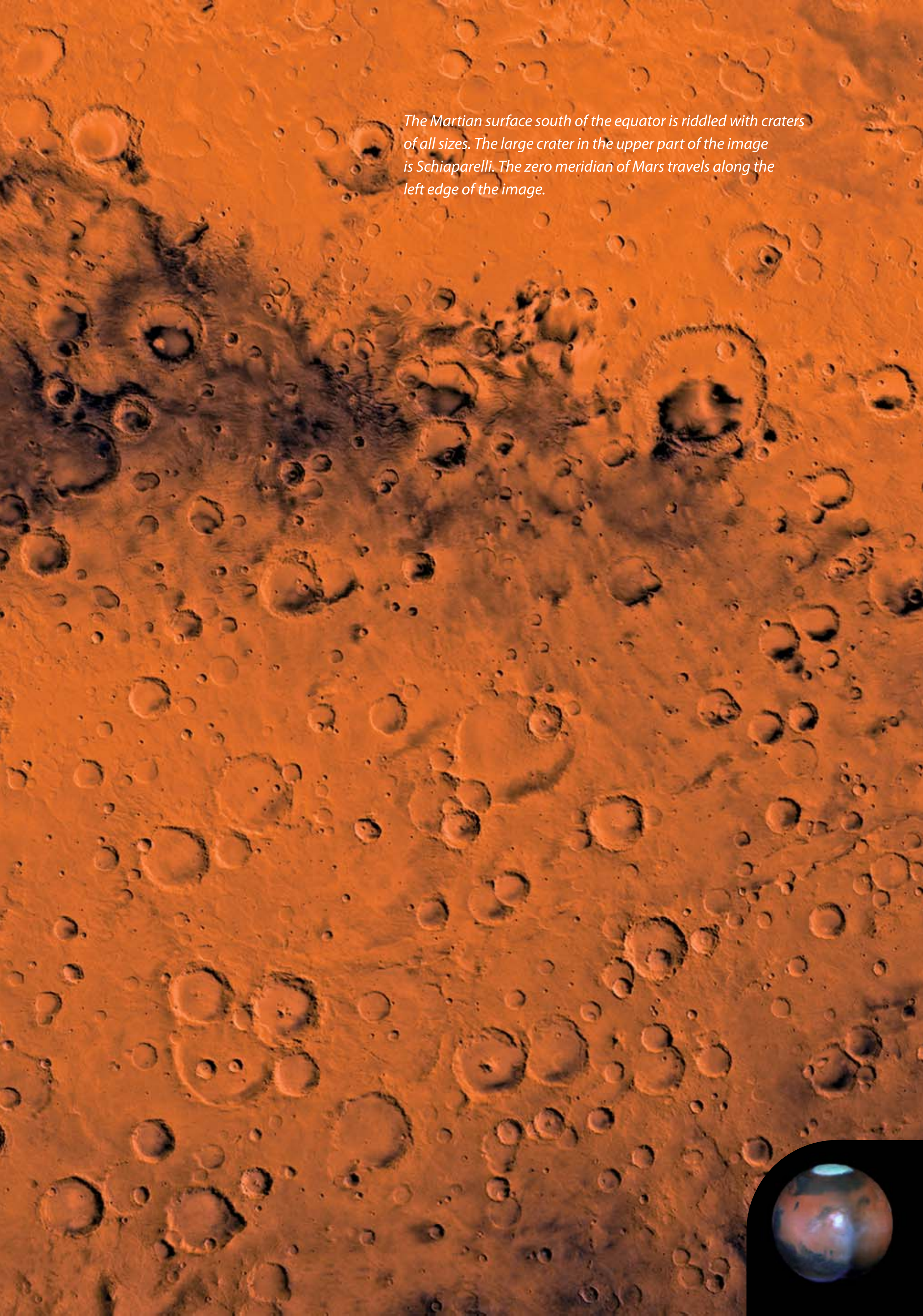


to draw justifiable conclusions on what happened on the surface of the planet long ago.

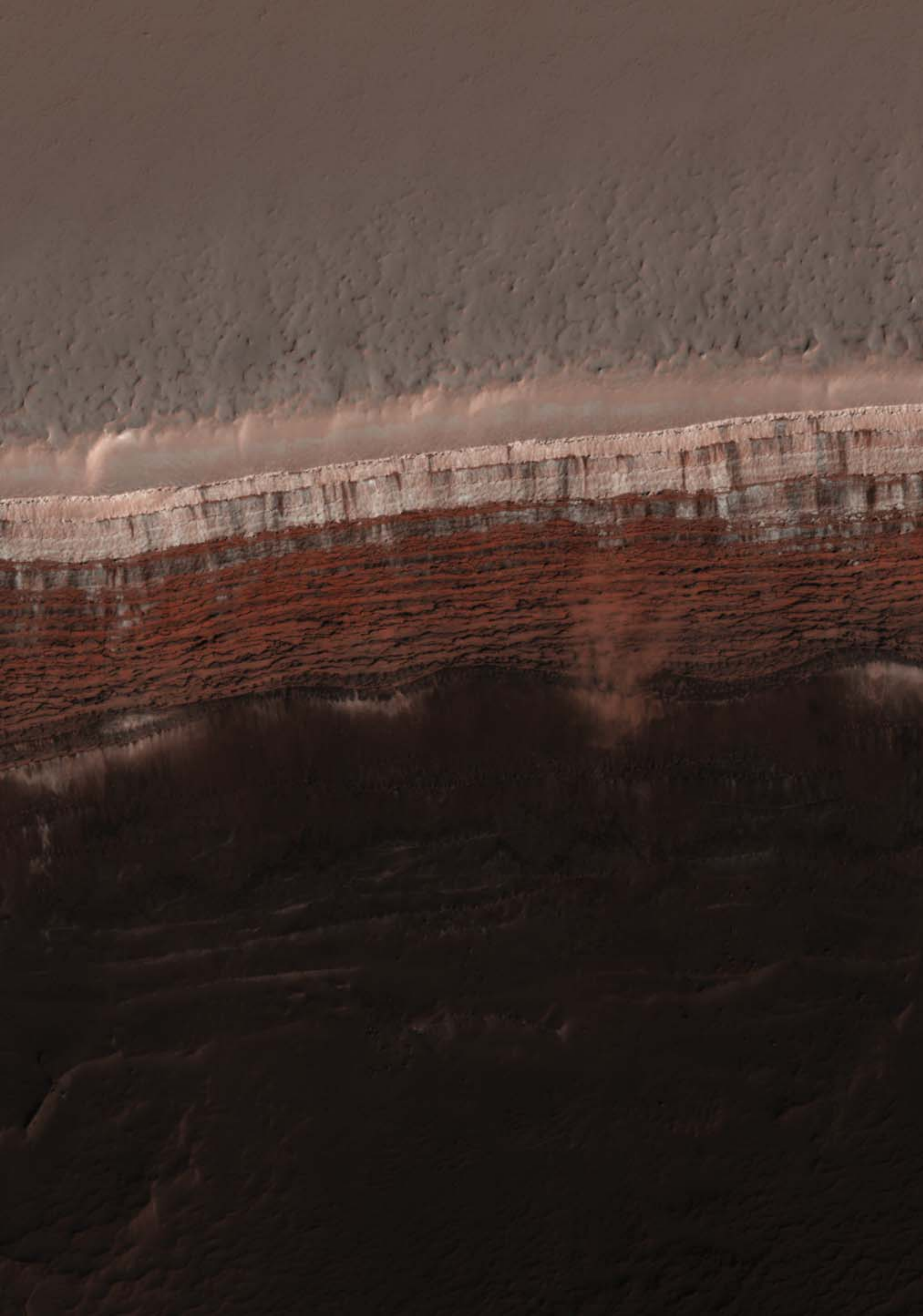
For example, the surface of Mars is very rocky. The rocks are of different sizes, colors, structures, and chemical compositions. Nevertheless, they are all thought to be material created by volcanic activity churned up by meteorite bombardment billions of years ago. It is difficult to test this theory, though, because meteorites seldom fall these days. Plus they are small rocks, not huge boulders, and volcanic activity is intermittent, if not nonexistent.

The surface of Mars has also been worked on by big floods. For example, *Pathfinder*/Sojourner landed in Ares Vallis, thought to be a vast floodplain. The images from the surface and the measurements made by the rover have validated the findings from the images taken from orbit: an ancient flood has brought a large number of rocks to the area with features suggesting that





The Martian surface south of the equator is riddled with craters of all sizes. The large crater in the upper part of the image is Schiaparelli. The zero meridian of Mars travels along the left edge of the image.



Alive and kicking. Mars Reconnaissance Orbiter's *HiRISE camera has recorded Martian avalanches in action on the edge of layered deposits at the north pole. The avalanches consist of fine-grained ice and dust with perhaps large boulders falling down a steep cliff over 700 m high. They are most probably caused by the melting of the ices in the spring.*

they came from very different regions. There is no liquid water on Mars anymore – at least not on the surface – so the effect of floods on the formations and other features of the terrain cannot be observed directly.

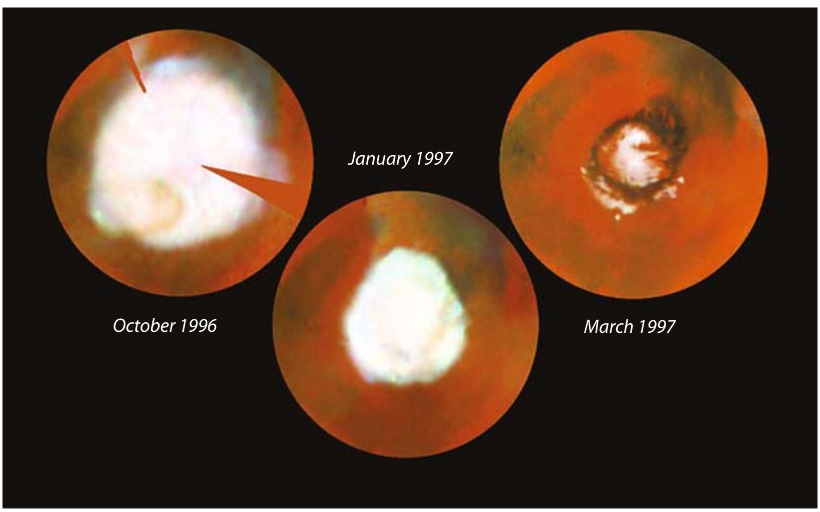
The meteorite craters on Mars are much more worn out than for example, those on the surface of the Moon. Despite their age of billions of years the lunar craters still look very fresh because there is no atmosphere, wind, or water to wear them out. Mars, on the contrary, used to have a much thicker atmosphere than it has now, and large amounts of water, which, together with volcanic activity, have affected the appearance of the craters. But not anymore; nowadays the surface is changed only by the dust carried by the winds.

Opportunity found an iron–nickel meteorite about the size of a basketball.

A "living" world

● There might not be life on Mars, there might never have been, but it is not a completely dead planet. Even though the atmosphere of Mars is very thin, it is thick enough to ensure that there is always something happening on the surface of the planet. While the footprints left by the astronauts on the surface of the Moon will look nearly the same even after millions of years, the dust carried by the winds on the surface of Mars is continuously covering up old formations and exposing new ones.

The size of the Martian polar caps varies with the seasons. Images taken with the Hubble Space Telescope show the northern winter changing into spring and summer.

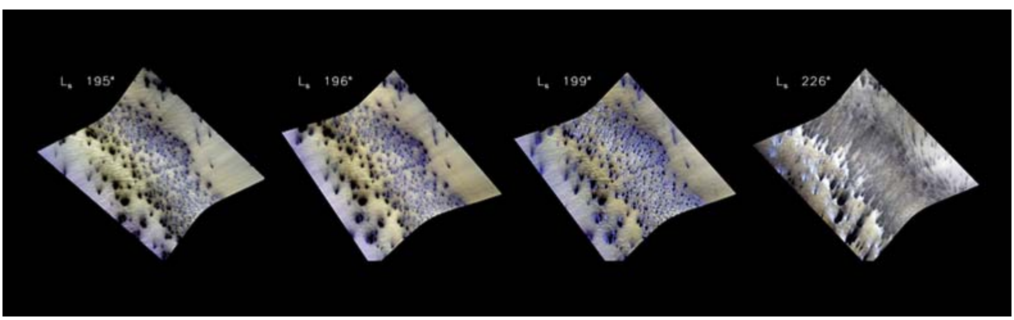


Mars's atmosphere consists almost exclusively (95%) of carbon dioxide. The amount of nitrogen is less than 3% and of argon about 1.6%. There is a tiny amount of water in the form of water vapor, and the oxygen is next to negligible. The atmospheric pressure on the surface is about 6 mbar, or 1/200 of the atmospheric pressure at sea level on Earth. In spite of the modest density and low pressure the greenhouse effect caused by the atmospheric carbon dioxide has raised the surface temperature by about 6°C.

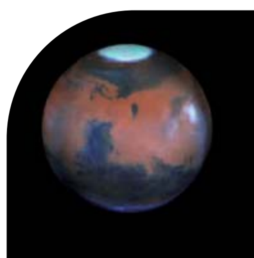
The atmospheric conditions and phenomena are continually affected by dust, which is always present in small amounts, but during dust storms in large quantities. The dust absorbs the radiative energy from the Sun and warms up the atmosphere. Going up from the surface the temperature drops so that at an altitude of 40 km it is some 60°C lower than on the surface. In theory the temperature should drop even faster, but it is slowed down by the dust floating in the atmosphere.

A large part, even as large as one third, of the carbon dioxide in the Martian atmosphere participates in the seasonal cycle between the polar areas. In the wintertime, carbon dioxide sublimates in the polar cap to form a layer a few meters thick, which in the spring sublimates back into the atmosphere, beginning a migration to the other pole. The southern polar cap is made entirely of carbon dioxide, so in the summer it disappears completely, but at the northern pole there is also water ice, which forms a permanent polar cap.

Just like carbon dioxide a part, although a small part, of the water ice sublimates in the spring and summer into water vapor, which is sometimes visible high in the atmosphere as thin clouds



The Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) aboard the Mars Reconnaissance Orbiter *has recorded seasonal changes in the south polar cap. When sunlight warms the soil beneath the ice, carbon dioxide frost starts to vaporize at its base. The gas is trapped under the frost until it is released in an outburst that makes the expanding gas cool and partially refreeze to form bright, wind-swept fans. (L_s = 180° is the southern spring equinox; L_s = 270° the southern summer solstice.)*



or after an especially cold night on the ground as a thin layer of frost vanishing with the first rays of the rising Sun.

Nowadays the winds in the thin atmosphere are a very important if not the only factor in the slow change of the formations on the surface of Mars. In the low gravity the strong winds have an easy job of taking dust and sand up with them to grind away rocks and cliffs. The winds also cause sand to drift into dunes in places covering very large areas. For example, the northern polar cap is surrounded by an almost continuous dune field.

The winds also affect the visibility of the surface features of Mars from Earth. Astronomers peering at Mars with their telescopes from the seventeenth century onward developed imaginative theories on why the appearance of the dark and light areas, the albedo features, change from one opposition to the other. Today we know that the dust carried by the winds is to blame. For example, Syrtis Major, the first feature identified on Mars, has changed considerably in the course of the centuries. In reality the dark area is a lava plain sloping gently upward. For short periods it is partly covered by light dust before being blown again away by the winds.

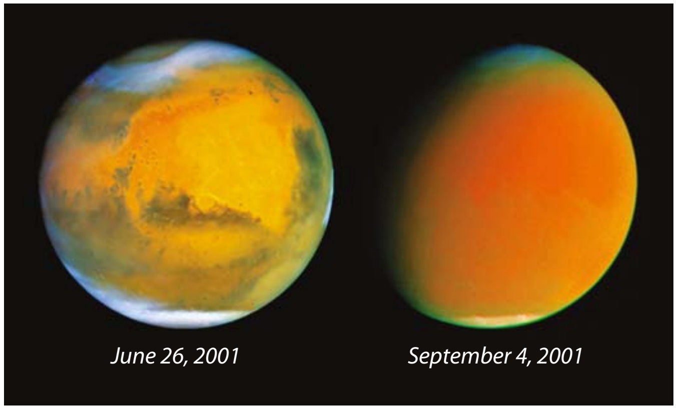
Dusty gusts

● The big dust storms are the most effective means of transporting dust around the planet. Usually their occurrences concentrate at post-perihelic time, when Mars is closest to the Sun and there is summer in the southern hemisphere. In certain areas there are small dust clouds almost all the time, but every now and then the clouds gather to form a storm that engulfs the whole planet. It was one of those storms that covered the surface of Mars in November 1971, when *Mariner 9* arrived at Mars, and the latest – though a lot smaller than the one in 1971 – was in mid-summer of 2007 in the southern hemisphere of Mars. By the latter half of June (by our calendars) dust clouds had appeared near the eastern end of Valles Marineris, and within a few weeks the whole planet was obscured by dust raised by both local and regional storms.

In broad outlines the cause of the dust storms is known rather well, but there is much to learn in the details. Usually they begin

A THEORY OF THE END OF THE WORLD

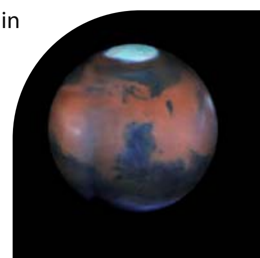
● The dust storms on Mars and their effects on the conditions of the planet gave rise in 1983 to a theory on nuclear winter, a prolonged period of cold weather following a large scale nuclear war. According to the theory the vast fires lighted by the nuclear explosions would release so much smoke, soot, and dust into the atmosphere that the Sun would be blacked out for months if not years. The mean temperature could set as much as 20°C, which would cause a global winter lasting for several years. The theory is known as TTAPS after the initials of the last names of the scientists – Richard Turco, Brian Toon, Thomas Ackerman, James Pollack, and Carl Sagan – who developed it. Nuclear winter theory played an essential role in the arms limitations realized in the 1980s.



The great dust storm of 2001. The images of Hubble Space Telescope show the same hemisphere of Mars. During the storm dust covered up the details of the surface almost completely.

in the Hellas Basin which – with its depth of 9 km and diameter of 2,300 km – is so vast that it affects the global circulation of the atmosphere. For example, in this case tiny stormlets began to raise enough dust into the atmosphere that it started to absorb the heat of the Sun. This caused the upper layers of the atmosphere to warm up, according to measurements by 20–40°C. But closer to the surface the temperature stayed low, since only some 20% or less of the solar radiation was reaching the surface of the planet. The temperature difference created between the upper and lower atmosphere gave rise to strong winds with velocities of almost 500 km/hour blowing between cold and warm masses of air. This raised more and more dust in the air, and the dust absorbed more and more heat, and so on. A Martian dust storm is a treadmill giving itself a push: the warming of the upper atmosphere is at the same time the result and the cause of the dust storms.

A dust storm may envelop Mars for months, but finally even the strongest of storms will lose vigor. When the temperature difference finally evens out, the winds start to calm down, and there is no more new dust rising in the air. In the low gravity of Mars the dust floats in the air for a long time, even if the storm subsides and there are small dust clouds here and there just like before the big storm. Dust particles with a diameter of about 1 μm, or one thousandth of a millimeter, usually fall back to the surface in a few months, but smaller particles might remain up in the thin



air for years. That is why there is always some dust in the atmosphere; the Martian sky is never completely clear.

An unsteady planet

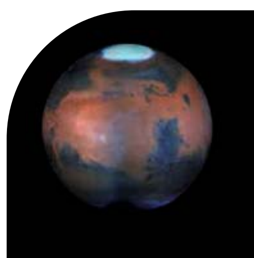
● One reason for the changes on Mars is the very large variations in the inclination of the axis of rotation, which is caused by the huge gravity of Jupiter, the effects of which are not balanced by a large satellite, as in the case of Earth. The position of the axis of Mars changes every 100,000 years by about 20° from the current value, but the variation is chaotic and unpredictable. During the past 10 million years the inclination of the axis of rotation might have changed between 0° and 60°.

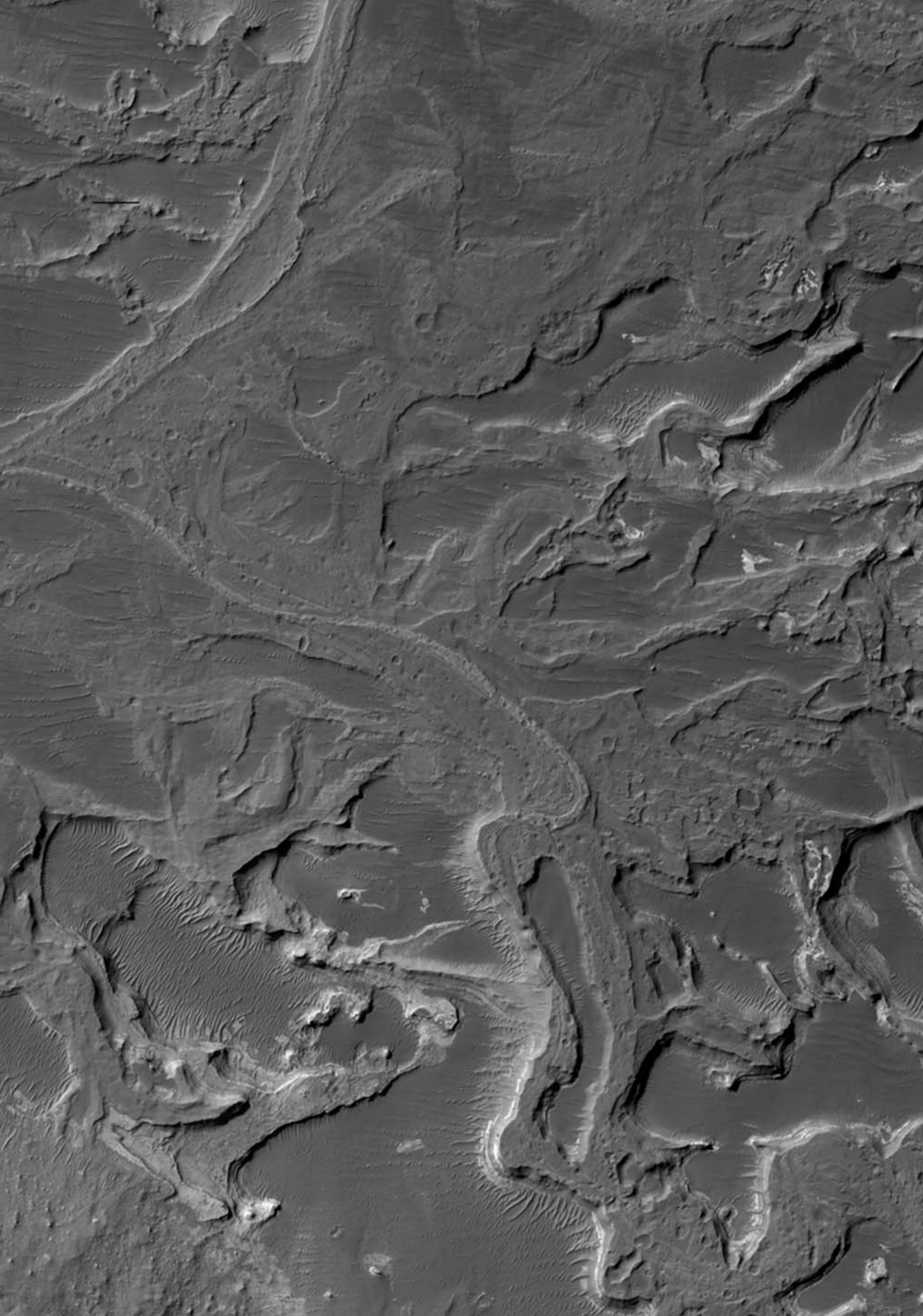
These changes affect the seasonal variations and the severity of the climatic conditions. When the axis is more or less in an upright position the polar areas receive less radiative energy from the Sun and it is colder there; at those times a very large part of the atmospheric carbon dioxide and water vapor sublimate into the polar caps. When the axis is more tilted, the polar areas receive more radiation, and larger amounts of the gases in the polar caps are released into the atmosphere. At present the sublimation of water vapor from the northern polar cap during the summer makes it thinner by only some tenths of a millimeter, but when the inclination of the axis is large, the cap may lose dozens of centimeters of ice. The increase of atmospheric carbon dioxide and water vapor will make the greenhouse effect stronger, and the climate may warm up considerably. According to some theories there is an ice age on Mars at the moment, the end of which will bring more favorable weather conditions with it.

Earlier the notion of the variations in the inclination of the axis of rotation of Mars and their magnitude was mainly based on theoretical calculations. In 2005 scientists got more direct evidence for the first time that the position of Mars has really changed a lot in the past billions of years. The Canadian astronomer Jafar Arkani-Hamed studied the large impact basins on the surface of Mars and noticed that five of them – Argyre, Hellas, Isidis, Thaumasia, and Utopia – lie in a straight line, or to be more precise, in a great circle. Three of the basins are easily seen in images and in topographic maps, but the other two were found only after studying the deviations in the gravitational field of Mars. At the site of the impacts the gravity is slightly stronger than in the surrounding areas, since due to the impacts the material at those sites has a higher density.

According to Arkani-Hamed the basins were formed after an asteroid with a diameter of about 1,000 km came close to Mars and broke up, with the fragments hitting the surface of the planet lined up in a row – much the same way as the pieces of the comet Shoemaker-Levy 9 hit Jupiter in 1994. The inclination of the axis of Mars's rotation at that time can be deduced from the fact that the fragments followed the same orbit and hit different spots only because the planet had time to rotate a little between the impacts. This makes the line of the basins parallel with the ancient equator of Mars.

What makes Arkani-Hamed's results even more interesting is that the impacts occurred before the formation of the Tharsis region. According to the current view there was lots of water on Mars in those days, flowing in rivers and standing in lakes and seas. If the inclination of the axis of rotation of Mars really was at that time what the theory indicates, it differs from the current inclination by nearly 60°. The areas now near the equator would have been close to the poles, so because of the cooling of the climate a thick layer of permafrost must have formed in those areas with possible layers of groundwater underneath it. And they might still lurk at depths of several kilometers beneath the surface.





07

MUSEUM OF WATER

They sat still and felt the canal water rush cool, swift, and glassy.

– Ray Bradbury: *Martian Chronicles* (1950)

In the beginning of the twentieth century the Martian channels vanished into thin air, and Mars turned out to be an arid world. This view was confirmed in the 1960s when the first probes sent images of desolate plains covered with craters reminiscent of the Moon. The pendulum swung in the opposite direction in the early 1970s, when *Mariner 9* photographed the true channels of the Red Planet. There had been water on Mars after all, lots of water.

Ancient liquid

● Liquid water flowed on the surface of Mars, but it has been a while. For the first 500 million years in the history of Mars there were rivers and lakes, perhaps even an ocean covering a large portion of the surface of the planet. At the age of about 1 billion years the conditions on the planet began to deteriorate rapidly. The atmosphere dwindled, the climate cooled, and the water disappeared. All that was left was terrain with records of the surging masses of water of a long time ago.

Ancient river deltas on Mars have sand accumulated by running water. The image shows a delta in an Eberwald crater with a diameter of 64 km. The total area of the delta is about 170 km^2.

The age of formations on a celestial body can be estimated by the number of craters on its surface. In their youth the vagrants of the Sun were constantly hit by boulders of different sizes, but after a heavy bombardment lasting a little less than 1 billion years the

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number of boulders swiftly decreased. Most of them had already been destroyed in collisions with larger bodies.

When there are areas on a planet with lots of craters, it can be said with certainty that the surface at those places is very old. If the number of craters is small or they are absent altogether, the surface is younger, because some later factor – lava flows, floods, or, as in the case of Earth, plate tectonics – has wiped out the craters completely or in part.

However, there is a problem with the dating of Martian terrain based on crater counts. It has been found that large impacts have ejected much more material into the air than previously thought. In falling back to the surface this material has created countless secondary craters with diameters of less than 2 km. Distinguishing them from the "real" meteorite craters has proved to be very difficult, so the surface appears to be more hammered by impacts than it really is and thus a lot older, too. The accuracy of dating the surface of Mars by crater count is about 10 million years at best.

The images taken by Mariner 9 *showed that there are canals on Mars after all. A long time ago water flowed in the Kasei Valles toward Chryse Planitia.*

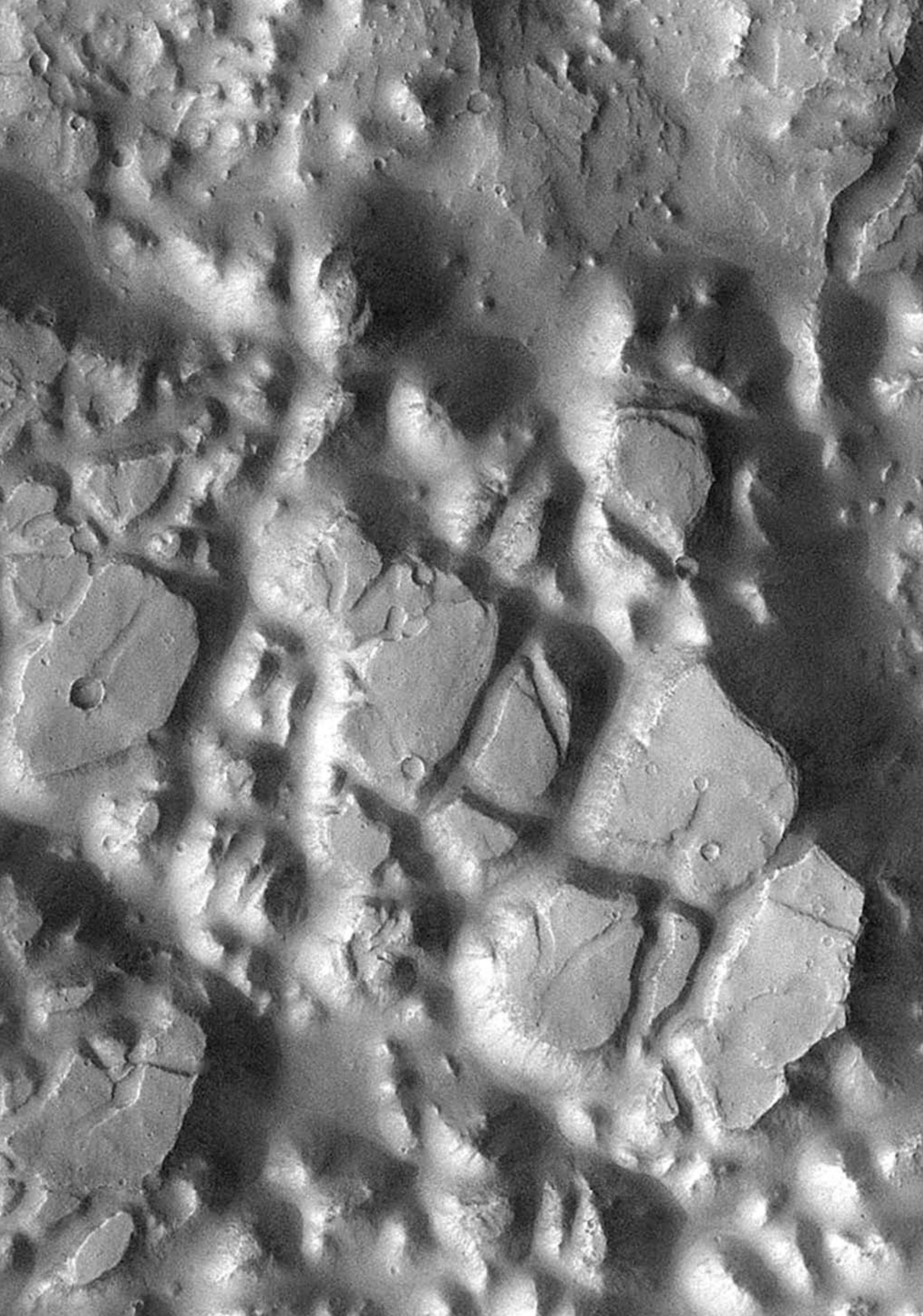
Nevertheless there are old, dried riverbeds, deep valleys carved by water, vast plains flushed by floods, and frozen mud splashed from craters on Mars. Some of the most convincing signs of water are the flows originating from "chaotic terrains," with effects reaching for hundreds, sometimes thousands of kilometers downstream. The prevailing view is that these were born by volcanic activity suddenly melting subsurface ice deposits. The ground above the deposit has collapsed because the ice underneath it has turned into water and flowed to lower areas.

Here and there signs of water overlap with ancient craters, but in some places it is the other way around: the surface of Mars has also been hit by cosmic rocks even after water flowed. Scientists are more or less unanimous on the wet past of Mars, but there is still an ongoing dispute on whether it was warm or cold when there was liquid water. According to some scientists the Martian climate was once – thanks to a strong greenhouse effect caused by a thicker atmosphere – much more temperate than it is now. Others think differently.

"Chaotic terrains" have been formed when subterranean ice deposits melted and the layers of soil covering them collapsed. The image taken by 2001 Mars Odyssey *depicts Aureum Chaos south of the equator.*

Icy lakes

● Water may be liquid even if the temperature is below freezing. In the solid state water is lighter than in the liquid state; hence ice



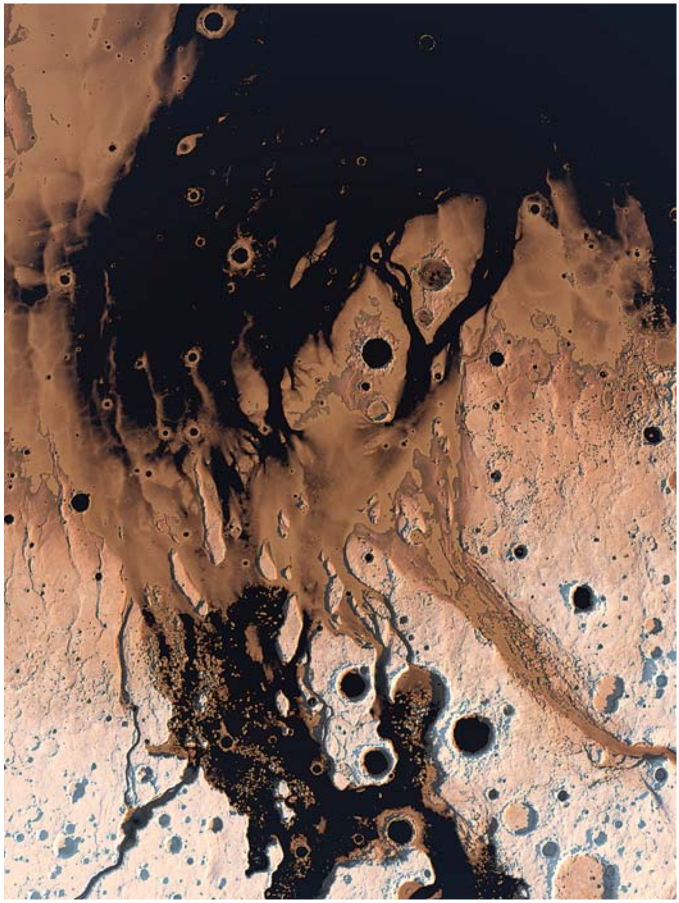
floats and can cover bodies of water with an insulating layer. This phenomenon is very familiar to people living in northern latitudes on Earth, where there are strong seasonal variations, but it is also common in extreme conditions with continuously cold weather.

Dry Valleys in the Antarctic is the most "Martian" environment on Earth, with an average annual temperature of −30°C and an annual rainfall – in the form of snow – of only a couple of centimeters. Still there are lakes to be found. The snow falling on the slopes of the valleys piles up slowly into ice. The meltwaters of the glaciers flow into lakes in valley depressions when the temperatures during the rare "warm" days of the short summers climb above zero. The energy required for melting the ice is bound in the water, and when it flows into the lake and freezes up again at the bottom of the permanent ice cover, the energy is released, keeping the water underneath the ice in a liquid state. This way the ice cover will not reach the bottom of the lake, but the thickness of the ice stays at around a few meters.

Gusev crater, the landing site of the Spirit rover, and Ma'adim Vallis running into it. The crater might have been an ice lake in the past.

A similar water cycle might have been possible on Mars when the climate was somewhat milder than it is now. With the inclination of the axis of rotation at maximum and Mars in perihelion – closest to the Sun – with either of the hemispheres experiencing summer, the mean daily temperature might have risen above 0°C. Should lakes have formed, they might have existed for hundreds of millions of years even after the temperature had fallen permanently below freezing. These kinds of "ice lakes" are not found on Mars anymore, since the atmospheric pressure is so low that any ice on the surface of the planet would sublimate into water vapor and not melt into the water needed to feed the lakes hiding beneath the ice. Unless . . . There is a slim chance that a thick layer of dust or volcanic ash covering the ice might act as insulation preventing the sublimation.

One of these ancient ice-covered lakes might have been in the Gusev crater near the equator, the landing site of the Spirit rover. Gusev and Ma'adim Vallis, a dry riverbed running into the crater, lie in an area covered with fresh-looking craters of all sizes, so the region obviously has not had any substantial rain for billions of years. However, water got there somehow and in such an abundance that it grooved a river valley in the middle of the plain and possibly filled up a large crater, creating an ice lake.



If there were still liquid water on Mars, the surface of the planet might look something like this. Waters from Valles Marineris flood the Chryse Planitia plains. Kees Veenenbos' computer graphics image is based on measurements made with Mars Global Surveyor's *MOLA instrument.*

A planet of a thousand lakes

● Just as Finland has been called "the Land of a Thousand Lakes," and for good reason, Mars could be called, for as good a reason, "the Planet of a Thousand Lakes" – or at least of a thousand past lakes. The images taken by the *Viking* probes in the late 1970s already revealed a couple of hundred formations identified as crater lakes, and with the improved resolution of instruments on later probes the number of lakes has multiplied many times.

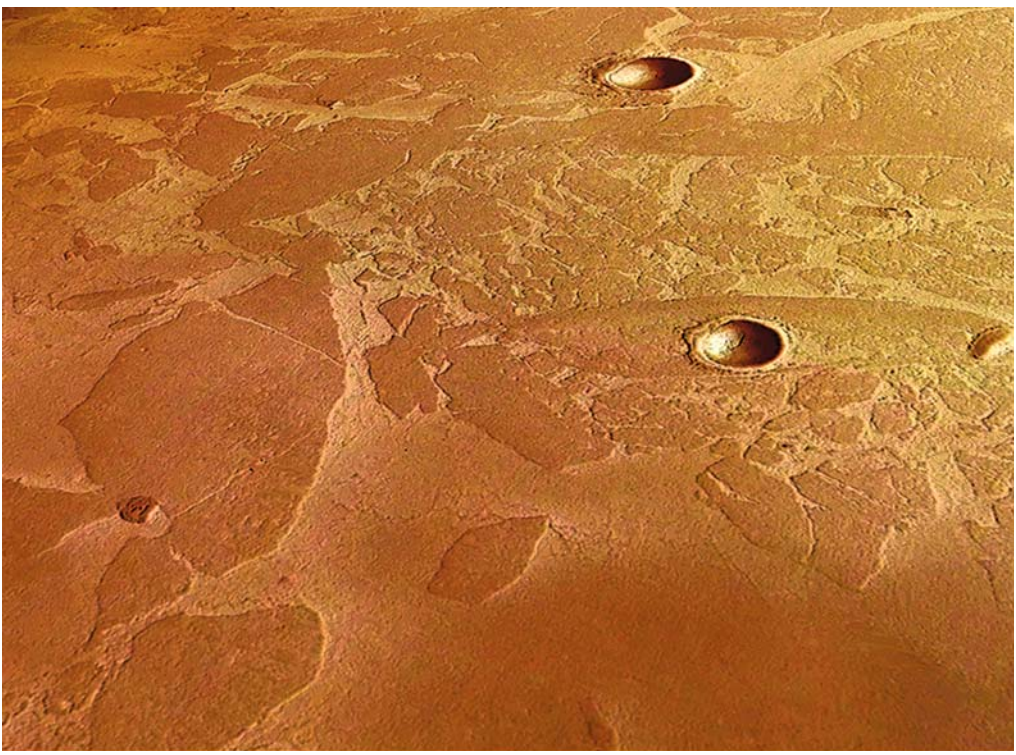
Most of the ancient lakes are situated in the southern hemisphere. This is because of two simple reasons. To begin with the southern highlands swarm with the craters necessary to accommodate lakes, while on the other hand the northern hemisphere was at that time possibly covered by an ocean.

Performing observations from orbit around Mars at a height of a couple of hundred kilometers makes it difficult to determine with any certainty whether there has been water in a particular depression, unless water has been present for so long that it has had time to leave clear and permanent signs of its existence. On Mars there are plenty of those signs.

There are deltas in the dried-up crater lakes formed when the rivers running into the lakes deposited sand and dust in the still water; there are banks that formed while waves eroded the shores of a lake; and there are different kinds of strata formed when soil in water sank slowly to the bottom of a lake or the shallow waters evaporated, causing a lake at times to completely dry up.

For example, the size of a delta gives a clue as to how long the lake existed. In some cases the total area of a delta is tens or hundreds of square kilometers. If the formations on Earth are to be used as a guideline, the formation of these Martian deltas took

A frozen ocean? Mars Express *has photographed formations on Elysium Planitia near the equator of Mars looking a lot like ice floes. The largest "floes" have an area of dozens of square kilometers. On the surface of Mars – except in the polar areas – water ice would normally sublimate rapidly into water vapor, but a thick layer of dust covering the ice would prevent it.*



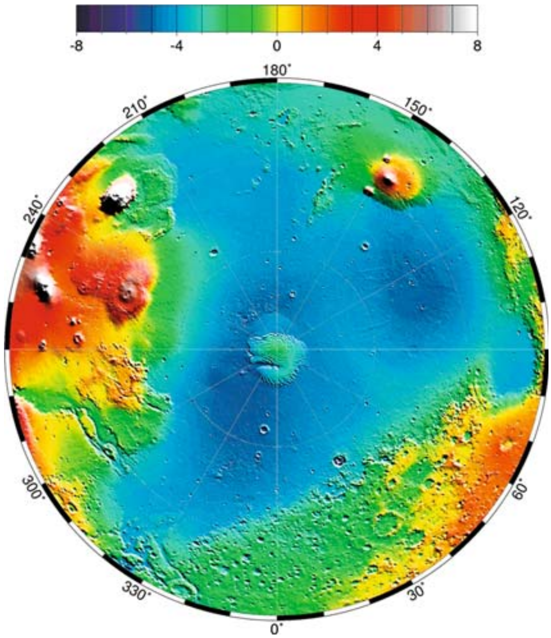
thousands of years. The river must have been running for the same amount of time, at least.

On the last shore

● Just like the lakes, the sea supposedly billowing on the northern hemisphere has left clear signs of its ancient existence – or it should have. The *Viking* imagery led the scientists to also suspect that there really has been an ocean there. Here and there are formations reminiscent of the shorelines of Lake Bonneville which covered the southeastern parts of North America around 15,000 years ago. The Martian images showed several shorelines thought to correspond to the different stages of evolution of the "Northern Lake" – just like the boulder fields in different parts of Finland tell us about the post-glacial development of the Baltic Sea. The problem is that the age of these formations on Earth is of some thousands of years, while on Mars it is thousands of millions of years. At best they give just a vague idea of the original banks.

This theory could be tested with unprecedented accuracy after the *Mars Global Surveyor* started to transmit the results of the Mars Orbiting Laser Altimeter (MOLA) at the end of the 1990s. Measurements revealed two fairly unbroken formations looking like shorelines, which were named "Arabia" and "Deuteronilus." In case they really are ancient shorelines, they should have been formed at a certain stage of evolution at the same height. Wider Arabia proved to have differences in elevation of more than 5 km, so it is very unlikely it is an ancient seashore. Although the ocean has a billion-year-old past, with the surface of Mars experiencing all manner of upheavals during that time, they could not have caused vertical movements this large in the northern hemisphere, where the terrain otherwise is very smooth. The differences in elevation of Deuteronilus are less than 300 m, so it might very well be what the scientists were looking for: an ancient shoreline.

The depth of the ocean covering the northern polar regions is estimated to have been more than 600 m, with the deepest point being about 1.5 km. In extent it would have corresponded to the Mediterranean and in amount of water to about a third of the Atlantic Ocean. The prevailing view is that the floodwaters coming



One reason behind the smoothness of the northern polar areas of Mars might be that they are an ancient ocean bottom. Based on measurements with MOLA instrument most of the blue and purple areas on the map could have been covered with water.

from the southern hemisphere gave rise to the ocean. In places volcanic activity would have melted the permafrost, and the waters released would have run into the northern hemisphere, which lies lower than the southern one.

Some scientists think that the events described might have happened in an opposite way: the great floods would have been caused by the ocean. With the climate getting ever cooler the ocean would have gotten an ice cover. Its weight would have squeezed the water still in liquid form toward the south, into the bowels of the ground. Reaching the southern highlands, water would have burst in places to the surface and run back to the ocean, until the permafrost grew so thick that the waters beneath it stayed there, forming groundwater that is possibly still in existence.

Snow and ice

● Dried riverbeds, ancient shorelines, and vast floodplains can be explained by assuming that they were born billions of years ago when the Martian climate was warmer than today – or at least wetter.

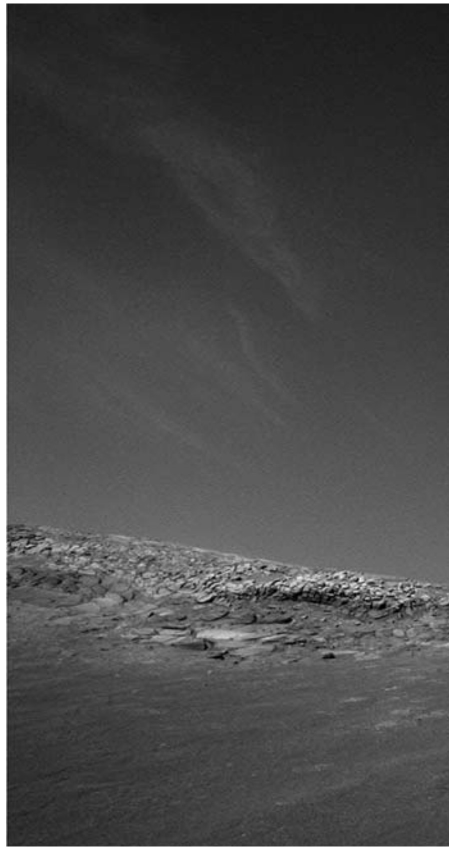
However, a large number of crater walls and ridge slopes have narrow gullies, the formation of which is far more difficult to explain.

The gullies cross older formations; they can be found in young craters, and all in all they look fresh. They must have been born not billions, but millions, perhaps just thousands of years ago. They might be even younger than that. The *Mars Global Surveyor* photographed a number of craters several times over a time interval of a few years, and some of them showed gully-like features only in the most recent images. Something must have happened there in between.

At first it was thought that the gullies were born when the subsurface water or ice deposits made their way through the crater wall because of heat, with running water carrying rocks and boulders carving the gullies. This explanation is weakened by the fact that the craters with gullies are most abundant at mid-latitudes, where the heat from the Sun is insufficient to melt any underground ice, and practically nonexistent at the equator, where there might be just enough warmth to do the job. Besides, the gullies in the northern hemisphere are concentrated on the north-facing slopes, and in the southern hemisphere on the south-facing slopes, both being at all times in shadow.

According to one theory the gullies were formed under heavy blankets of snow. The snow once present on the surface of Mars was gradually covered with dust. This "dirty" snow absorbed more heat, so the snow in the lower parts of the drifts started slowly to melt. This produced only a small amount of water, something like a leaking faucet, but in the course of several millennia it had enough time to carve deep gullies. When the snow finally melted completely, the fresh-looking gullies were exposed.

This theory also supports the current view on the heavy wobbling of Mars. With the inclination of the axis of rotation at maximum, the polar regions receive more solar heat than usual, making them warmer and thus releasing water vapor from the polar caps into the atmosphere. At the same time the mid-latitudes cool down, so the water vapor turns into snow and falls. The blanket of snow can grow up to 10 m thick, but it snows very seldom, perhaps once every 100,000 years. Still, it could explain the enigmatic gullies.



Celestial climate change

It is a known fact that the precession of Mars has an effect on the climate of Mars and the presence of water on the planet. In 2007 yet another phenomenon related to this was found with the ESA's *Mars Express* probe. The Omega instrument (Visible and Infrared Mineralogical Mapping Spectrometer) of the probe had earlier found perennial deposits of water ice on the southern pole that had gone unnoticed before. The mapping and spectral analysis of water ice made with the instrument revealed that the deposits come in three different types.

There is water ice mixed with carbon dioxide ice, large areas of water-ice tens of kilometers wide, and water ice covered by a thin layer of carbon dioxide ice. According to recent observations and model calculations based on them water on Mars has a somewhat

The gullies in the crater walls are carved by water. They have lengths up to several kilometers.

Winter time clouds above Endurance crater photographed by the Opportunity rover.

similar cycle to carbon dioxide. It is transported between the northern and southern poles over a period of tens of thousands of years in which the precession of Mars is inverted.

A research group lead by the French Franck Montmessin discovered that because of the instability of water ice on the northern pole it was easily sublimated into water vapor which, after being transported to the southern pole, froze again on the surface. The process was continuous and cumulative, depositing up to 1 mm of water ice at the pole each year. The unstable condition of water ice was caused by the fact that 21,000 years ago Mars was closest to the Sun at the time the northern hemisphere was experiencing summer – a condition opposite to the present one. With the estimated rate of depositing and the time it continued – some 10,000 years – the layers accumulated this way reached a thickness of several meters.

About 10,000 years ago the precession of Mars reached its maximum and started to swing back to what it is today. The cycle of water ice was reversed, too, and water ice began to accumulate again on the northern pole of Mars. However, some 1,000 years ago the process was stalled, since water ice was, for an unknown reason, covered by layers of carbon dioxide ice, preventing any further sublimation of water ice.

Lost water

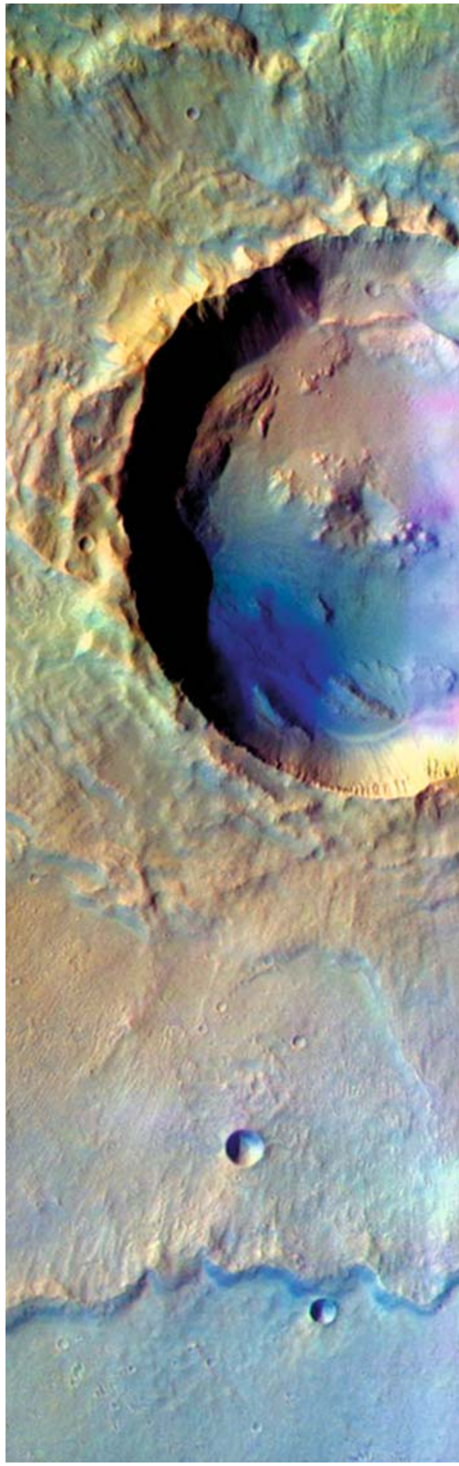
● The original water supply of Mars might have been even larger than Earth's – at least relatively speaking. Later, perhaps as much as 90% of the water disappeared. Where is it now?

The largest estimates on the amount of ancient water would correspond to a planet-wide ocean with a depth of 1 km (evenly spread the water in the oceans of Earth would form a blanket 2.8 km thick). If there really were lots of water on Mars, it has three feasible hiding places: the atmosphere, the polar caps, or the ground, where it might exist as either permafrost or groundwater – or both.

The amount of water vapor in the atmosphere of Mars has been measured, and it has proven to be next to negligible. The water vapor content in the Martian atmosphere corresponds to a layer of water only 0.015 mm thick. Furthermore, the ultraviolet radiation of the Sun continually breaks down the atmospheric water vapor into oxygen and hydrogen. Most of the oxygen forms chemical compounds with other elements. The rest of the oxygen and the hydrogen rise to the upper parts of the atmosphere, where the unhindered solar wind blows them into space because Mars lacks the protection a magnetic field gives to Earth. However, this explains only a tiny fraction of the missing water, so the atmosphere is not the place to look for the vanished water.

The polar caps are known to contain water ice in addition to carbon dioxide ice, but the amount of the water ice is not exactly known. However, even an optimistic estimate would give an amount of water large enough to cover the planet with a layer of only about some tens of meters. Most of the water seems to be hidden under the surface of Mars, but the question is how deep, and in a liquid or a solid state?

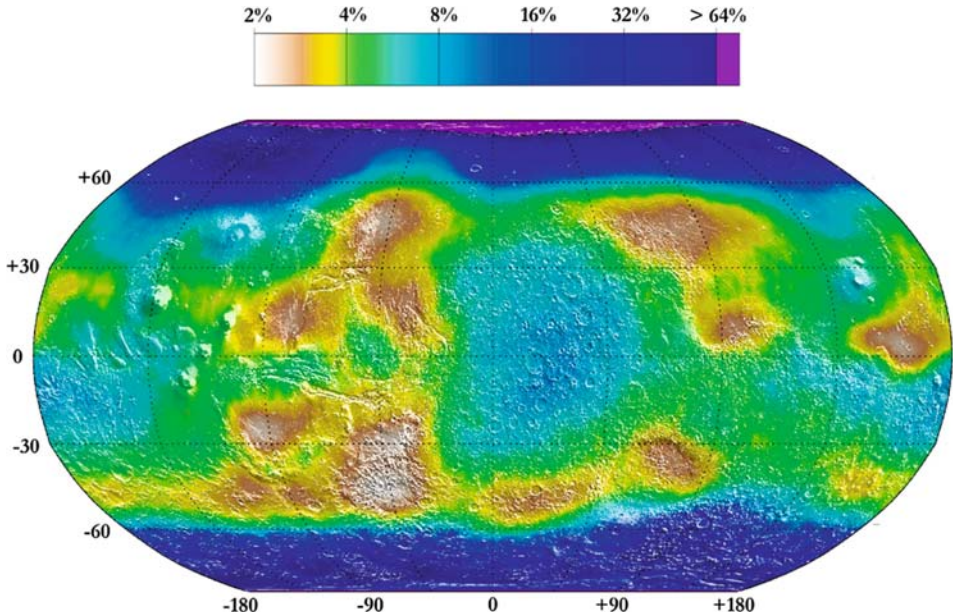
The traditional idea is that the water is there in the form of permafrost. This view is supported by certain type of craters where the meteorite impacts have melted the permafrost and splashed mud all around the craters. Recent observations and theories based on these seem to indicate that there might be groundwater underneath the permafrost. The low surface temperature of Mars and the low internal heat of the planet would mean that the layer of frozen water could be several kilometers thick. However, if you go even deeper the circumstances might be favorable for the water to be in a liquid state.



"Follow the water!"

● The guideline for Martian studies adopted by NASA is "Follow the water." Life on Earth needs water to survive, so in case Mars is found to harbor or having harbored life, it will be found where there is water, too. Thus, to find life it is best to look for water. And if it is not found, the second best choice is to look for places where there appears to have been water. The surface features strongly indicate the effects water may have had, but they do not prove beyond any reasonable doubt that there has been water on the surface of Mars long enough for life to emerge.

At first the concept of water and its effects on the Red Planet were based on images obtained with probes, but they just



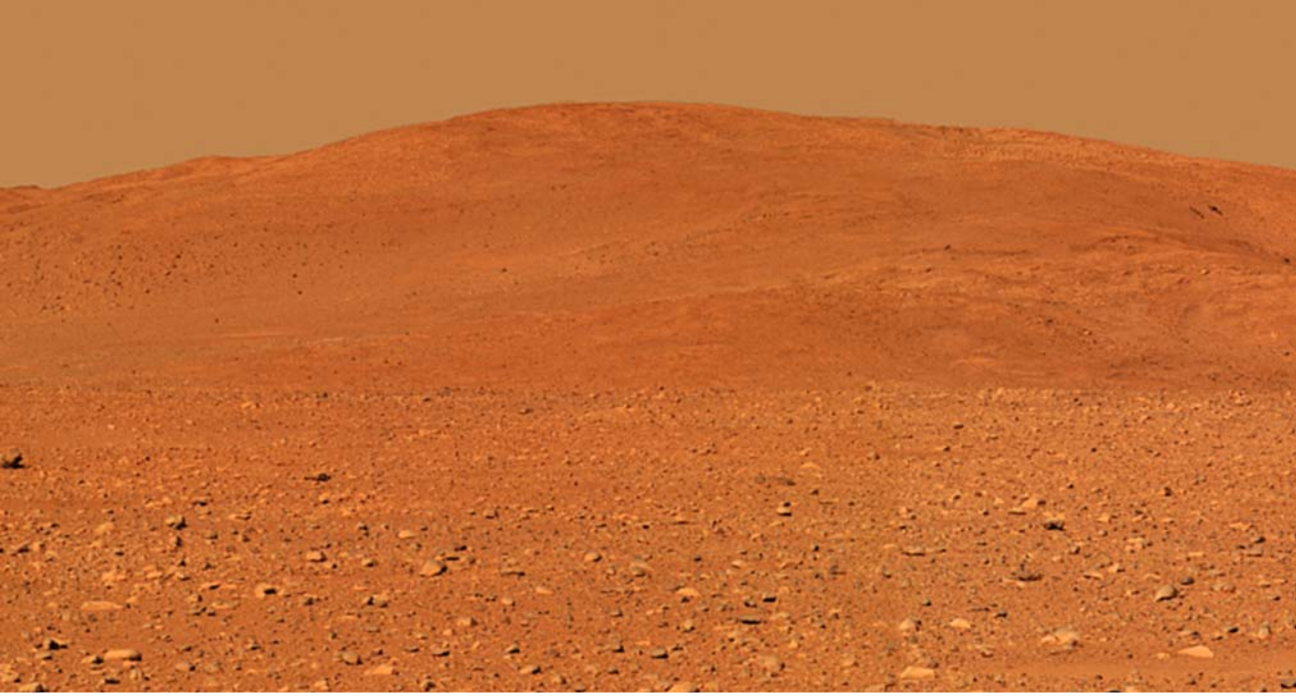
The abundance of water in the topsoil of Mars as mapped by 2001 Mars Odyssey. *The polar regions have most of the water ice, but it exists even on the equator.*

scratched the surface. The planetary probes studying Mars at the moment are capable of examining both the surface and its chemical composition and the underground, which was a previously completely unknown world.

One of the instruments on *Mars Odyssey* is a gamma-ray spectrometer, which measures very short-waved gamma-ray radiation coming from the surface of Mars and beneath it. When hitting the Martian surface the gamma-ray radiation – cosmic radiation from space – will release neutrons that penetrate to a depth of about 2 m. At the same time these neutrons hit the atoms of different elements in the ground. This causes emission of more gamma-ray radiation, the properties of which can be used to deduce the elements it is emitted by. Observations made with the probe have proven that there is a lot of hydrogen underneath the surface – hydrogen which, together with oxygen, makes molecules of water.

The instrument is capable of mapping the presence of hydrogen – that is, water ice – to a depth of about 1 m. The biggest ice deposits are in the southern polar region, where the ice in places takes up as much as one half of the volume of the ground. At latitudes corresponding to the most southern parts of Finland at latitude 60°, the ice begins at a

Large meteorites hitting Mars have melted the subsurface permafrost and splashed mud all around the craters.



depth of more than 50 cm, but at latitude 75° it is present already at a depth of some 30 cm.

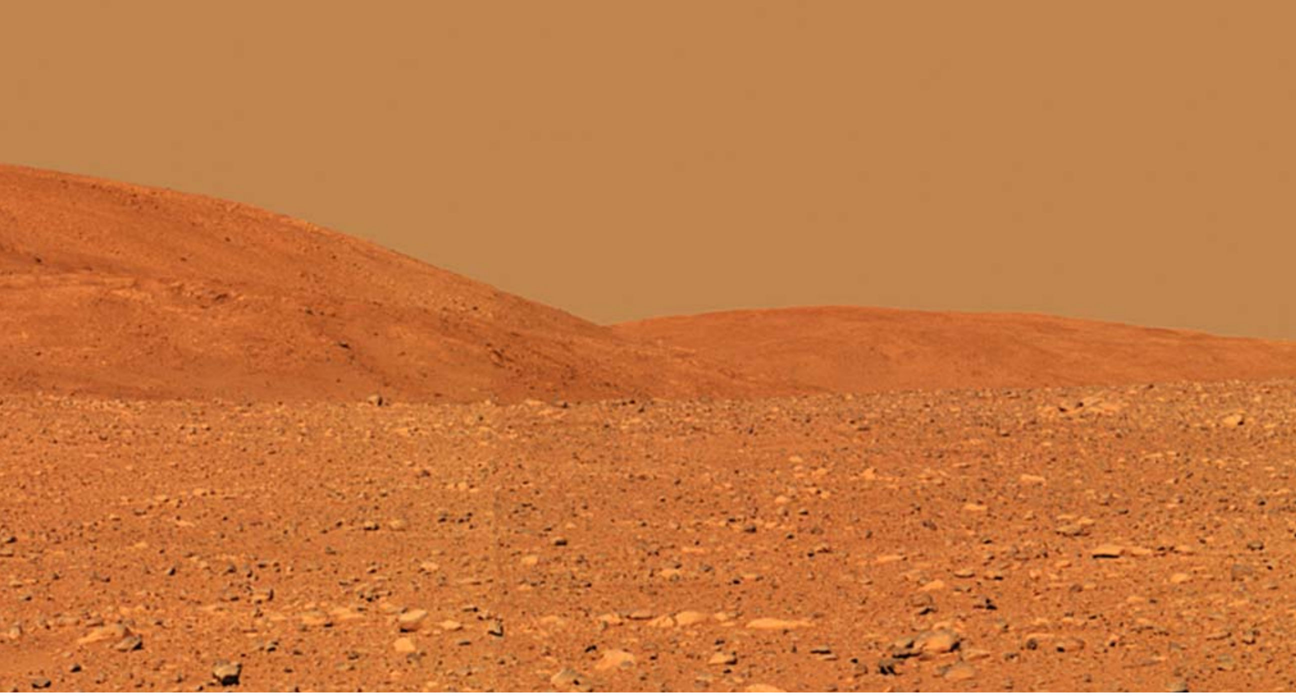
So far it is not known how far down there is ice. An instrument called the Sub-surface Sounding Radar Altimeter aboard the European *Mars Express* made it possible to study the presence of ice and possible groundwater to depths of several kilometers. The observations have confirmed the earlier estimates that there are large reservoirs of water beneath the surface – frozen underground lakes that might temporarily melt into water that would flow on the surface, leaving signs of past changes in climatic conditions.

Spirit studied Columbia Hills and found evidence that its surroundings have most probably been covered by water.

Fe_2O_3, $K_2Fe_6(OH)_{12}(SO_4)_4$, FeO(OH) . . .

● In the presence of water elements can form different kinds of chemical compounds, and in turn these form minerals that reveal the circumstances of their formation. Several types of telltale minerals have been found on the surface of Mars, including hematite, jarosite, and goethite.

Soon after landing in the beginning of 2004 the Spirit rover found hematite around the Columbia Hills (named after the space shuttle *Columbia,* which was destroyed during re-entry in January 2003) in the Gusev crater. The presence of hematite was strongly hinted at by the measurements made by the *Mars Global Surveyor*



from orbit around Mars, but the rover confirmed the findings. The existence of hematite gave rather good evidence on the existence of water, but only “rather good”; under certain circumstances hematite can be formed without any water at all.

In the spring of 2004 the other rover, Opportunity, found iron sulfate known as jarosite in the rocks of Meridiani Planum. On Earth jarosite is only found in watery environments, most often in acid lakes and hot springs. Back again to Spirit and the Columbia Hills with the finding of a mineral named goethite: goethite was the final proof for the existence of water, since the formation of goethite requires without exception water, either in liquid, solid, or gaseous state.

On Mars – just like on Earth – hematite comes in two forms: fine-grained and coarse-grained. Fine-grained hematite makes Mars the Red Planet, since it absorbs blue light and strongly scatters red light. Getting in close contact with the red version of hematite does not require a trip to Mars. All it takes is to leave a nail out in the rain or a damp autumn night: the rust that appears on the nail is fine-grained hematite.

The color of coarse-grained hematite is dark gray. With a diameter of more than 10 μm, or 1/10 thousandth of a millimeter, the grains of the mineral are so large that light is unable to penetrate them, and so it is only reflected from their surface. Gray hematite may be found even closer to hand than the red hematite on rusty nails: it is used as a gemstone. It is a rather fascinating – and apt – coincidence with the mythical history of Mars that the gemstone is usually called "bloodstone."

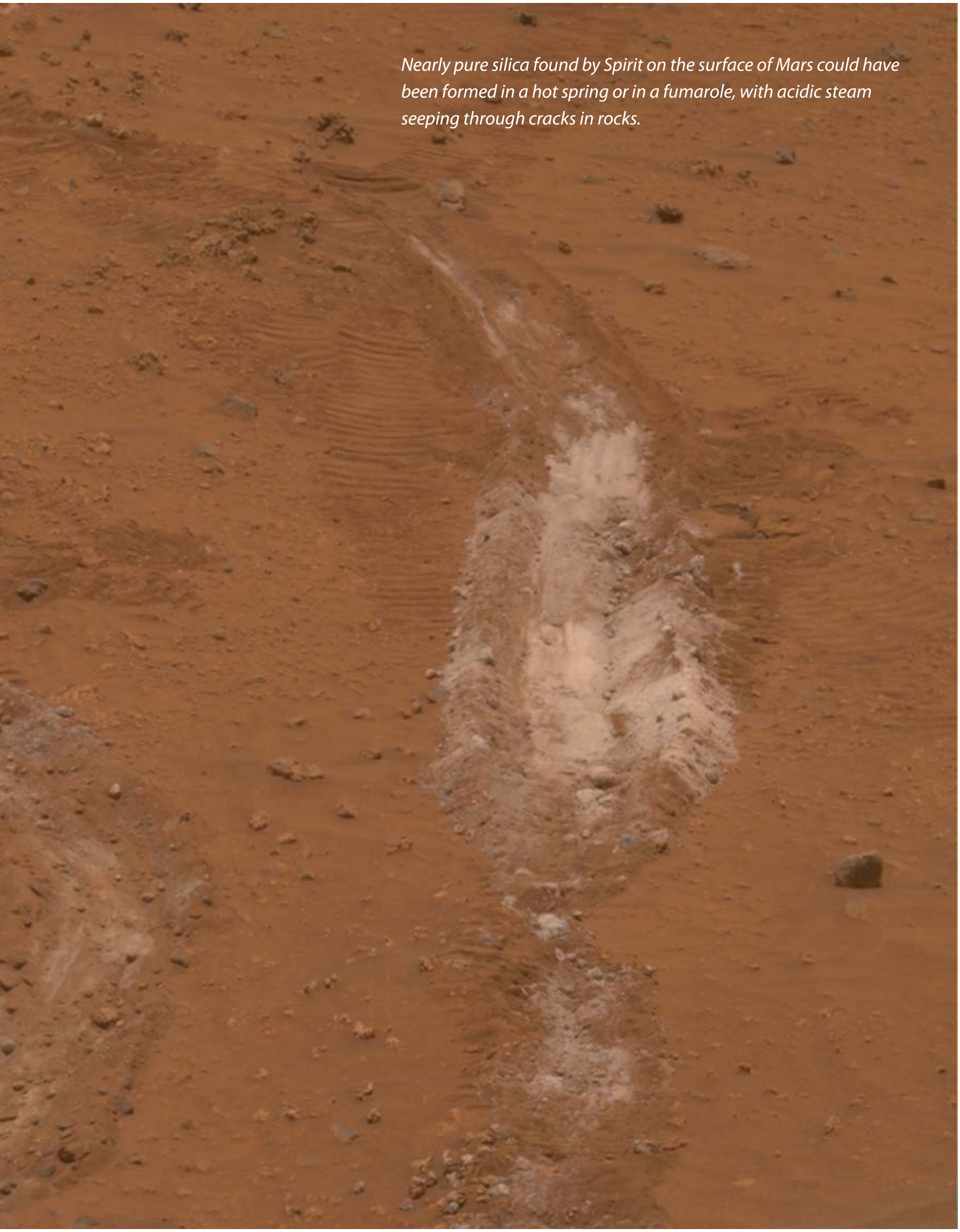
From the point of view of Martian research gray hematite is more interesting, since it is most often formed in wet environments. The *Mars Global Surveyor* charted the hematite deposits on the surface of the planet, and it was found in only three places: Valles Marineris, Aram crater, and Meridiani Planum – which is the reason why the latter was chosen to be the landing site of the Opportunity rover.

On Earth hematite is formed, for example, when iron in water is oxidized and deposited on the bottom of a lake. Another alternative is hot springs in which hydrothermal activity caused by volcanism makes hot water flow in the cracks of rocks. Later the iron released from the minerals in the rocks is oxidized into hematite. The presence of hematite alone is not enough to conclude whether there was water only as groundwater or whether it formed puddles or lakes on the surface of the planet.

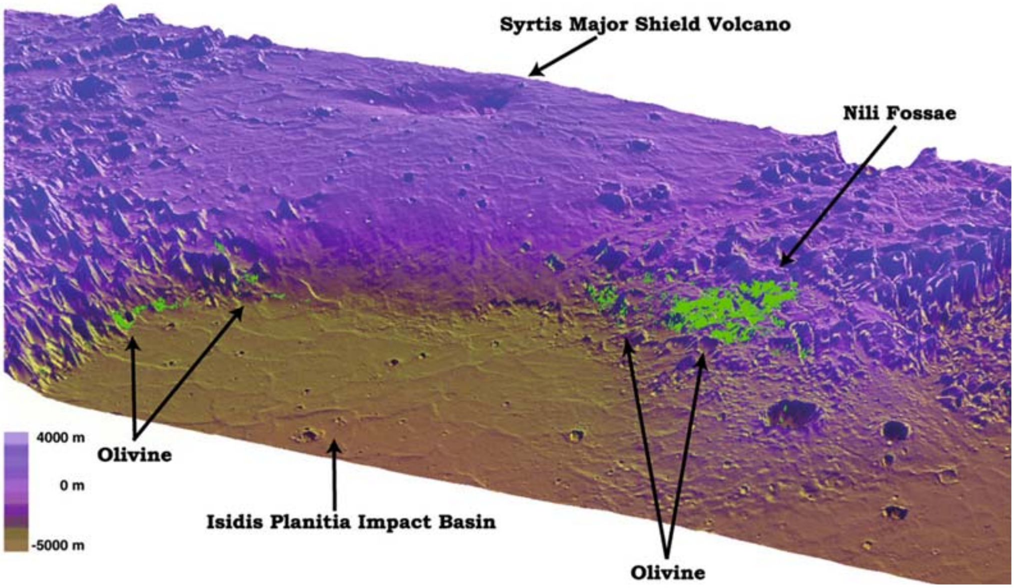
One of the most important discoveries made by the Spirit rover is a patch of nearly pure silica (the material is over 90% silica), which indicates the past existence of a hot spring or fumarole. In these structures, acidic steam seeps through cracks. The finding is important not only because it is still more evidence for a wet history of Mars but because these types of environments are favorable for microbial life – at least on Earth.

The same kind of deposits on our home planet might also give clues to the origin of those deposits on Mars. The silica-rich soil found by Spirit has an increased amount of titanium, just like some fumarolic deposits here on Earth.

The discovery of one more "proof-of-water" mineral, meridianiite, provides an excellent example of the synergy between different disciplines and between different planets. In 2005 Opportunity found magnesium sulfate dust and crystal molds in sedimentary rocks on the surface of Mars. Canadian scientist Ronald Peterson suggested that these findings indicate the existence of a previously unknown mineral, a kind of low-temperature version of Epsom salts,



Nearly pure silica found by Spirit on the surface of Mars could have been formed in a hot spring or in a fumarole, with acidic steam seeping through cracks in rocks.

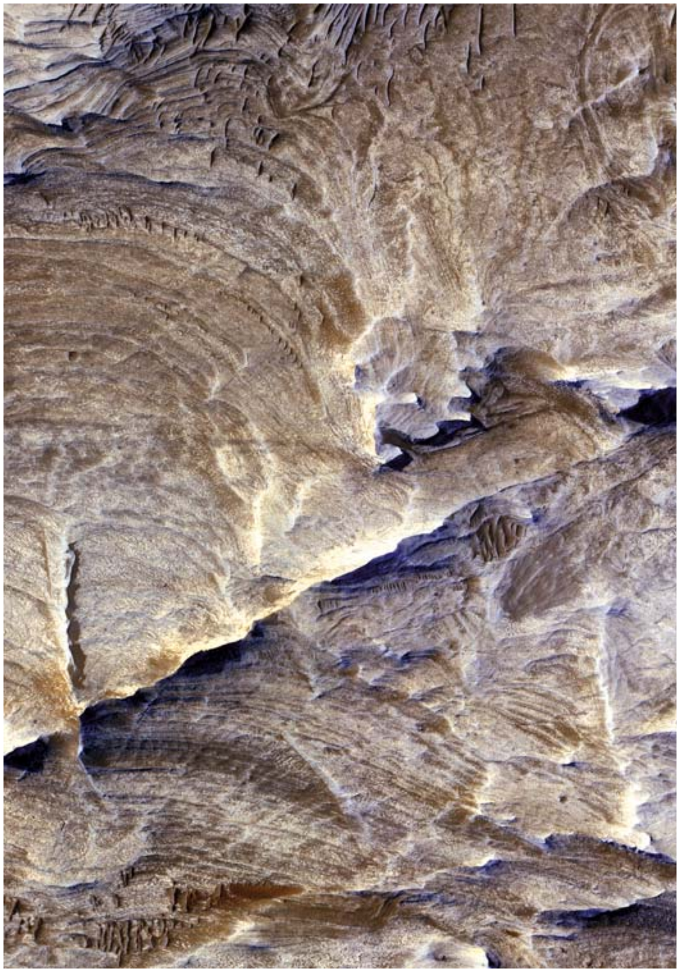


which has a platelike structure. Meridianiite is stable only below 2°C; if the temperature rises above that, it will melt to a mixture of epsomite and water. Later Peterson found meridianiite on Earth, too. He found it on the surface of a frozen pond in British Columbia, Canada. The name of the new mineral refers back to the site – Meridiani Planum – where it was first detected on the Red Planet. It is quite possible that this mineral will be found in abundance in the polar ice caps of Mars.

The existence of green olivine on the Red Planet is difficult to explain if Mars were a wet place for lengthy periods of time.

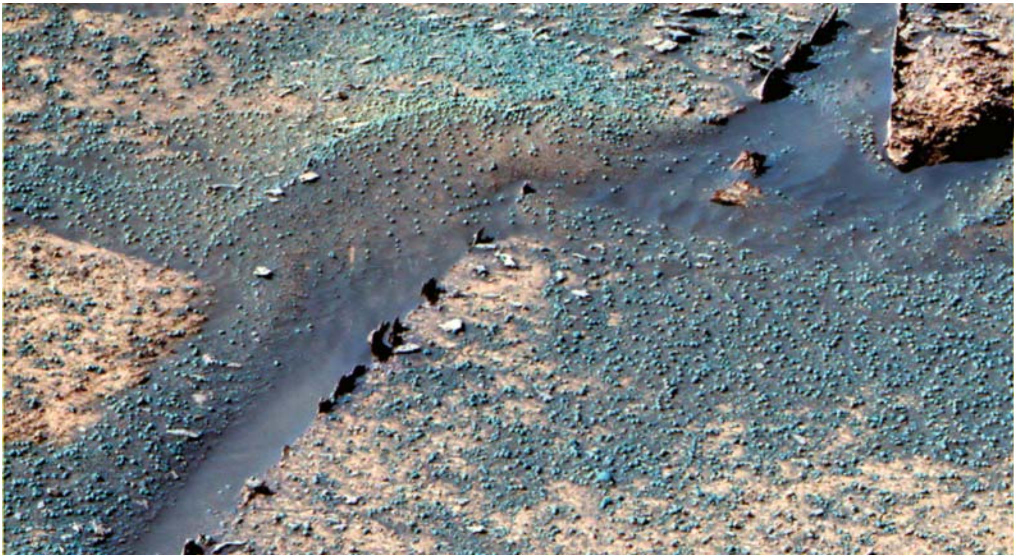
There is yet another mineral that has been found in abundance on the surface of Mars: olivine. According to observations made with the Thermal Emission Spectrometer (TES) aboard the *Mars Global Surveyor,* olivine may be present in many places on the planet in isolated outcrops. In some areas it might cover perhaps as much as 30% of the ground. However, unlike hematite, jarosite, and goethite, olivine is problematic when it comes to interpreting the watery past of Mars. This greenish iron-magnesium silicate is easily eroded, so if the planet really became wet and warm after the olivine deposits were formed, they should not be there anymore. The fact that the Red Planet has turned out to be a bit green could indicate that Mars might have been more dry than wet.

Due to heavy eroding the Martian landscape tells a story of what happened beneath the surface a long time ago.



Signs of groundwater on the surface

● One of the first observations made by the *Mars Reconnaissance Orbiter,* which arrived at Mars in 2006, was related to water flowing not on the surface but through underground rock on ancient Mars. The area photographed was in Candor Chasma, a canyon just south of the equator and forming part of Valles Marineris. Candor Chasma has been one of the sites of heavy erosion in the past, and as a result there are exposed layers with signs of ancient activity occurring deep below the present surface. What caught the scientists' eyes was light-colored material along the fractures in the ground.



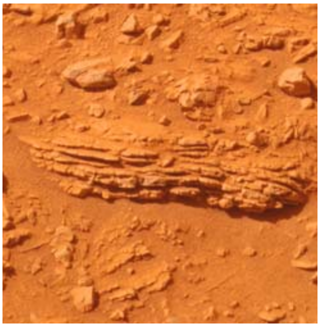
Basalt spherules covered with hematite.

The light-tone fractures are thought to have been caused by mineralization that took place along faults and fractures through which the underground water – or possibly gas – with dissolved minerals once flowed. It is a process geologists are familiar with on Earth, and later it was observed to have occurred in other places on Mars, too. The deposits, obviously harder than the surrounding rock, were revealed after the overlying, softer layers were eroded away during the thousands of millennia since their formation.

The discovery was made possible by the High Resolution Imaging Science Experiment (HiRISE) camera aboard the probe, which is capable of resolving features as small as 1 m across. In addition to providing clues to the flow of ancient water the observations might give information on chemical and perhaps even on biological processes that might have taken place deep underground, in an environment considered to be a possible habitat for some primitive life.

Blueberry fields forever

● Perhaps the most surprising – at least the most unexpected – discovery made by the Opportunity rover was spherules a few mm in diameter covering the surface of the planet very thickly in places. These were nicknamed "blueberries" because in color-enhanced images they showed up as vivid blue; in reality they are dark gray.



Water has eroded Martian rocks and revealed their layered structure.

According to analyses their interior is made of olivine, a constituent of basalt, a lava stone created in volcanic eruptions and also found on Earth. The surface of the spherules was found to be gray hematite, so the Martian blueberries are hematite-covered basalt.

Most probably the spherules were formed inside the stones from minerals in water. Later they were spread across the surface of Mars by strong winds after they had sloughed off the weather-worn stones. There are similar, only larger, spherules on Earth, for example in southern Utah. They are known to have been created after groundwater dissolved iron and other elements in the stones, and reassembled them into different kinds of minerals in a chemically suitable environment.

According to scientists, the minerals found by the twin rovers tell us that the regions studied were possibly covered with water that has gradually evaporated and all that is left is a variety of minerals. Another option is that groundwater is responsible both for the changes observed in the stones and the minerals contained in them. What is essential is that both of these interpretations strongly suggest that there has been water on Mars – and it has been in a liquid state.

In addition to the composition of the stones, their structure tells about the effects of water, too. The first thing Opportunity did at its landing site in the Eagle crater was to study a rocky outcrop. Distinct layers with uneven erosion appeared; the material between the harder layers seemed to have been dissolved. The rovers have also found rocks with small cavities that were formed when minerals that had crystallized in the stones later dissolved again. Is there any substance capable of dissolving stones and their minerals other than liquid water? Well, there is, but water is after all the simplest explanation.

Plan B: a carbon dioxide river?

● A phrase used by people whose hobby is cars when referring to the horsepower of an engine is “only too much is enough.” This can also be applied to the evidence on Martian water. How much evidence is needed before the past existence of water is indisputable? Obviously more than we have now, since not everyone is convinced that the Martian terrain clearly affected by some flowing substance has in fact been touched by water.

Some scientists have proposed that the cause of these formations could be carbon dioxide, a gas that turns into liquid at about −55°C. These temperatures are quite normal on Mars, so basically this theory could be valid. However, for carbon dioxide to maintain its liquid state the atmospheric pressure should be a thousand times larger than what the current pressure is. In principle there might be subsurface reservoirs of liquid carbon dioxide, although their formation would be difficult to explain. At times they could burst out and carve the "riverbeds" seen on Mars.

The problem is time: almost immediately after reaching the surface the carbon dioxide would sublimate into gas, and it would not have enough time to flow any substantial distance. A large number of river valleys are of tens, hundreds, sometimes even thousands of kilometers in length, so carbon dioxide can be deleted from the list of possible explanations – at least in its liquid state.

White Mars

● According to some theories the carbon dioxide that shaped the terrain could have been in a gaseous state. In the beginning of this century the Australian Nick Hoffman outlined a hypothesis he named "White Mars" to emphasize a thoroughly icy history of the planet. According to this theory, Mars has always been an arid and cold planet, so there could not have been large amounts of water flowing on its surface. Hoffman thinks that the current view of a wet Mars has several inconsistencies that make the model suspect.

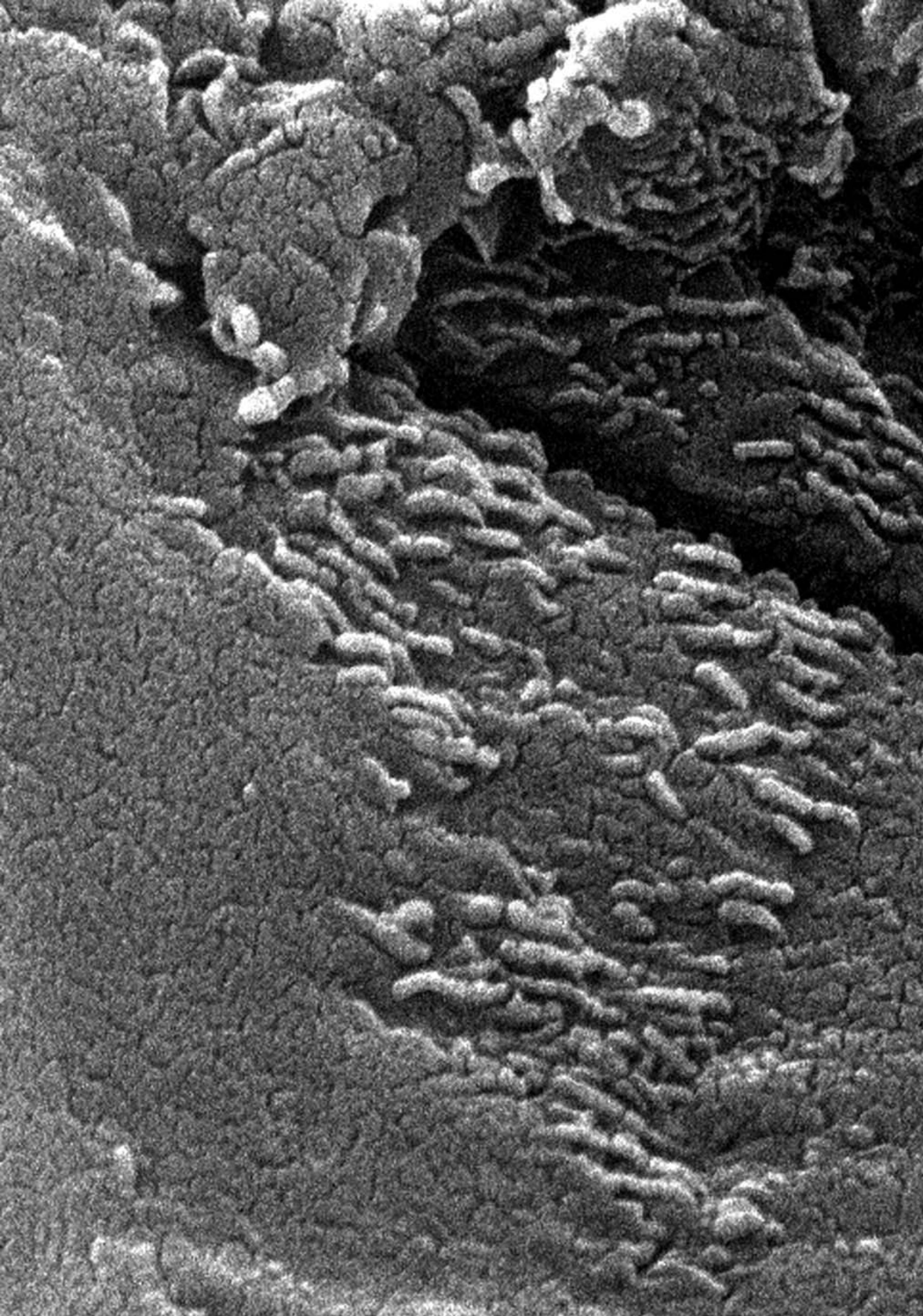
One of the crucial problems is the carbonate paradox. If water has been on the surface of Mars for any considerable length of time, the carbon dioxide in the Martian atmosphere should have been dissolved more or less completely in the water. The dissolved carbon dioxide would have formed carbonate compounds, which in turn would have formed, for instance, limestone strata. However, no such things have been found on Mars, so allegedly there could not have been the water these strata would have required to form in.

Hoffman's theory takes into account the fact that carbon dioxide is unable to maintain its liquid state on the surface of Mars – actually, this is the very basis of the theory. In the increased pressure a few kilometers below the surface liquid carbon dioxide could exist in large amounts, but if the ground above the reservoir cracks, the carbon dioxide would gasify explosively and create a kind of "cold volcano." The resulting eruption would be so powerful that it would break up stones and rocks, the debris of which together with the escaping carbon dioxide would form a dense cloud, a so-called "density flow" moving forward on the surface like liquid. According to Hoffman this density flow could be compared to the pyroclastic flows of volcanic eruptions on Earth, with their super-hot gas and rocky material descending the slope of a mountain at a speed of about 100 km/hour.

In Hoffman's model these cold gas flows, "cryoclastic" clouds, could travel hundreds or even thousands of kilometers. They would explain the flat "seabed" of the northern hemisphere, too. A cloud reaching the northern plain would already have lost its larger boulders, so all that would be left is fine dust, which eventually would settle down and form a smooth layer. The model would also explain the "lakes" with layered structures that have been found all over Mars. The large meteorite impacts in the past would have released vast amounts of carbon dioxide from the ground. The temporarily thicker atmosphere would have harbored even stronger dust storms than the present atmosphere. These storms would have transported lots of dust around the planet, piling it up especially in craters. After the storms subsided the "extra" carbon dioxide would have sublimated into ice, and a substantial part of the atmosphere would have collapsed back onto the surface of Mars. The strata in the craters would then be the signature left by the ancient storms.

From the point of view of the existence of life, Hoffman's theory is devastating. According to it, the conditions on Mars have always been too harsh for liquid water – and thus for life. Perhaps that is one reason why the theory has not gained much support. Another reason might be that most probably the theory is not valid. There has been water on Mars.

Carbon dioxide eruptions on Mars were like volcanic pyroclastic clouds, with gas of some 400°C transporting rocks with a speed of more than 100 km/hour. The image shows the eruption of Mount St. Helens on Earth in August 1980.



08

DEAD OR ALIVE?

In the 'reality' of scientific opinion, life on Mars had been born and died a dozen times.

– Frederik Pohl: *Man Plus* (1976)

How about life on Mars? Or, as the question should be put at least for now, is there life on Mars?

Opinions have changed during the past centuries from a certainty brought forth by ignorance to an uncertainty based on knowledge. At the end of the nineteenth century people were convinced that Mars is abode of life just like Earth. Not everyone believed in the existence of an advanced civilization, but even the most skeptical scientists thought it was evident that there is some kind of life on Mars, at least primitive vegetation, if nothing else. This belief held firm, since it was held by many scientists until the beginning of the 1960s.

In 1965 Martian research entered the Space Age. *Mariner 4* passed by the planet, and the images it sent back once and for all made all the notions concerning Mars and its life obsolete, incorrect, and erroneous. The blurred black and white images of the probe revealed a surface peppered with craters resembling more our lifeless Moon mangled by cosmic collisions than the more familiar terrain of Earth seething with all kinds of life forms. There was no trace of any life or any prerequisites for life. Mars had effectively died in the arms of scientists by July 1965.

ALH 84001, a meteorite from Mars, contains structures bearing a close resemblance to fossilized organisms.

M. Hotakainen, *Mars*, DOI: 10.1007/978-0-387-76507-5_8,
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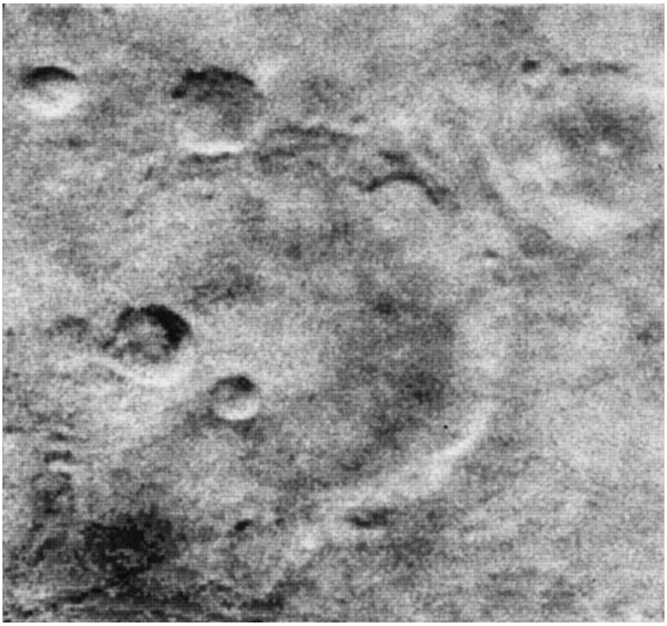


Slow awakening

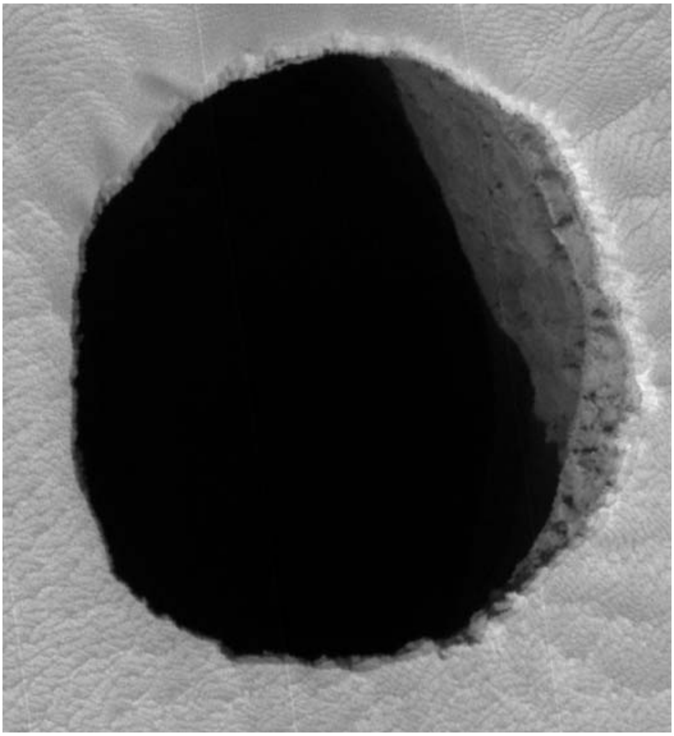
The image taken by Mariner 4.

● In the beginning of the 1970s the pendulum started to swing back in the opposite direction. The images sent by *Mariner 9* showed craters too, but also distinct signs of water. And if there is water, there is – or might be – life. A few years later *Viking* landers took miniature biological laboratories to the surface of Mars aimed at clearing up the question on the existence of life. However, they gave no definitive answers, since the results were contradictory. Nowadays there are only few scientists who still maintain the view that the results were positive, giving testimony in favor of life.

The problem in designing the *Viking* probes was that no one really knew what to look for or how and with what kind of criteria to do the search. The most malicious critics have said that even if the Martian equivalent of a dog had raised its leg against the lander, no absolute proof on the existence of life would have been found. One further problem is that any organic molecules – whatever their origin – on the surface of Mars would break up soon after they were exposed, because of the strong ultraviolet radiation and extremely oxidizing environment.

The samples studied by the Viking *landers led to some unexpected reactions that may have been caused by the superoxides in the Martian soil.*

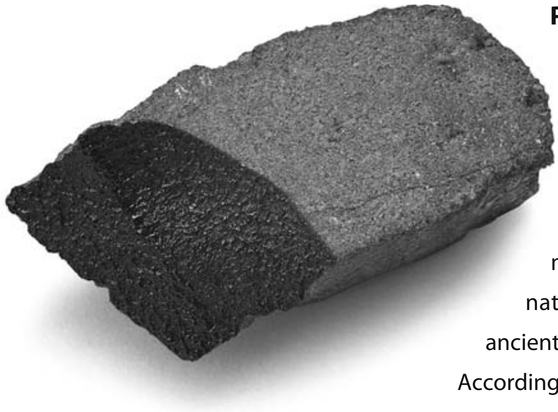
Knowledge on the prerequisites for life and its hardiness has increased tremendously since the days the equipment onboard the *Viking* landers were designed. A recent study on cyanobacteria made at the University of Dublin by the Finnish scientist Milja Tammi has shown that an exposure of 20 minutes to the radiation levels typical on the surface of Mars diminished the activity of the bacteria by only a small amount, and a couple of days later they had completely recovered. Another group of bacteria called extremophiles, the abundance of which has become evident only during the past few years, are happy – in accordance with their name – with different kinds of extreme conditions. In almost complete aridity, in temperatures dozens of degrees below 0°C or past the boiling point of water, or in the vast pressures in the depths of the oceans life thrives. There are also large communities of bacteria found dwelling deep down in the bedrock. These life forms have to get by without the energy of the Sun, and with having as their only source of energy and nutrients the chemical compounds of the minerals. This kind of life – if ever it were born on Mars– would have a good chance of surviving even on present-day Mars, for example in caves, like those that have been discovered on the slopes of the Arsia Mons volcano in the Tharsis region.



Dark pits found on the surface of Mars by the HiRISE camera of the Mars Reconnaissance Orbiter *proved to be "caves," vertical shafts cutting through lava tunnels on the slopes of the Arsia Mons volcano. The one pictured here has a diameter of 155 m. These kinds of formations, so called "pit craters," also appear on Hawaiian volcanoes.*

The *Viking* probes of the 1970s were looking for life capable of surviving in "normal" conditions familiar to us, even though the conditions on Mars are, and most probably have never been, anything like "normal." The negative results of the *Viking* probes were so bitter a disappointment both for scientists and the general public that interest in the planet died out. The next time any probes were sent toward the Red Planet was only at the end of the 1980s, but the real renaissance in Martian research had to wait until the 1990s. What were the reasons interest was reawakened? A rover and a meteorite.

The general public got interested in Mars again in 1996 after *Mars Pathfinder* landed on Mars. A miniature rover named Sojourner it released on the surface relayed red-hued panoramas in an almost real-time Internet broadcast. At least as important scientifically was a meteorite found in the Antarctic more than 10 years earlier, which was not just any lump of rock that fell from the sky.



A 40-g piece of Zagami meteorite that fell in Nigeria in 1962 from the collections of the Geological Museum of the Finnish Museum of Natural History. It solidified on Mars approximately 165 million years ago and was thrown out into space some 3 million years ago.

Patterns on a stone

So far the most thorough and useful studies undertaken on possible life on Mars were performed on Earth. In August 1996 a research team from NASA announced that they had found chemical compounds and microscopic structures in a meteorite originating from Mars that were possibly signs of ancient life.

According to the traditional view meteorites come from the Asteroid Belt. They are thought to have been formed in the collisions between asteroids, which grind boulders into smaller and smaller pieces of rock. However, a small but ever-growing group of meteorites did not fit in with the prevailing theory. The group was named SNC, after its first specimens that fell in *S*hergotty, in India (1865), El *N*akhla El Baharia, in Egypt (1911), and *C*hassigny, in France (1815). The meteorites later found to be SNCs – or "snicks" – were named according to their characteristics as shergotites, nakhlites, and chassignites.

All the "snicks" are igneous rocks; they have similar isotopic ratios of oxygen, and most of them crystallized no more than 1.3 billion years ago. Their volcanic origin is not enough to make them special, but the isotopic ratios of oxygen imply that they originate from the same celestial body and formed from molten lava either on the surface of the planet or just below it.

More than 3 billion years after the birth of the Solar System there was molten lava only on bodies with diameters of thousands of kilometers, that is, on planets. Long-lived radioactivity inside these bodies was capable of maintaining high enough temperatures to keep rocky material molten, while the heat inside the smaller bodies created by accretion and released by short-lived radioactivity was lost in space eons earlier. The possible places of origin of the "snicks" could be limited to the terrestrial planets and our satellite, the Moon. The giant planets have no solid surface at all, and their moons, the largest of which can be compared to planets by size, are for the most part ice.

Scientists still had to get accustomed to the thought that the cosmic collisions that have ravaged the planets were so immense that they could have thrown surface material all the way out into space. Mercury is completely covered with craters, but its surface is much too old to be considered the site of origin of these mysterious meteorites. The thick atmosphere of Venus, with a pressure equal to what prevails at a depth of about a kilometer in our oceans, effectively protects the surface of the planet from all but the most devastating impacts. At the same time it prevents debris from being thrown out into space even if the impact itself might have been powerful enough. Only the Moon and Mars are unprotected, and their gravitational fields are weak: on the Moon it is about one sixth and on Mars a little more than one third that of gravity on Earth. Calculations have shown that it is possible for material to be thrown out into space from the Moon and Mars if the impact is large enough and the impacting body hits the surface at an oblique angle. The ground at the exact site of impact is vaporized and farther away it is pulverized, but at a certain distance the rock maintains its original structure, at least partially, even though it has been thrown out into space.

Thus the rare exceptions among the meteorites could originate only from the Moon or Mars. And they did. At the moment the total number of Martian meteorites is over 30, even though some of them may be pieces of the same rock; the number of lunar meteorites is approximately the same. Identification of lunar meteorites is rather easy, as they can be compared with the rocks brought back from the Moon in the 1960s and 1970s. There are no samples from Mars yet, so in this case all that scientists had was something we are familiar with from all those police and law series on television: circumstantial evidence.

The crucial piece of evidence – a kind of "People's Exhibit A" – was a meteorite called EETA 79001, also found in the Antarctic. There are tiny glass spherules inside this rock that were formed from the material melted by the impact that threw the meteorite out into space. Pressure created by the impact squeezed the atmospheric gases of the planet of origin into the spherules, and this made it possible to determine the chemical composition of the atmosphere in question. It turned out to be the same as the one examined by the *Viking* landers in the 1970s. There was no question

The ice plains of the Antarctic are a treasury of meteorites.

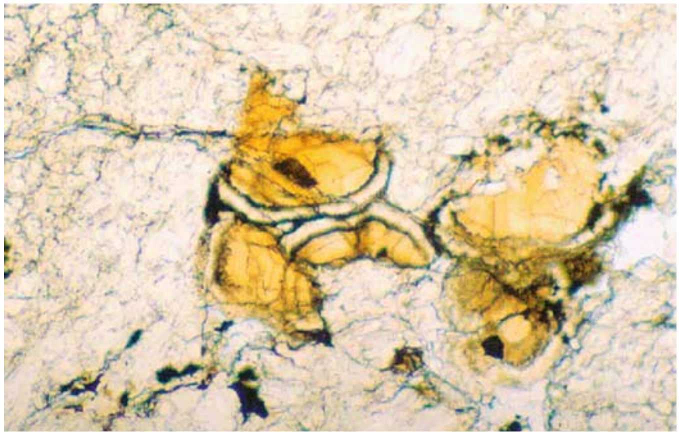
about it: the meteorite had to have come from Mars. Since the other "snicks" have similar characteristics to EETA 79001, they have to be of Martian origin, too.

Martian worms

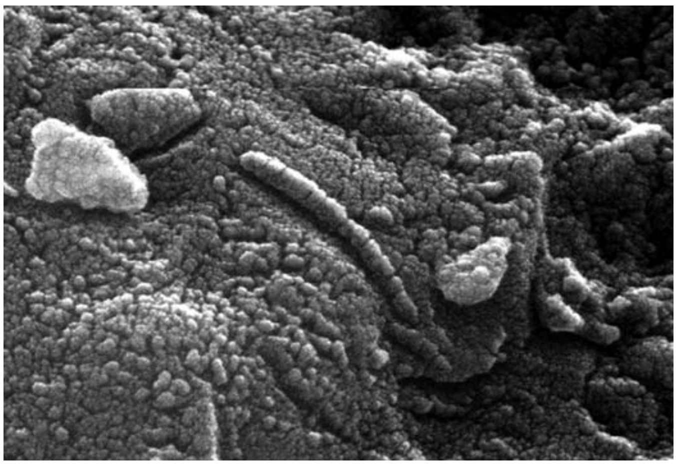
● The meteorite studied by NASA scientists called ALH 84001 was named for the place it was found, Allan Hills in the Antarctic, the time it was found, in 1984, and the fact that it was the first discovery of that particular year (EETA 79001 was found on Elephant Moraine 5 years earlier). The meteorite is mainly orthopyroxene, a silicate stone consisting of silicon and oxygen with trace amounts of iron and magnesium.

ALH 84001 began its long journey – both in time and space – 4.5 billion years ago, when it slowly solidified from molten lava. It led a peaceful existence for some 500 million years before the impact of a large meteorite partially melted the stone (or actually the rock it was part of). After that it was left alone for almost 4 billion years. Then, some 15 million years ago a new impact threw the stone out into space. Only about 13,000 years ago it plunged into the atmosphere of Earth, creating a bright meteor and coming to rest on an Antarctic glacier.

The claims the scientists made on the possible remains of life in this Metuselah of a meteorite were based on four observations. It contains a lot – about one-hundredth of its mass – of small carbonate grains with a diameter of 100–200 μm, which is comparable to that of a human hair. These grains are mineral formations consisting of carbon, oxygen and a few other elements and are similar to formations produced on Earth by certain organisms living in seas. The carbonate grains also contain compounds called polycyclic aromatic hydrocarbons, or PAHs, which, on the other hand, form in the decomposition of living organisms – or in barbecuing meat. The grains were also noticed to contain iron oxide and iron sulfide crystals, the like of which some primitive bacteria on Earth produce and use as tiny magnets for orienting themselves. In addition to all this, the edges of the carbonate grains harbor microscopic oblong structures that look very much like fossilized single-cell bacteria.



The carbonate grains in ALH 84001 have a diameter of about 200 μm, or 0.2 mm.



Martian worms?

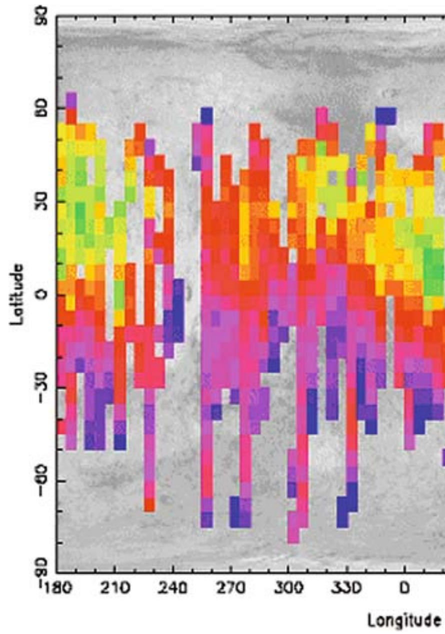
The problem with these observations is that the structures – the carbonate grains, PAHs, iron crystals – could also be produced in chemical reactions that have nothing to do with life. In the case of the microfossils the concern is with their size. The most primitive bacteria on Earth are several times larger than the "worms" found in the meteorite. The material for a heated scientific debate was all there, and the scientists swiftly chose their sides on the front line.

Is there life on Mars – or on Earth?

● Scientists at NASA and the proponents of their interpretation underline that none of the four observations alone would be enough to prove the existence of present or past life on Mars. For instance, PAHs have been found in meteorites not originating from Mars. However, the scientists maintain that the combined weight of these observations as evidence is sufficient, especially because they are all from one and the same meteorite. Thus, there is or has been life on Mars.

Or not. Their opponents are not convinced that the chemical compounds and structures found in the meteorite were formed on Mars in the first place. The meteorite spent 13,000 years inside and on a glacier in the Antarctic, and despite the fact that life does not flourish there, it still is there – if not in any other form than as bacteria carried by winds. Life on Earth might have contaminated the meteorite, so all the scientists of NASA had managed to do was to prove that there is life on Earth.

Even though ALH 84001 with all its peculiarities does not prove that there once was life on Mars, it doesn't exclude the possibility of it either. The increasingly heavier body of evidence suggests that in ancient times Mars was a completely different world than what it is now. The atmosphere was thicker, the temperature higher, and water flowed on the surface of Mars. From the point of view of the puzzle of life the essential question is how long ago the conditions were different and for how long they were more favorable than the present ones.

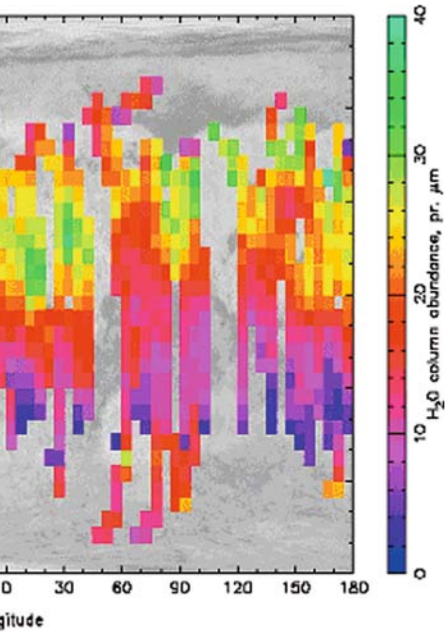


Methane seems to concentrate in the same areas as water vapor. Based on measurements made by Mars Express, *the map here shows the amount of water vapor, with green representing a large abundance and purple a small*

Mars and the riddle of methane

● In 2003 and 2004 both the giant telescopes on Earth and the ESA's *Mars Express* probe made observations that indicated that there are tiny amounts of methane gas in the atmosphere of Mars. There is not much methane, only a few hundred millionths of the total volume of the atmosphere. However, even a small amount of methane is problematic. Solar radiation easily breaks it up into carbon dioxide and water, and the amount observed should completely disappear in a few centuries. This means that in one way or another new methane is being produced continuously, at the rate of a total of 150 m tons a year according to some estimates.

A simple explanation would be volcanic activity, which Mars evidently has had. Recent studies suggest that there might have been volcanism not so long ago, at most a few million years ago, so it is quite possible that it is still there. This would explain the atmospheric



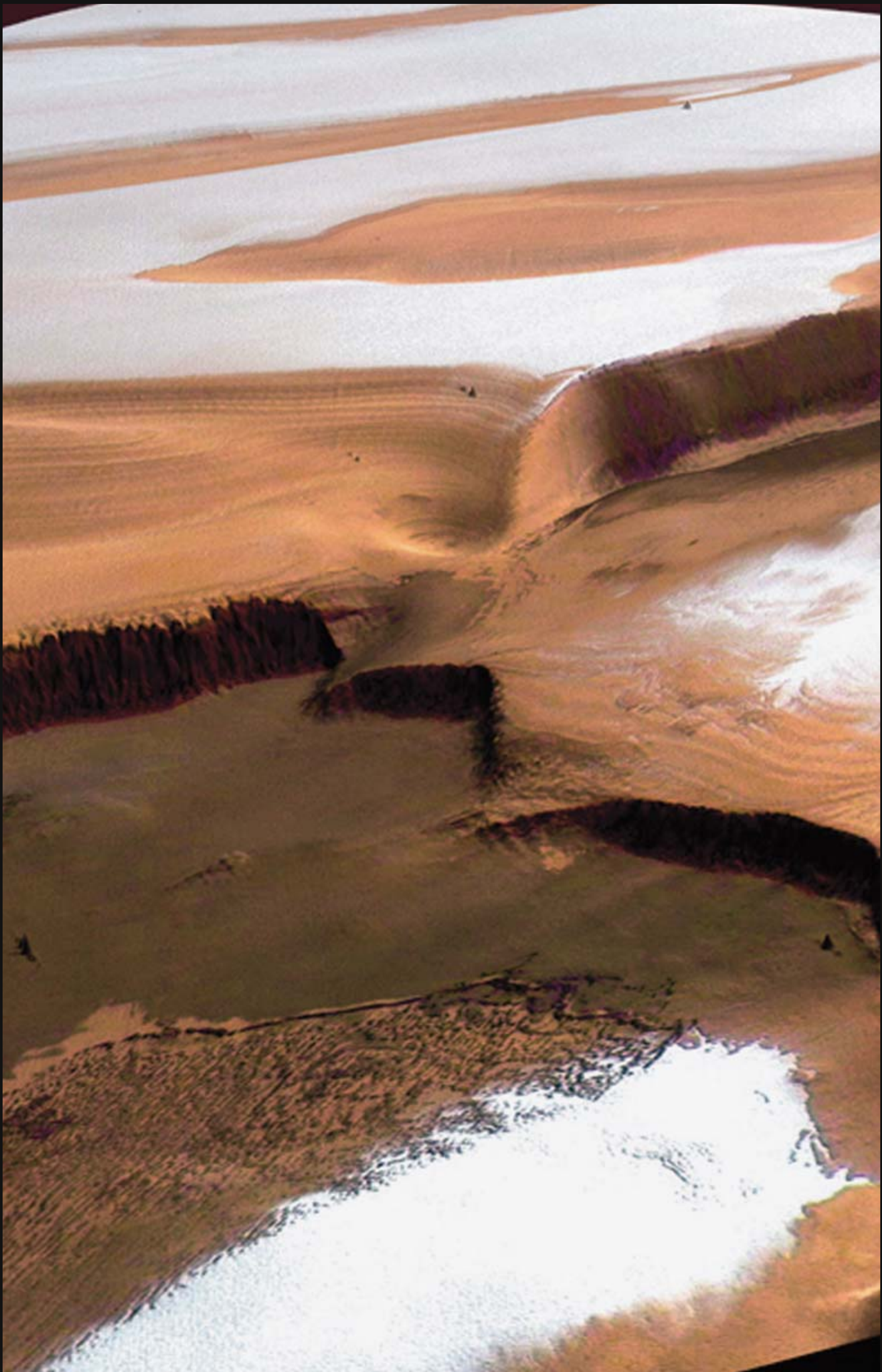
methane, since volcanic eruptions also release lots of different gases, one of them being methane.

What makes the methane riddle more difficult is the fact that it seems to be most abundant in areas where the amount of water vapor is largest, too. According to the observations made by *Mars Express* the atmospheric water vapor is evenly distributed at an altitude of 10–15 km. Closer to the surface some areas have more water vapor than others. There are three regions at the equator where the amount of water vapor is 2–3 times larger than the average value. Most of the methane seems to be concentrated in these same areas. Some scientists think that this could mean that the methane comes from living organisms, Martian microbes, which need water to survive. The present view has it that water is found in a liquid state only beneath a layer of permafrost several kilometers thick, so that is the place to find Martian life, too.

Not everybody is convinced about the organic origin of methane or even on the significance of the occurrences of methane and water vapor. The distribution of water vapor is mainly controlled by the air currents in the Martian atmosphere, not by the location of potential subsurface reservoirs of water. If winds accumulate water vapor in certain areas, the same goes for methane – there is no need for life.

More evidence on possible life came up less than a year later, when *Mars Express* showed that there is also formaldehyde in the atmosphere of Mars. Formaldehyde is a chemical compound formed by the oxidation of methane. According to the observations, the amount of formaldehyde seems to be some 20 times larger than the amount of methane. To produce that much formaldehyde requires a much larger production rate of methane than the mere 150 m tons a year; it would take a total of 2.5 million m tons a year. This large amount would be very difficult to explain with geological processes. One more problem is that the observed amount of formaldehyde would disappear from the atmosphere of Mars in just a few hours, much more rapidly than methane. If many scientists have strong doubts on Martian methane, they have stronger doubts still on Martian formaldehyde.

Thus the evidence on Martian life is still insufficient. But as the late American astronomer Carl Sagan once said: "Extraordinary claims require extraordinary proof." The jury is still out.



09

GALLERY MARS

So we are not able to see what we would like to see?

– Kurd Lasswitz: *Auf Zwei Planeten* (1897)

"Gallery Mars" exhibits a collection of some of the best images taken by the ESA's *Mars Express* probe. These have been selected not only because of their spectacular visual impact but also because of the variability of the scenery they present. One thing several of the images have in common is water and the markings left by it. The first image gives a vista on the north pole; the rest of the images are arranged according to their increasing eastern longitude. The captions are based on descriptions given in the ESA Multimedia Gallery.

The images have been taken with the High-Resolution Stereo Camera, or HRSC. It yields 3-D color images of the Martian surface with a resolution of about 10 m. The whole planet will be photographed with this resolution and selected areas with an even better resolution of only 2 m. The images taken with the instrument can be used to create views of landscape with the surface of Mars seen at an oblique angle. This brings out both the differences in terrain and in elevation.

However, producing spectacular images is not the main purpose of HRSC. The instrument is used to examine the weather of Mars, the role of water in past climate changes, the interaction between the atmosphere and the surface, the changes in volcanic activity, the natural resources of the planet, the alternative landing sites of future probes, and Phobos and Deimos, the satellites of Mars.

The northern polar areas exhibit thick layers of water ice and dust. The height of the cliffs in the image is nearly 2 km. The dark material in the caldera-like formations and on the dune fields in front of the cliffs is probably volcanic ash.

M. Hotakainen, *Mars*, DOI: 10.1007/978-0-387-76507-5_9,
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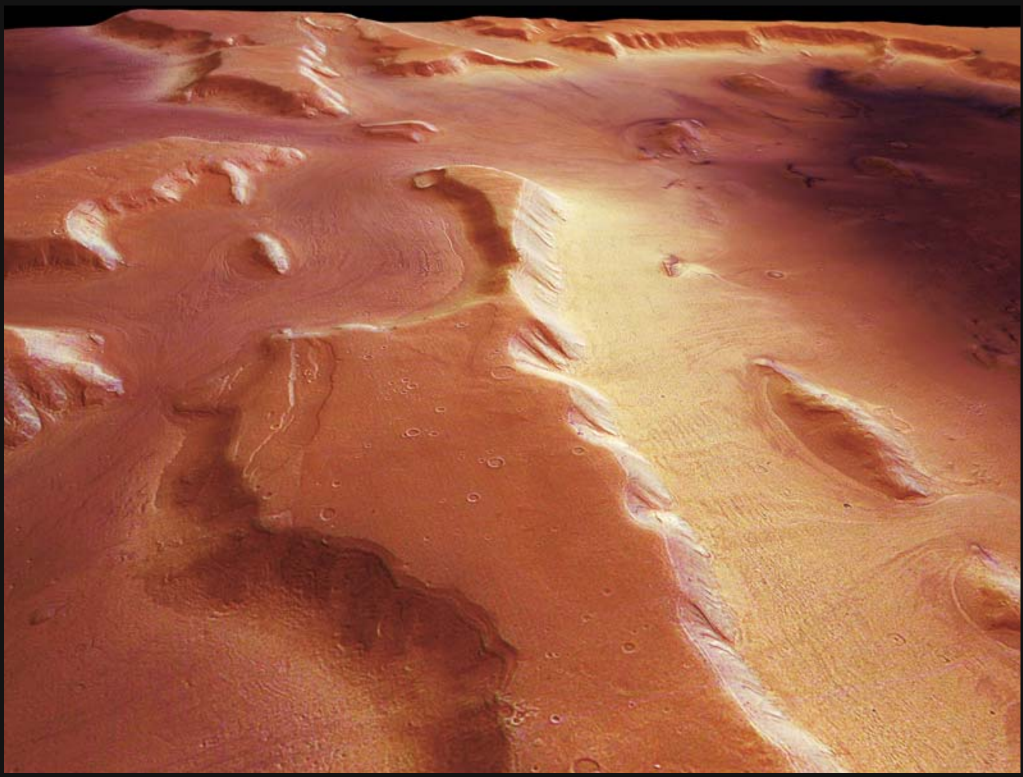
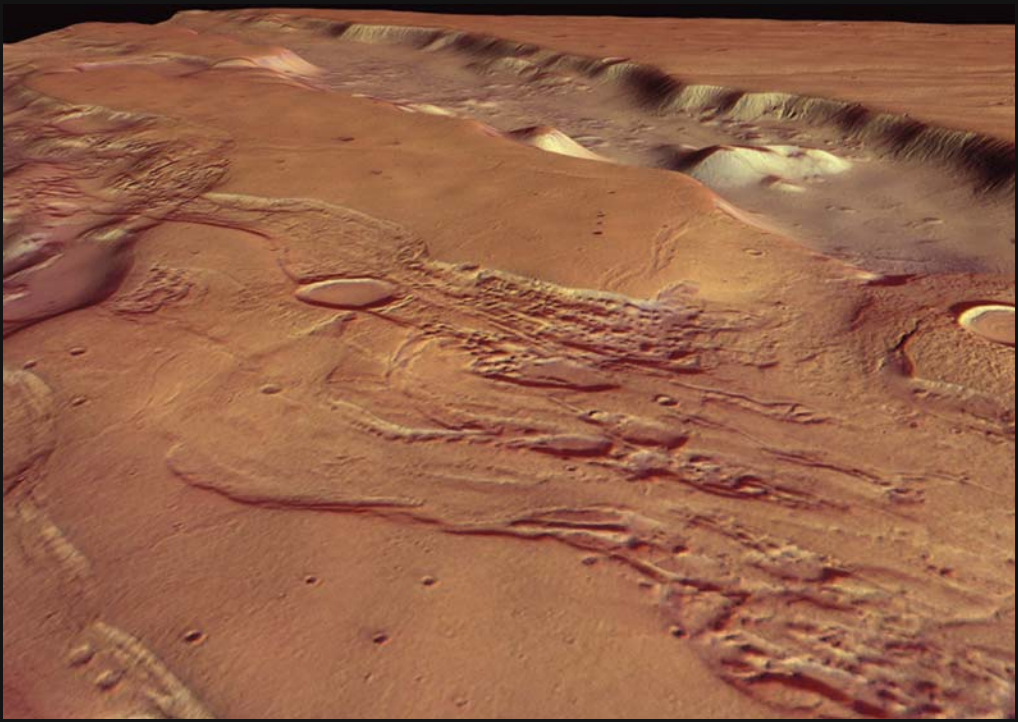


Deuteronilus Mensae

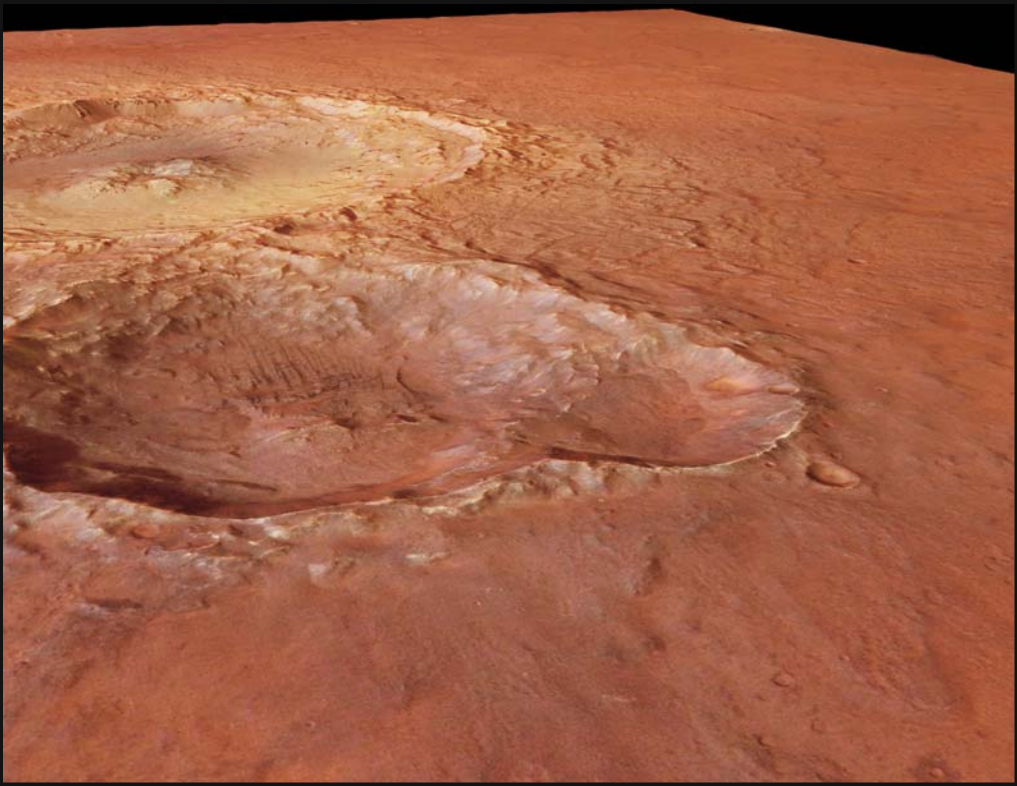
Deuteronilus Mensae is an area characterized by glacial features. It is located on the northern edge of Arabia Terra bordering the southern highlands and the northern lowlands. The depressions in the image most probably originated from intense flooding by melted water ice. Because of the low temperature the released water froze quickly and flowed down the 1,000-m-high slopes of the valleys like glaciers. (The center of the image is at 39°N, 23°E, with a view due south.)

Crater Huygens

Huygens is an impact crater in the southern hemisphere of Mars with a diameter of 450 km. It was formed almost 4 billion years ago. The eastern rim visible in the image is heavily eroded and shows "dendritic" patterns, which are riverbeds created a long time ago by running water. Also part of the crater itself is filled with sediments transported most probably by water. (14°S, 61°E, due north.)



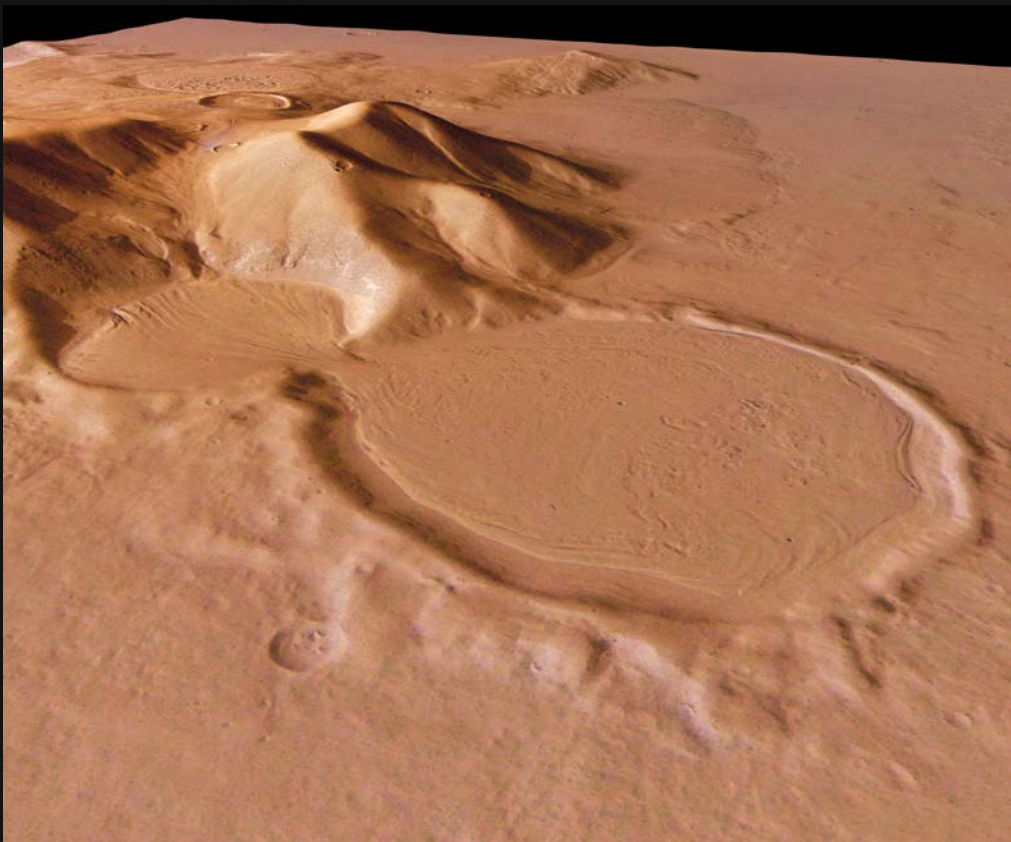
Dao Valles and Niger Valles
Dao and Niger Valles, situated at the meeting-point of the impact basin of Hellas and volcanic area of Hesperia Planum, are valleys shaped by great floods. Dao Valles, the northern one, is about 2.5 km deep; Niger Valles 1 km shallower. The valleys were most probably formed when subterranean ice melted and the waters carried the land masses away. (32°S, 93°E, due south.)



Craters in Tyrrhena Terra
This is a crater with a diameter of 35 km and a depth of about 1 km, with a steep rim rising some 400 m above the plain. The appearance of the "ejecta blankets" around the crater suggests there has been an abundance of subsurface ice and water on the site. The other crater with a diameter of 18 km seems to be a "double crater." It was born when two objects hit the surface simultaneously. (18°S, 99°E, due south.)

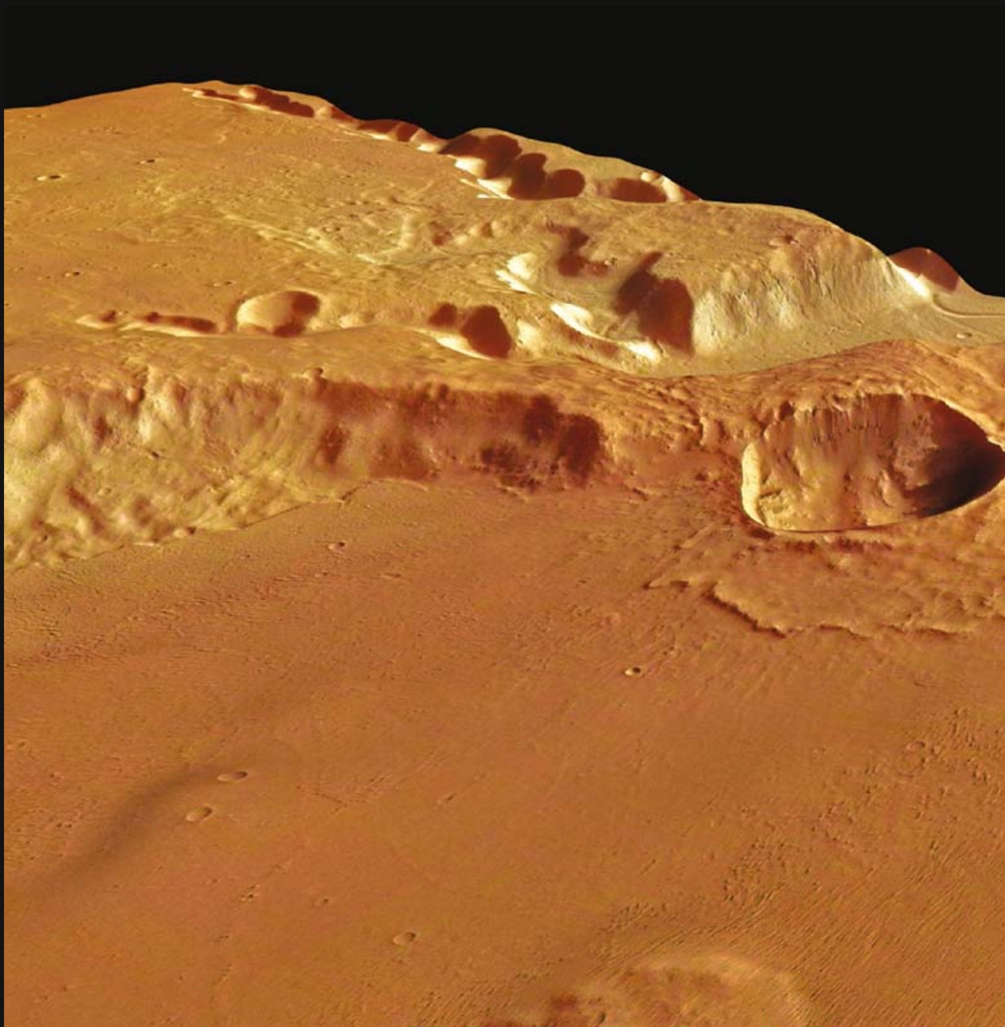
Reull Vallis

Reull Vallis, a 1,500-km-long valley, is carved along with its tributary Teviot Vallis by water and ice. It is 20 km wide in places and almost 2 km deep. The valley winds across Promethei Terra toward Hellas, a huge impact basin with a diameter of 2,300 km and a depth of nearly 9 km. (42°S, 102°E, due southeast.)



Hourglass Craters

In Promethei Terra on the eastern border of Hellas lie two craters with diameters of 9 and 17 km. These are filled with ice-rich material that has flowed from the nearby mountains. The ice could have precipitated from the atmosphere as recently as a few million years ago. It has been preserved from sublimation by the dust covering the ice. (38°S, 104°E, due southeast.)

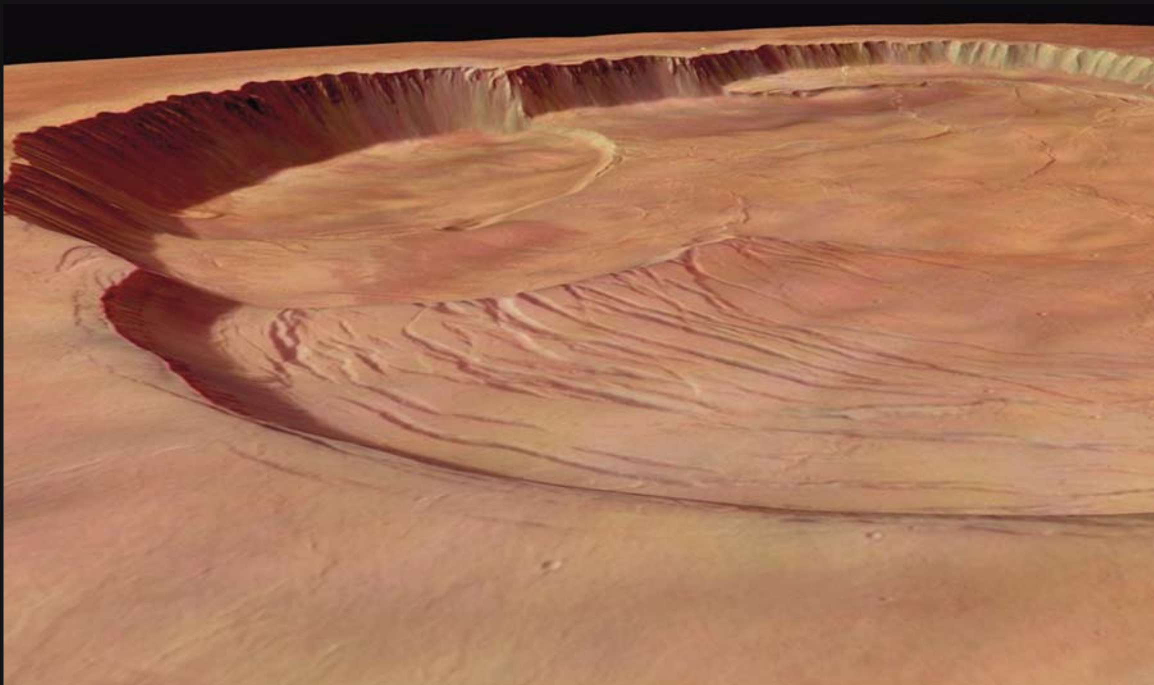


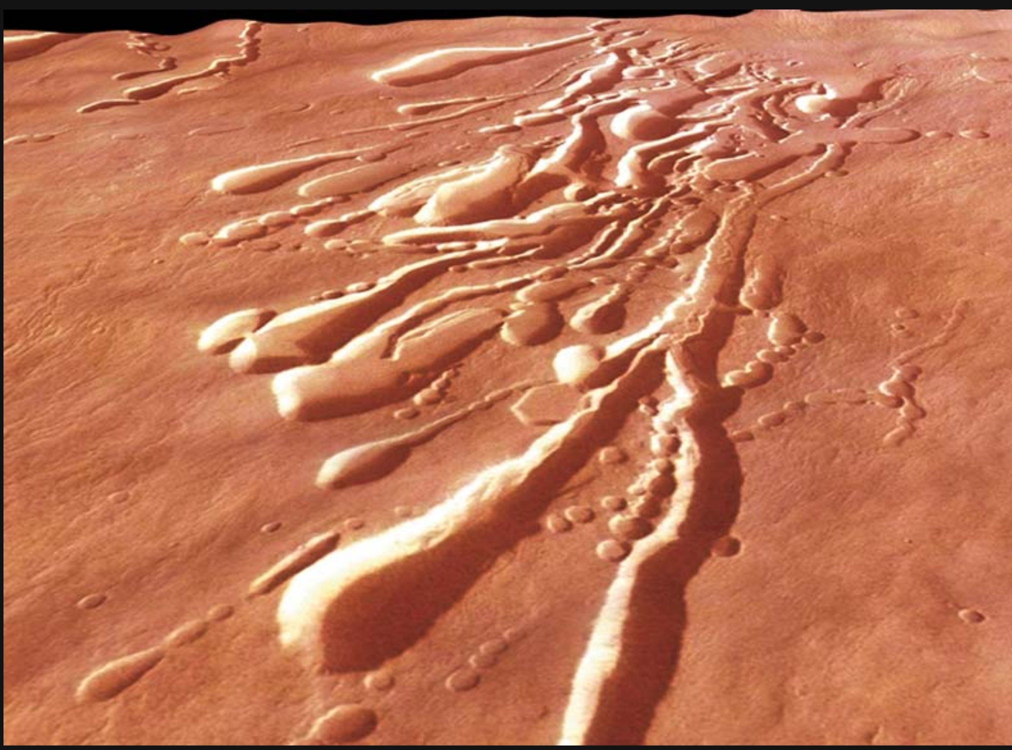
Medusa Fossae

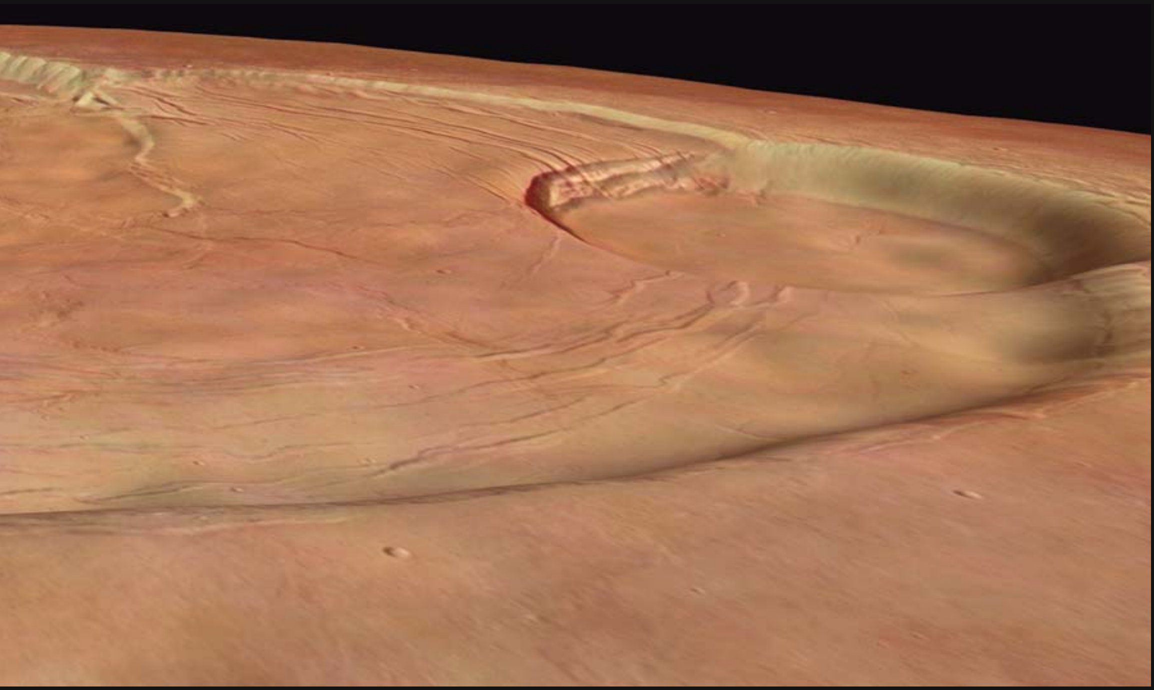
The boundary between the rugged southern highlands and the smooth northern lowlands exhibits high cliffs. The area in the lower half of the image has very few craters, thus being much younger than the surface riddled with craters in the upper half of the image. (5°S, 213°E, due southwest.)

Western Slope of Olympus Mons

The edge of Olympus Mons, a 27-km-high shield volcano, is a steep cliff, reaching on the western and northern flanks a height of more than 7 km. At the base of the cliff there are layered "aureole" deposits extending several hundred kilometers into the surrounding plains. These are thought to have been formed by massive landslides and glacial activity. (22°N, 222°E, due east.)

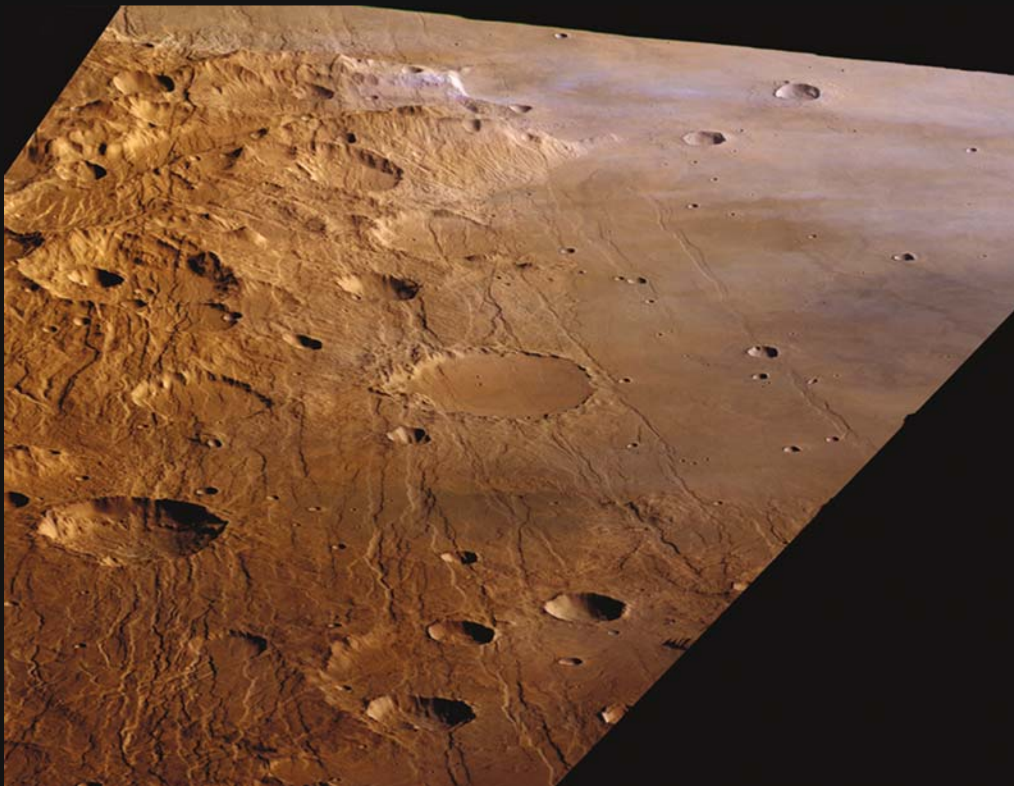






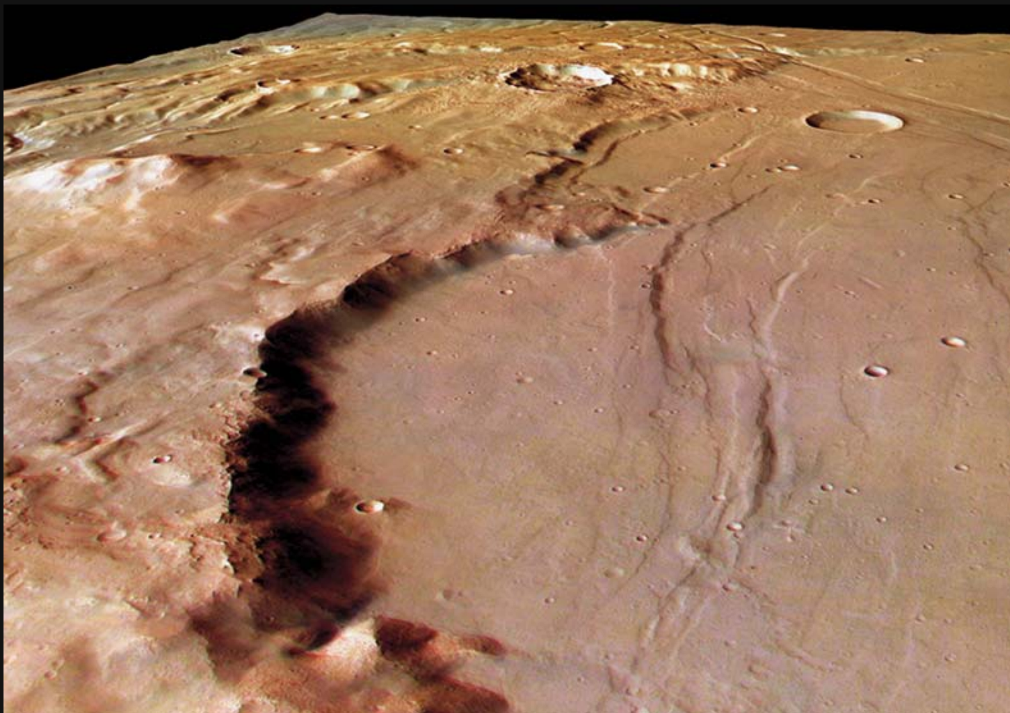
Calderas of Olympus Mons
The top of the biggest volcano in the Solar System is dominated by a depression formed of several calderas, with walls up to 3 km high. The calderas were born at different times, when lava chambers beneath the mountaintop emptied and their "rooves" collapsed. (18°N, 227°E, due north.)

Lava tubes on Pavonis Mons
Found on the southwestern flank of Pavonis Mons, the central volcano of the three Tharsis Montes exhibits lava tubes. These were formed by hot lava forming a crust as the surface cooled. Lava continued to flow beneath the surface, but at the end of lava production the tunnels emptied and the surface collapsed, creating channel-like depressions. The lengths of the lava tubes in the image are tens of kilometers and the widths are hundreds of meters. (1°S, 246°E, due northwest.)

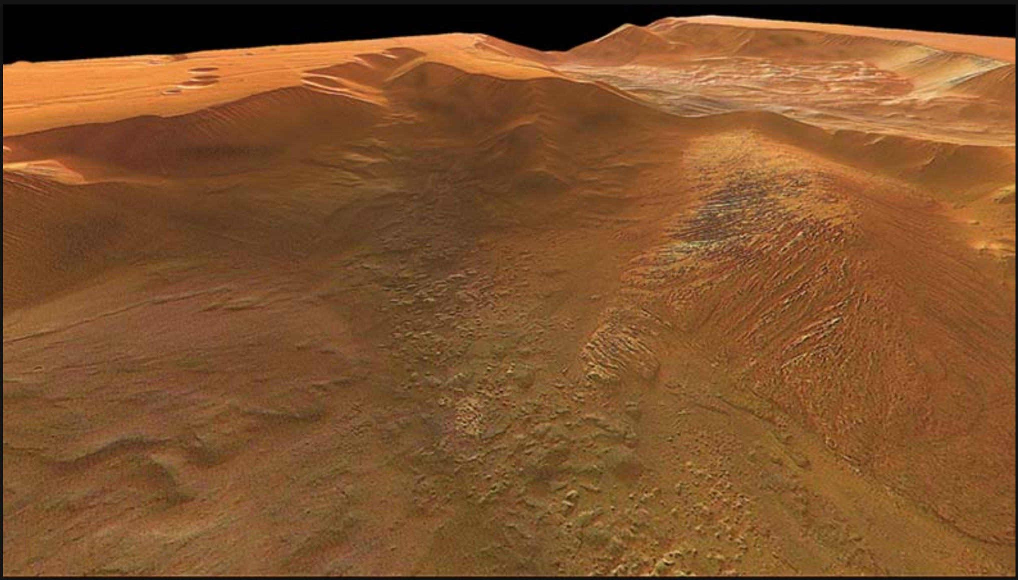


Claritas Fossae

The outskirts of Tharsis region shows signs of both heavy meteorite bombardment and tectonic activity, with movements of Martian crust creating different kinds of structures on the surface. The most prominent of these are "grabens," deep grooves that can be traced several hundred kilometers up to the Tharsis volcanoes. (28°S, 260°E, due north.)



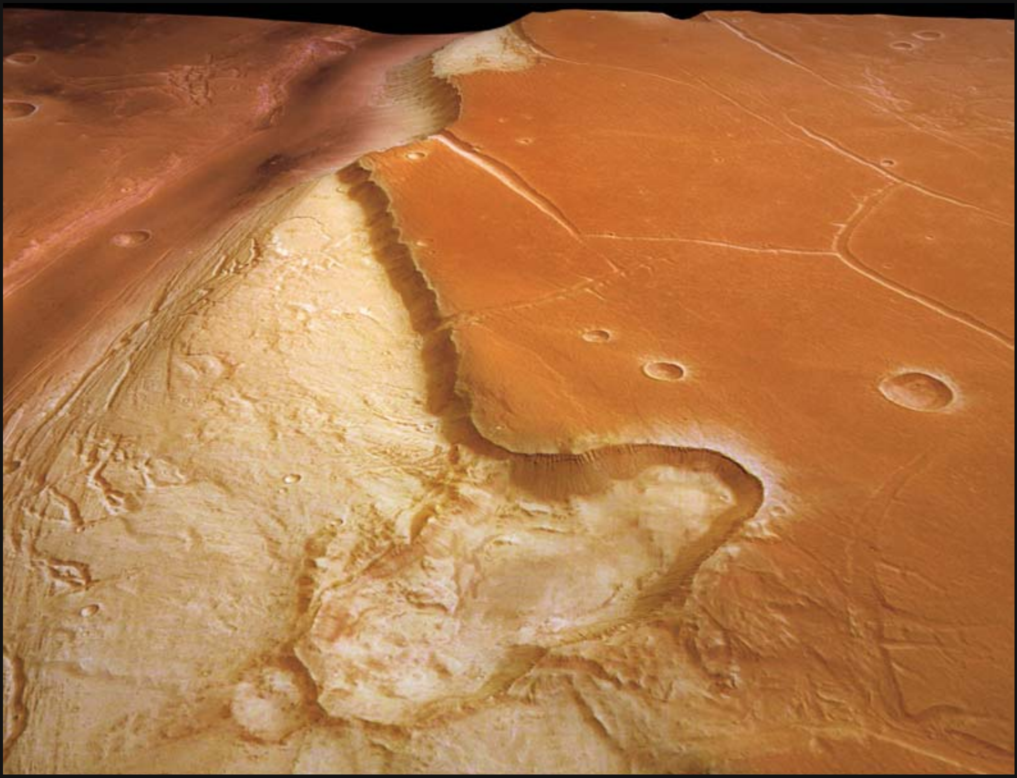
Solis Planum
Except for its rim, an ancient crater with a diameter of 53 km on Solis Planum in the Thaumasia region is almost completely eroded. The eastern rim of the crater visible in the image has a height of some 800 m. Crisscrossing fractures on the surface tell of tectonic upheavals in the past. (33°S, 271°E, due southeast.)

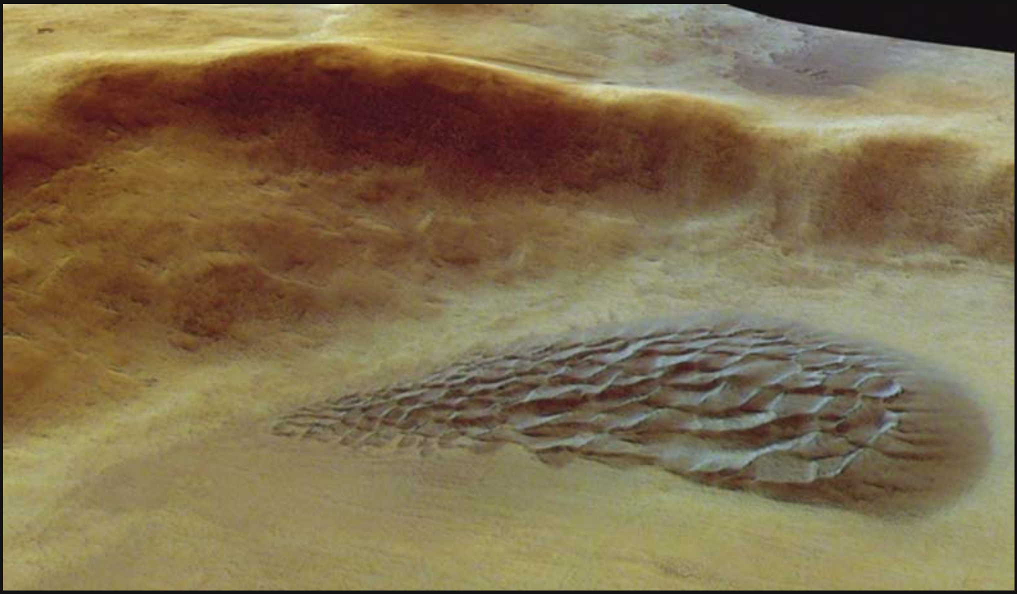


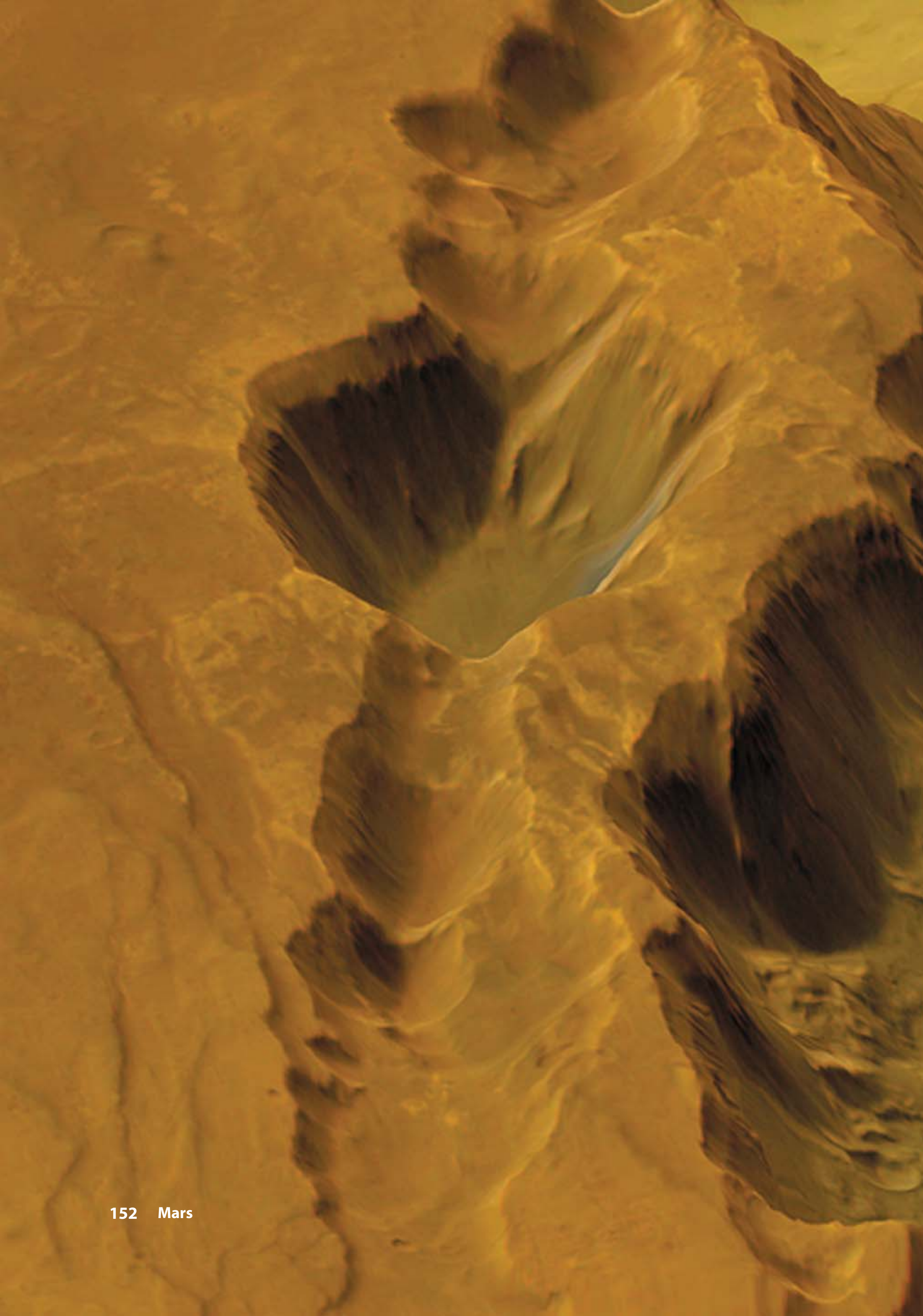
Tithonium Chasma
Tithonium Chasma in the western end of Valles Marineris is a canyon 10–110 km wide and up to 4 km deep. Linear features on the slopes of the hill in the foreground are caused either by fluvial or Aeolian erosion, that is, by either water or wind. (5°S, 280°E, due northeast.)

Kasei Valles
The northern branch of Kasei Valles crossing the area of Sacra Mensa is nearly 3 km deep. Kasei Valles is one of the biggest outflow channel systems on Mars. It was probably formed by gigantic floods and later shaped by glacial activity. The oval structure in the foreground is a crater caused by an oblique impact. (27°N, 292°E, due east.)

Dune Field
On the bottom of a 45-km-wide crater on Argyre Planitia there are dunes created by prevailing eastern winds. The length of the dune field is 12 km and the width 7 km. The dark color of the sand of the dunes indicates it is of volcanic origin, most probably basalt. (43°S, 303°E, due east.)

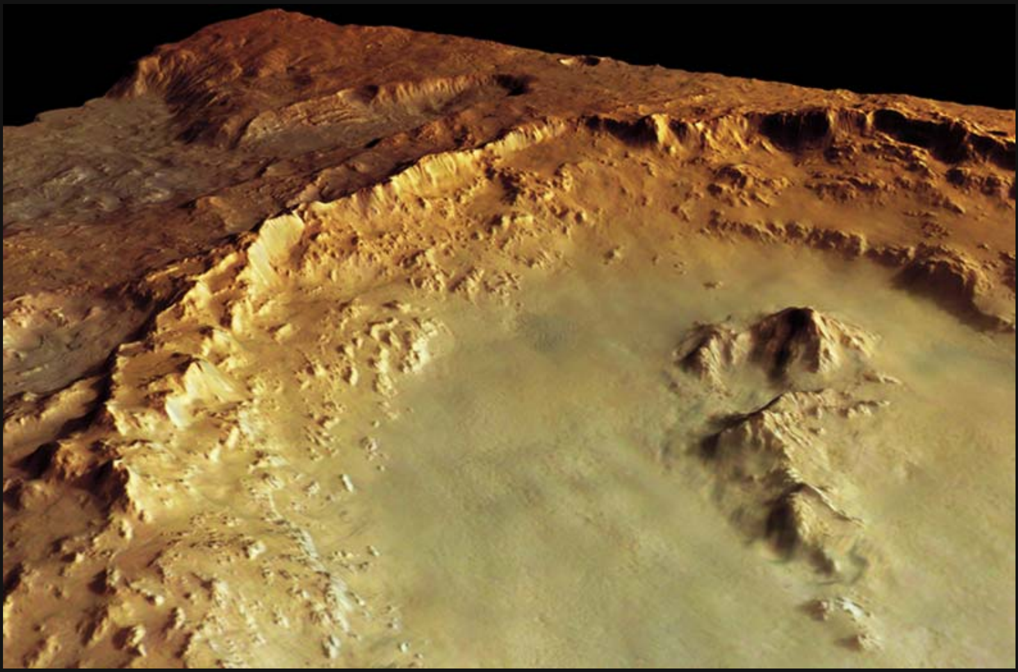






Coprates Catena

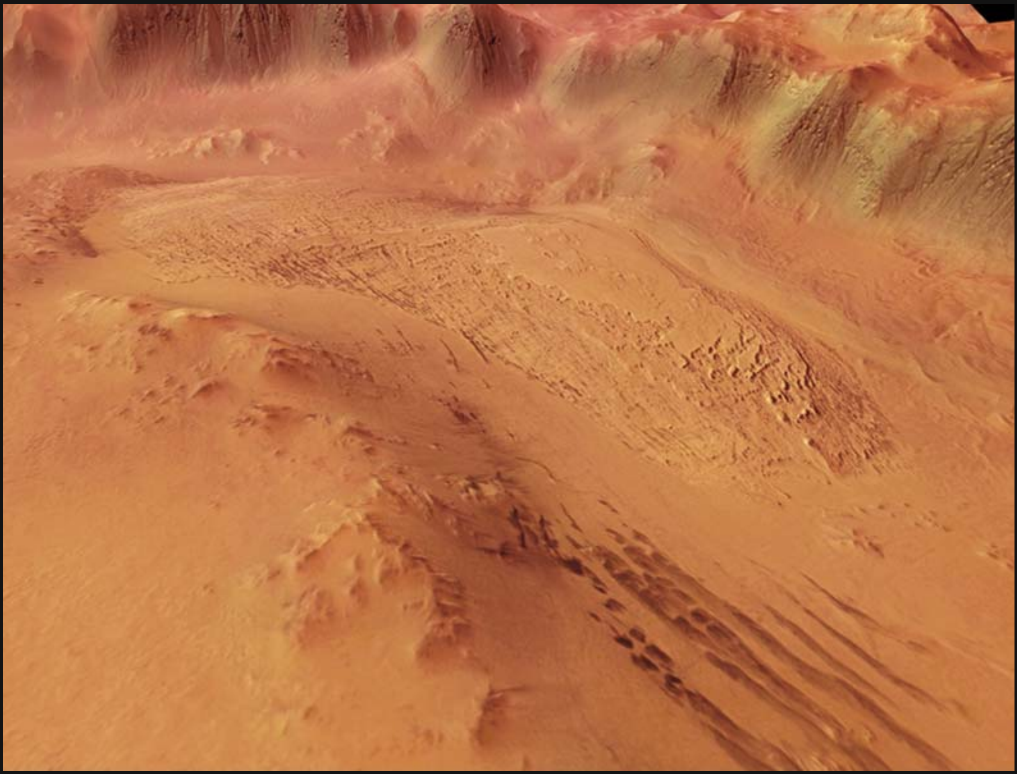
Coprates Catena, the southern part of the Valles Marineris canyon system, is a chain of collapsed structures. It possibly formed when subterranean ice melted and ground above it collapsed. The depth of the gorge is 2.5–3 km while the main valley, Coprates Chasma, is 7 km deep. (14°S, 301°E, due east.)

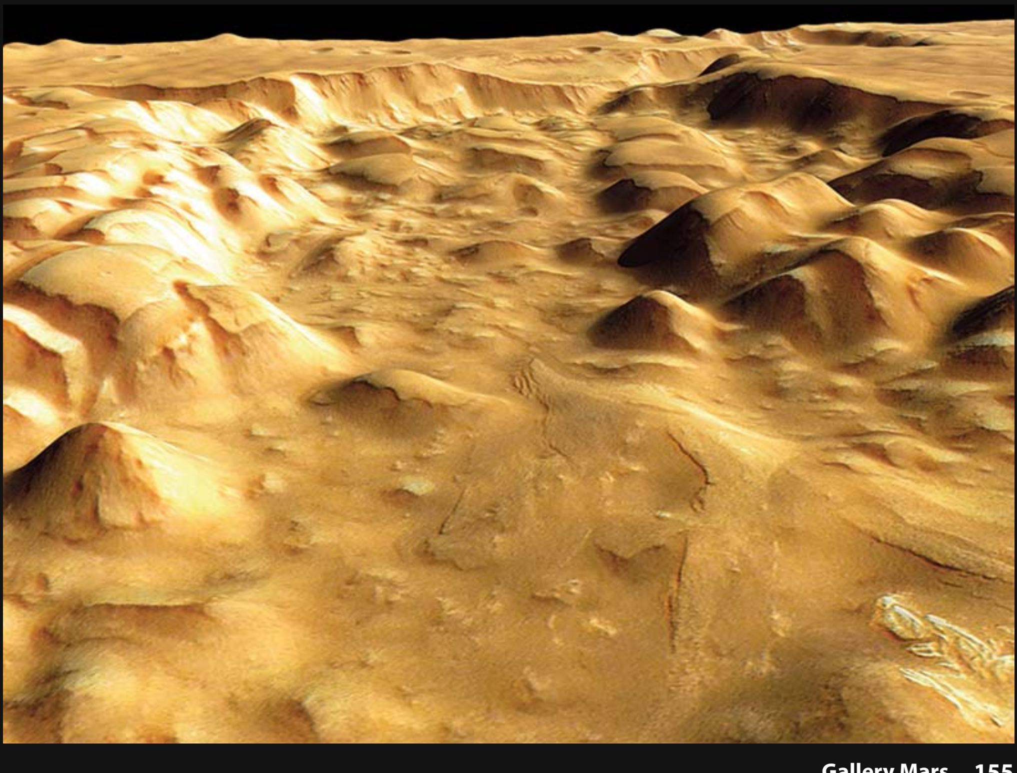


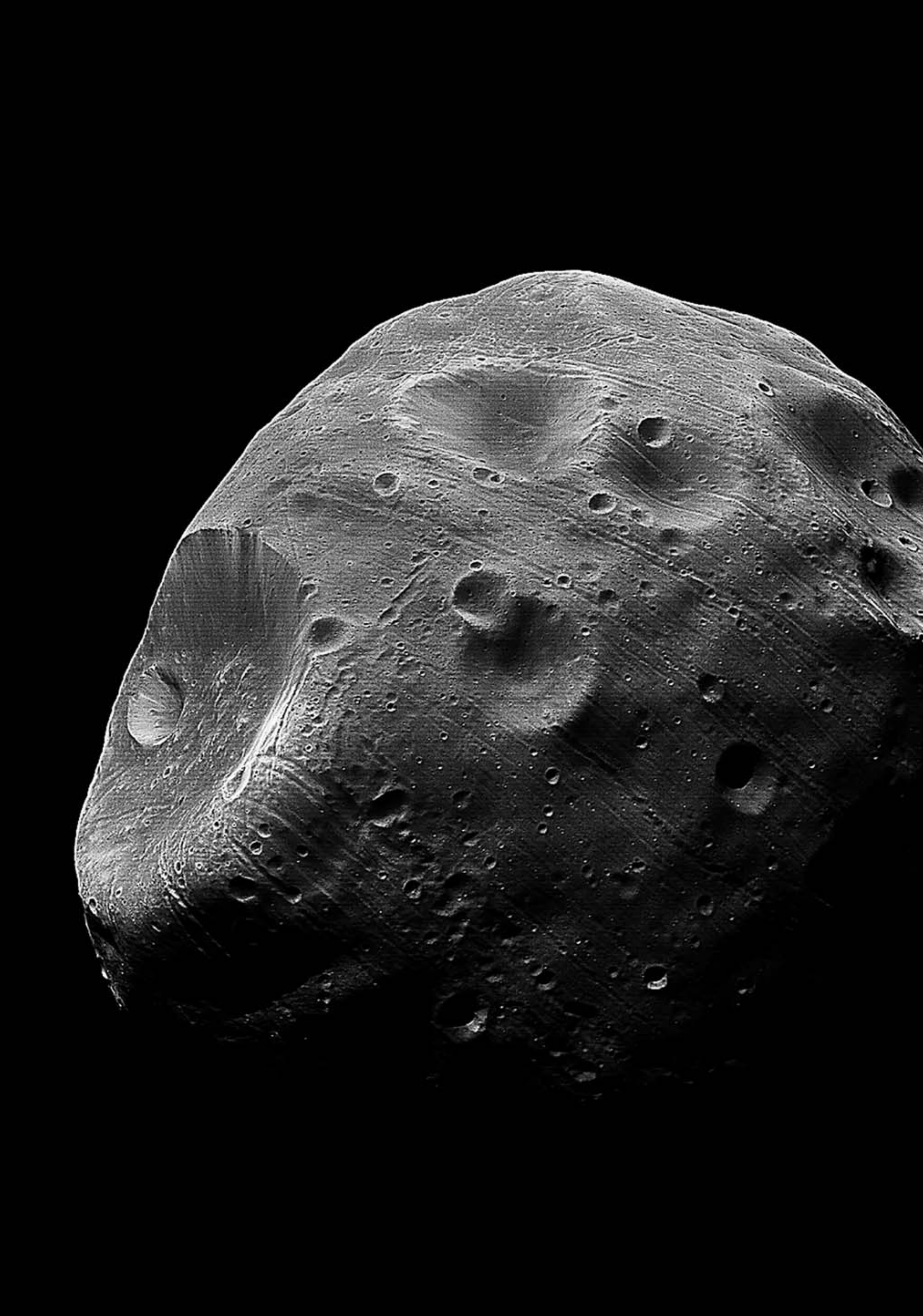
Crater Hale
Hale in the Argyre basin has a diameter of 149 km and shows all the characteristics of a large impact crater: central peak, terraced walls, and inner ring. Part of the rim has collapsed into the crater and has also been eroded by flowing water. (36°S, 324°E, due northwest.)

Crater Galle
Crater Galle, the "Happy Face," contains a large stack of layered sediments that forms an outcrop in the southern part of the crater. The image also shows parallel gullies originating at the inner walls of the southern rim, which are a strong evidence for liquid water on the Martian surface. (51°S, 329°E, due southeast.)

Aureum Chaos
A "chaotic terrain" in the eastern part of Valles Marineris was formed when subterranean ice deposits melted and the layers covering them collapsed. The largest of the table mountains between the depressions have diameters of tens of kilometers. The bright, layered material in the lower right-hand corner of the image may have been created by the evaporation of fluids or by hydrothermal activity. (3°S, 335°E, due northeast.)







10

FEAR AND PANIC

smaismrmilmepoetaleumibunenugttauiras

– Galileo Galilei: *A letter to Johannes Kepler* (1610)

The existence of the two small satellites of Mars has been known for about 400 years. This might come as a surprise, since there was no chance of finding these tiny bodies with the primitive instruments of the seventeenth century. The German Johannes Kepler, who had just solved the problem of the celestial movements of Mars – and of all the other planets, too – was the originator of the idea. Despite his good guess Kepler was not any great seer or possessor of some secret knowledge. There is a simple explanation for his accidentally correct conjecture on the number of satellites of Mars. He misunderstood the information he received from the Italian Galileo Galilei.

In the summer of 1610 Galileo was once again gazing at the skies. He aimed his poor, but nevertheless revolutionary, telescope at Saturn, the outermost of the planets known in those days, gleaming in the evening sky. To his surprise Galileo noticed that the shape of Saturn deviated from the circular, the classical shape of perfection. On closer inspection it seemed to be made up of three parts. It was only 50 years later that the reason for this anomaly was understood: Saturn has rings around it.

Competition in those days in the realm of science was at least as ferocious as it is today, so Galileo searched for a way to ensure his status as the discoverer of this phenomenon. This meant that he had to avoid revealing the true nature of the discovery until he

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had been able to publish it in print. With the first scientific journals still half a century away in an unforeseeable future, Galileo decided to resort to a common gimmick of that time. He let his colleagues know about his observation in the form of an anagram:

s m a i s m r m i l m e p o e t a l e u m i b u n e n u g t t a u i r a s

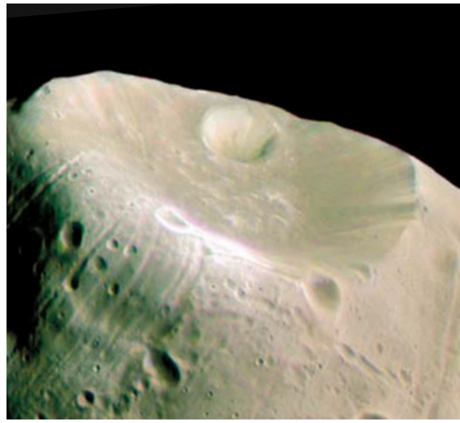
This way the others got information on both his significant discovery and the date on which he made it. The anagram consisted of so few letters (37) that Galileo could not shuffle them afterward into another message that might translate into some other discovery made by someone else. However, that is exactly what Kepler managed to do.

The bunch of letters Galileo mailed to his colleagues make up the Latin sentence "*Altissimum planetam tergeminum observavi,*" or "I have observed the most distant planet to have a triple form." Kepler thought that Galileo's discovery had something to do with Mars, his own object of greatest interest, so he came up with an alternative sentence, *"Salue, umbistineum geminatum Martia proles,"* or "Hail, twin companionship, children of Mars." Thus Mars would have two satellites, which was extremely compatible with Kepler's (who had a tendency toward number mysticism) concept of the world: Earth has one, Mars two, and Jupiter four, the last being found by Galileo sometime earlier. The answer was correct, but only by accident.

Domestic support

● The two satellites of Mars became a scientific reality in 1877 when the American Asaph Hall discovered two tiny points of light revolving around Mars. This was the same year that Mars came exceptionally close to Earth in opposition, and the Italian Giovanni Schiaparelli set the stage for the dispute on the existence of Martian canals, a dispute that lasted for decades.

Hall was not the first to try to find the satellites of Mars. The first alleged observation of Martian satellites was made in 1643 when a Capuchin monk named Anton Maria Shyrl reported seeing small bodies circling Mars. In 1744 the German Eberhard Kindermann thought he saw one satellite, the orbital period of which he was even able to determine: 59 hours 50 minutes 6 seconds. William Herschel



Stickney crater dominating the terrain of Phobos has a diameter of about 10 km.

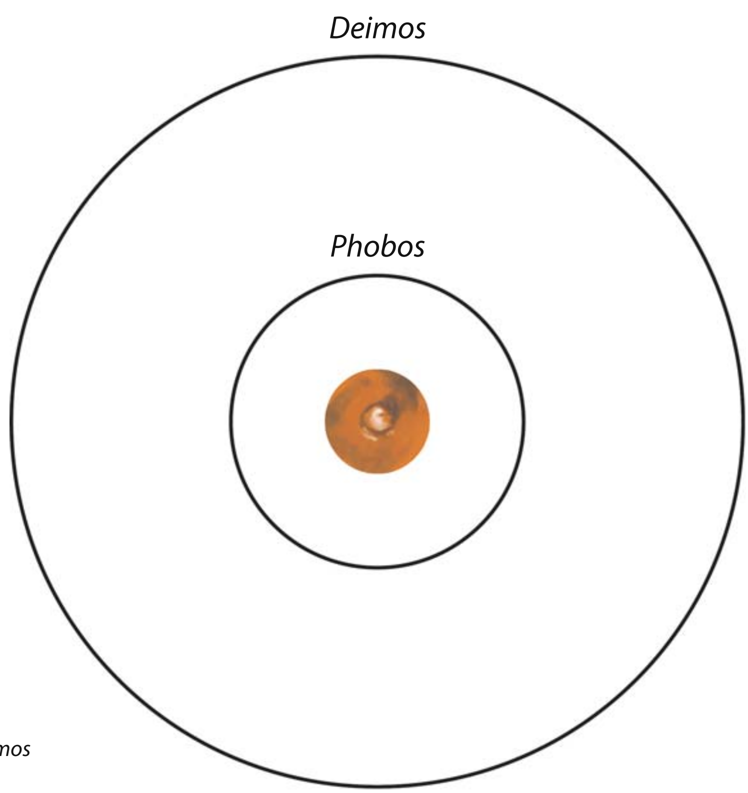
LITERARY FANTASIES

● As miraculous an inkling as Johannes Kepler's guess on the number of Martian moons is to be found in *Gulliver's Travels*, a novel published by the Irish Jonathan Swift in 1726. Mr Lemuel Gulliver, the narrator of the story, tells how the advanced astronomers of the floating island state of Laputa had discovered *two lesser stars, or satellites, which revolve about Mars*. Swift's hunch might very well be explained by his knowledge on Kepler's ideas. When an author plans to tell something about Mars in his novel, it is probable that he would read texts on his subject. Swift was a scholar who most probably had an access to some book written by Kepler or a publication introducing his thoughts with a mention of Kepler's assumption on the satellites of Mars and their number.

searched for the satellites in 1783, and the German Heinrich d'Arrest in the 1860s, but to no avail. In 1875 the American Edward Holden photographed Mars to find any possible satellites, using the very telescope Hall later used to make his discovery, but the effort was futile. However, after Hall finally found the two Martian satellites, Holden claimed to have found two more. These "disappeared" rather soon, though, without a trace.

Hall began his quest for the satellites in the beginning of August that year and it took only a couple of weeks to make the discovery. The largest crater on the surface of the larger satellite,

	Diameter	Distance from the Center of Mars	Period
Phobos	26 × 18 km	9,377 km	7 h 39 min
Deimos	15 × 11 km	23,463 km	30 h 21 min



The orbits of Phobos and Deimos are very close to Mars.

Phobos, was named Stickney, after Hall's wife Chloe Angeline's maiden name, and she really deserved the credit. A disappointed Asaph was about to give up a seemingly useless hunt, but his loving wife encouraged him to return to the telescope.

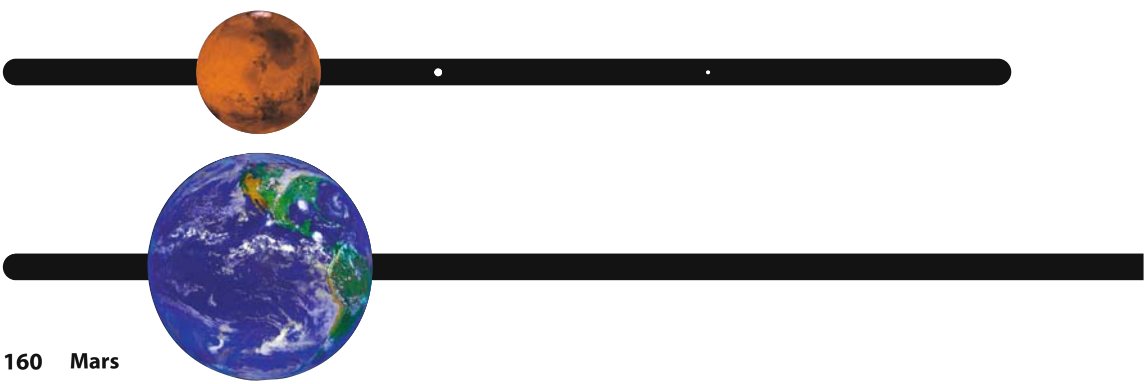
Why were the satellites found only in 1877 even though they had been searched for since the early years of the seventeenth century? First of all, they circle so close to Mars that they are easily lost in the glare of the planet. On the other hand, they are very small and thus appear only as tiny points of light, so tiny that they would be difficult to see even without the glare of Mars. The reason for Hall's success was his insight to look for them very close to the planet, much closer than anybody else before him.

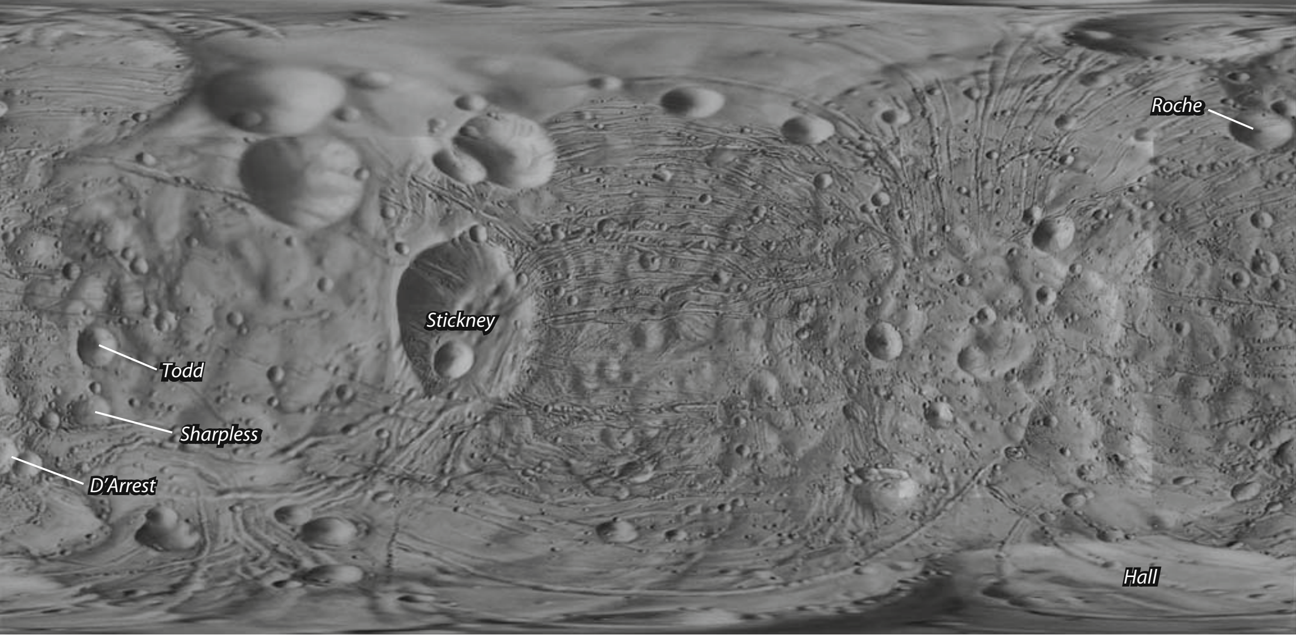
Following the suggestion by the Englishman Henry Madan, Science Master of Eton, the satellites were named Phobos and Deimos, Fear and Panic. These were the sons and loyal armor bearers of Ares, the god of war in Greek mythology (or Mars in the Roman one). Homer wrote in the fifteenth song of the *Iliad* how Ares prepared for a reprisal raid and

> . . . ordered Phobos and Deimos to harness his horses, and himself got into his shining armour.

For almost a century all that was known about the Martian satellites were the basic facts: their distances from Mars and their orbital periods, which made it possible to accurately calculate the mass of Mars. Only with the advent of the planetary probes did Phobos and

Earth with the Moon and Mars (with its satellites) in the same scale. Earth's Moon is found on page 165.





A map of Phobos based on images taken by the Viking *orbiters.*

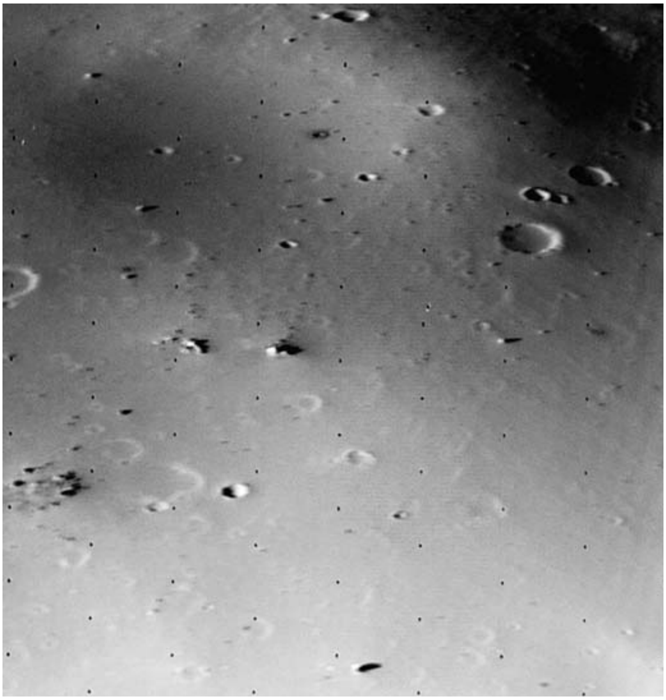
Deimos change from tiny points of light into celestial bodies with definite shapes and individual characteristics.

Scabbed potatoes

● Both satellites of Mars are irregular bodies. They are so small that gravity has not been able to pull them into a spherical shape. The widest part of Phobos is 26 km and the narrowest 18 km, while the diameters of Deimos are 15 and 11 km, respectively.

Depicting the terrain of a round body on a flat map is difficult enough, but mapping the satellites of Mars is even more challenging. The only way to give a correct idea of their shape is to create a three-dimensional model, but nevertheless there are traditional maps of Phobos and Deimos, too. However, the map of Deimos is only partial and besides that it has poor resolution in places.

Both of the satellites are pockmarked with craters. Those on the surface of Phobos resemble the craters on Mars, but on Deimos they are more shallow and in part filled with dust, making them look more worn-out. The dust that covers the surface of Deimos, which makes the terrain smooth like a blanket of snow, most probably originates from the satellite itself. As a result of bombardment billions of years ago the weak gravitational field of Deimos let



pulverized material escape into orbit around the satellite, and in the eons since it has gradually fallen back onto its surface. Another possible explanation for the smoother appearance of Deimos could be related to the saddle-like gouge on its southern hemisphere. If this was created by a large meteorite the impact could have thrown material all over the satellite, wrapping it in a layer of dust possibly half a kilometer thick.

Phobos, on the other hand, is very rough. The most prominent features on its surface are crisscrossing grooves, which may have formed simultaneously with crater Stickney having a diameter of 10 km. The collision was so violent that it nearly shattered the satellite into pieces. And that is just what might have happened. It is possible that the cracks created by the impact permeate Phobos, which would mean that in practice it is just a loose pile of rocks. Even though the gravity of Phobos is only one-thousandth that of Earth's, it is strong enough to keep the satellite together. On the

Surface of Deimos near the north pole of the satellite. The diameters of the smallest craters are about 20 m.

The grooves on the surface of Phobos are probably fractures filled with dust. They were caused by the same impact as caused the Stickney crater.

surface the cracks appear just as numerous grooves. They are thought to have obtained their appearance when the dust covering the surface slowly flowed into the innards of the satellite.

Double moonshine

● There is not much moonshine in the night sky of Mars, even when one or the other of the satellites has risen. Phobos orbits so close to Mars that despite its small size it is visible as a bright, somewhat irregular disc with a diameter of about a quarter of that of the Moon in our sky. However, Phobos' brightness is only one-tenth the brightness of the full Moon, or approximately the same as the brightness of the first or last quarter of the Moon. Nevertheless Phobos is some 300 times more luminous than Venus so it could easily be seen in broad daylight. Deimos, being more distant and smaller, would show itself as a mere point of light only a bit brighter than Venus in our sky.

Because Phobos is so close to Mars it never rises above the horizon in regions north of 50° northern latitude and south of 50° southern latitude. The same goes for Deimos more than 75° from the equator. This is a phenomenon known on Earth, too. At times the Moon does not rise for days if you are above latitude 62 in the northern or below that in the southern hemisphere, but at other times it does not set for days. However, in this case it is due to the inclination of the orbit of the Moon, not its proximity, and what is more important, its invisibility is only intermittent.

The lack of bright moonshine at night is somewhat compensated for by the strange behavior of the satellites in the Martian sky. The orbital period of Phobos is only 7 hours 39 minutes, about a third of the rotational period of Mars. In the course of one Martian day – 1 sol – the satellite travels around the planet more than three times and what is most peculiar – at least compared to the leisurely wanderings of our Moon – it rises from the west, rapidly crosses the vault of the heavens, and sets some four hours later in the east.

Rising Phobos is always in a different phase to the previous time it appeared from behind the horizon. Moreover its size appears to double as the satellite climbs from the horizon to high up in the sky. When setting in the east it shrinks again. A "full-Phobos" can occur twice a night. If Phobos is "new" when rising around sunset, its phase will grow from a thin crescent through a "first quarter" to "full" before it sets. The next time Phobos rises just before sunrise, it is once again full, but diminishes rapidly through the "last quarter" and a "crescent" into "new Phobos." Admiring "full-Phobos" is made difficult by the fact that once every revolution the satellite travels through the shadow of Mars and is totally eclipsed more than 1,300 times a year. It is only around the summer and winter solstices, when the inclination of the orbit of Phobos with respect to the Sun has its maximum value, that Phobos manages to avoid the shadow by going above or below it.

Deimos' behavior is more familiar, since it rises from the east and sets in the west. It moves very slowly, though: it takes a total of 60 hours, more than two Martian days, to travel across the sky. During that time Deimos goes through its phases twice. The apparent diameter of Deimos is so small that it would be impossible to discern the phases with the unaided eye. Deimos also disappears when plunging into the shadow of Mars, but only about 130 times a year.

The transit of Deimos on March 4, 2004 photographed by the Opportunity rover.

Eclipses or transits?

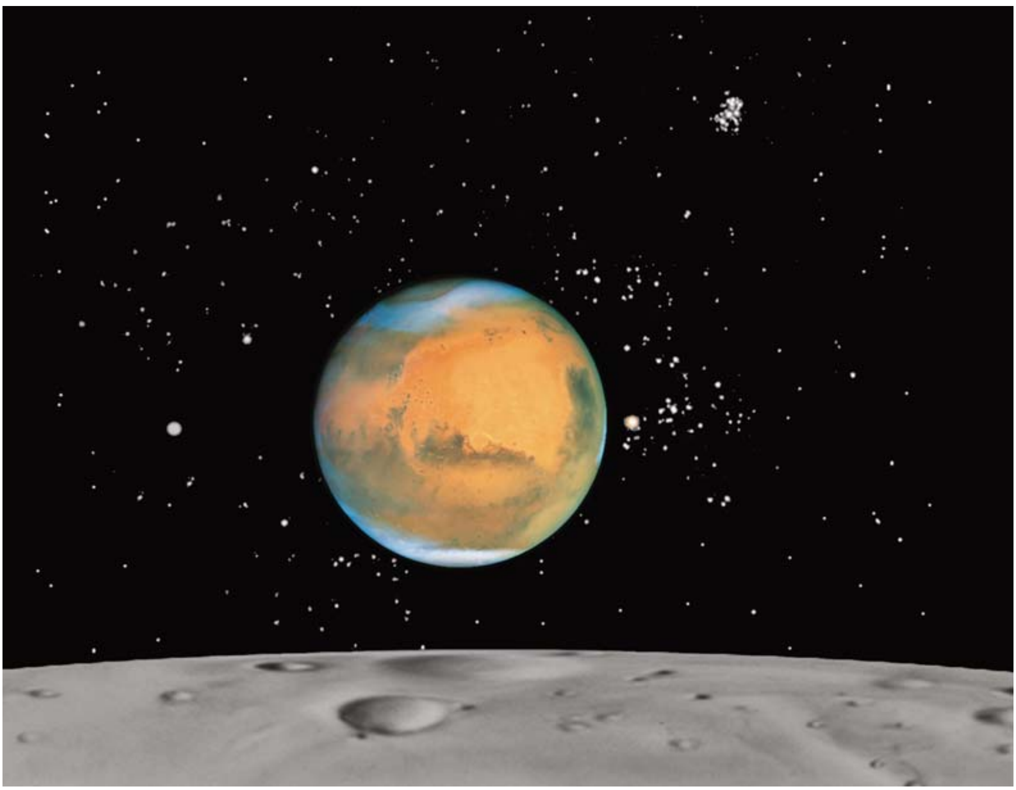
Phobos and Deimos cross the face of the Sun as seen from the surface of Mars as regularly as the satellites are eclipsed in the shadow of the planet. However, these "eclipses" are nothing compared to the spectacle we may experience at the time of a total solar eclipse. They are more like transits, phenomena similar to when Mercury and Venus wander across the Sun as seen from Earth.

Being smaller and more distant, Deimos would be visible only as a black dot, taking about 1 minute to cross the Sun. Phobos' size is much larger, its apparent diameter being about half of that of the Sun, so it would make a noticeable, clearly irregular notch in the disk of the Sun. The eclipse would not last very long, though, since Phobos speeds across the face of the Sun in only 19 seconds.

Rings of Mars

● The orbit of Phobos is so close to Mars that the tidal forces caused by the gravitational field of the planet ensure that it slowly, but surely, draws closer to Mars. According to calculations it will crash into Mars in 50–100 million years. The impact of a body some 20 km across will cause great devastation. If there were advanced life on Mars, the fall of Phobos would most certainly destroy it. And in case there are representatives – or descendants – of the human race on Mars at that time, it would be fatal to them, too. However, the tiny satellite will probably disintegrate prior to the crash into smaller pieces, which might form a ring around Mars, similar to, but a lot more modest than, the spectacular system around Saturn.

Mars and Phobos as seen from the surface of Mars. The size of Phobos is exaggerated.



Phobos' gradually shrinking orbit gave the Soviet Iosef Shklovskii in the 1950s a reason to speculate that the satellite is not natural but an artificial, hollow structure, a space station built by an alien civilization. The reason given for Phobos being found only in 1877 is alleged to be that it was launched into space just then. It is for anyone to judge that, by the images sent by the probes, if Phobos really is a space station, it has been camouflaged with extreme diligence.

Real-time celestial mechanics

● Due to the *Apollo* flights to the Moon in the 1960s and 1970s we know what Earth looks like from the surface of our own satellite. So far nobody has laid their eyes on Mars from the surface of Phobos and Deimos (nor vice versa, for that matter), but one day it surely will happen. The vista opening up before those space pioneers would really make the journey worth all the trouble.

Both satellites keep the same hemisphere at all times toward Mars, so as seen from one side Mars would loom motionless in the sky, from the other it would never be seen. To be precise, because of the slow swaying of the satellites – the libration – Mars would seem to wander back and forth just like Earth does as seen from the surface of the Moon.

Phobos is so close to Mars that the planet would seem to cover most of the sky. If the limb of Mars were on the horizon, the opposite limb would be verging on zenith. The planet would seem to make one rotation in 11 hours, and it would go through its phases from "new Mars" to "full Mars" and back in a little over 7 hours.

As seen from the surface of Deimos the apparent diameter of Mars would be some 30-fold compared to the Moon seen in our sky. If you would stretch your arm out, Mars would just about be covered by the palms of your hands – though for an astronaut in a spacesuit it would take only one gloved hand to cover the planet. The orbital period of Deimos is a little over 30 hours, so Mars would seem to go through its phases in the same length of time. An almost motionless Mars would appear to make one rotation around its axis in just a little longer time, in less than 33 hours.

To counterbalance the immobility of Mars in Deimos' sky, Phobos would swing back and forth, alternately crossing the disc of Mars and disappearing behind the planet, going through its phases in rhythm with Mars. The largest distance of Phobos from Mars would be only about the same as the diameter of the planet, so as seen from the surface of Deimos the angular diameter of the orbit of Phobos would be approximately the same as that of a rainbow in our sky.

The surface of the outer satellite of Mars would offer an exceptional vantage point for viewing the orbital motion of the inner satellite – except for the times it would be behind Mars or in its shadow. It would take some 5 hours for Phobos to swing from one side of Mars to the other and at best it would seem to speed across the sky of Deimos almost 20 times faster than the Moon wanders among the stars in our sky. Because of the rotation of Earth, the Moon seems to move in the sky about 15° an hour, which would make its apparent speed double that of Phobos.

The situation would also be different in another respect. We would not be watching the motion of the satellite from the surface of a central body, but we would see both the planet and the satellite in orbit around it. This makes Deimos the only place in the Solar System – or the only place accessible in a reasonably near future – from the surface of which we could watch the workings of celestial mechanics controlling the movements of all the bodies in the Solar System in real-time, with the unaided eye, and so that the motion could be discerned.

The captured and the crushed

● Traditionally the prevailing idea has been that Phobos and Deimos are asteroids captured by Mars. Most of the minor planets travel around the Sun between the orbits of Mars and Jupiter, but at times many of these come closer to the Sun than do Mars, Earth, or even Venus. In this respect it would be no wonder if some straying asteroid came close enough to Mars with an appropriate velocity to be captured by the planet.

There are a couple of strong arguments against this theory. First, the orbits of the Martian satellites are very nearly circular, and second, they orbit Mars almost exactly in the plane of its equator. The satellites supposedly captured by giant planets have either very elliptic or very inclined orbits – or both. However, Phobos and Deimos do resemble asteroids and not only by their irregular shape. They are very dark, reflecting only a few percent of the light falling on them. They differ from the mainly light bodies in the inner regions of the Asteroid Belt, but the characteristics of their surfaces are close to those of the carbon-rich asteroids in the outer fringes of the belt. It is possible that the enormous gravity of Jupiter has thrown Phobos and Deimos into orbits taking them close to Mars and its gravitational field.

It is also possible, though, that the birth of the satellites was a much more violent event, just as in the case of the Moon. About 4 billion years ago a young Earth still in the process of formation was hit by another celestial body about the size of Mars. As a result a substantial portion of Earth's material was thrown out into space. This material formed a short-lived ring around a badly damaged Earth. Part of the material fell back to Earth, causing more destruction, but part of it was accumulated into what is now the Moon. The time all this took was probably very short, perhaps only about 1 year, maybe just months or weeks.

The formation of the Martian satellites could be explained by a catastrophe, too, though not as destructive as in the case of the Moon. Originally both Phobos and Deimos could have been part of just one, much larger satellite. Some scientists think that the grooves on the surface of Phobos might suggest this: perhaps they are not cracks created by a large impact after all but layers of sediment formed on the surface of a far larger body before it broke up.

The original satellite would have been captured by Mars very early, perhaps in the final stages of the planet's formation. The satellite would have taken a so-called synchronic orbit, with the period of revolution being the same as the period of rotation of Mars. According to computer simulations a body with an orbit like this would before long have broken up because of the tidal forces

Phobos, Deimos, and asteroid Gaspra in scale.

created by the gravity of the planet. The largest pieces would soon have fallen on the surface of Mars, but the smaller ones would have stayed in orbit a lot longer – the last of them being Phobos and Deimos. And even Phobos is rapidly coming to the end of its celestial journey.

There are myriads of craters on the surface of Mars, varying in size from small pits to basins hundreds and thousands of kilometers across, so it would take no time at all to find signs of potential impacts. This version of the origin of the Martian satellites could be linked with the ideas of the Canadian scientist Jafar Arkani-Hamed mentioned earlier on an ancient series of impacts that revealed the past changes in the inclination of the axis of Mars's rotation.

The problem with the theory is that in the case that Phobos and Deimos do originate from the same body, they would have to have similar composition and structure. If the images of the satellites are to be believed, this is not the case, because the surfaces of Phobos and Deimos are very different from each other. Proving or disproving the theory would require a more thorough study of the satellites. If their composition were found to resemble that of Mars, it

The last image sent by the Soviet Phobos 2 *probe before the loss of contact. The tiny satellite was at that moment at a distance of 188 km. The diameters of the smallest details are 34 m.*

would prove all of them to have been born in the same region of the Solar System. If the satellites were found to be nearly identical, they would have been part of a same body.

Evaluating the different theories on the origin of Phobos and Deimos would take more detailed knowledge both of the surface and subsurface of the satellites, but it seems that it will have to wait – but perhaps not for long. Russia and China are planning to send a probe, *Phobos-Grunt,* in 2009 to study both Mars and Phobos. While the Chinese orbiter will concentrate on Mars and its atmosphere, the Russian probe will land on Phobos to conduct research and take soil samples. However, first in line are the open questions on Mars.

11

ONE REALLY GIANT LEAP

Well, here I am.

– Pamela Sargent: *Danny goes to Mars* (1992)

In the heat of *Apollo* fever in the 1960s and 1970s a manned flight to Mars was considered to be a natural and almost immediate follow-up to of the "conquest" of the Moon. It was later revealed that when the Soviets realized they were losing the race to the Moon, they considered Mars to be their next target. However, they were quick to realize that this was an impossibility using technology that had failed to take the Soviets to the Moon. Due to budget cuts NASA had to cancel the remaining *Apollo* flights, and this too was a death blow to manned Mars missions. However, ever since those days small circles have cherished hopes of a flight to Mars. Lately the topic has been brought up – for the first time in very many years – in a concrete way, but the actual flights are still at least 20 years into the future, as they have been for the last 30 years.

Man – a beneficial nuisance

● The British Freeman Dyson, who was involved in a nuclear rocket project in the late 1950s, has written that

> we shall know what we go to Mars for, only after we get there.

M. Hotakainen, *Mars*, DOI: 10.1007/978-0-387-76507-5_11,
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That is not enough. There is no sense in undertaking manned spaceflights unless there is a really good reason for them. They are extremely expensive even if their destination is only low Earth orbit. Mars – at its closest – is at a distance of some 60 million km, and the length of an actual flight path would be hundreds of millions of km.

One benefit of weightlessness is that you feel very light, but a long exposure to that condition is harmful to the body.

That is why Mars has diligently been studied with space probes. Nevertheless, the *Apollo* missions already established almost 40 years ago the benefits of manned versus unmanned flights. With only basic training in field geology, insufficient equipment, and a very tight schedule the *Apollo* astronauts were able to perform observations and experiments space probes were incapable of making, no matter how advanced they were. Humans have the capability of observing their environment and pondering various different alternatives prior to making decisions on what to do next, and that is something rovers equipped even with the best of artificial intelligence do not possess.

There are lots of problems with manned Mars flights that did not require worrying about on the journeys to the Moon. A return trip to the Moon takes only a few days, whereas a flight to Mars takes about 6 months – one way. If trouble turns up during a flight, it would have to be dealt with in situ. And even if everything went well, a flight of several months sets strict standards on the reliability of equipment – and on the crew.

Astronauts and cosmonauts have spent months, even more than a year, in space stations orbiting Earth, and these missions have provided valuable information in relation to a flight to Mars, too. Weightlessness makes the calcium in the bones disappear at such a pace that without proper precautions its amount would be halved every 2 months. Another problem is with musculature. In space muscle exertion is minimal, and unless astronauts exercised at least 2 hours a day, their muscular system would deteriorate during the months it would take to get to Mars.

The third and worst problem is with radiation in space. It is quite well known how much radiation there is, but its effects on the human body are not yet known in detail. Low Earth orbit is safely inside the magnetosphere of Earth, which creates an effective shield against much of the radiation, but on a flight to Mars both the ship and its crew would have no natural protection. And creating artificial protection will be somewhat problematic. Ordinary water would be an effective insulation against cosmic radiation, but the layer of water that would be needed to stop the harmful particles would be several meters thick. This would mean an extra mass of hundreds of tons even if the shelter were only a small one.

Another possibility would be to imitate the protective cover of the atmosphere of Earth. According to tests being made at the University of Washington this could be done with a superconducting magnet and a relatively small amount of gas in the form of plasma. Because of its electrical charge it would be captured in the magnetic field and form a shield against the radiation.

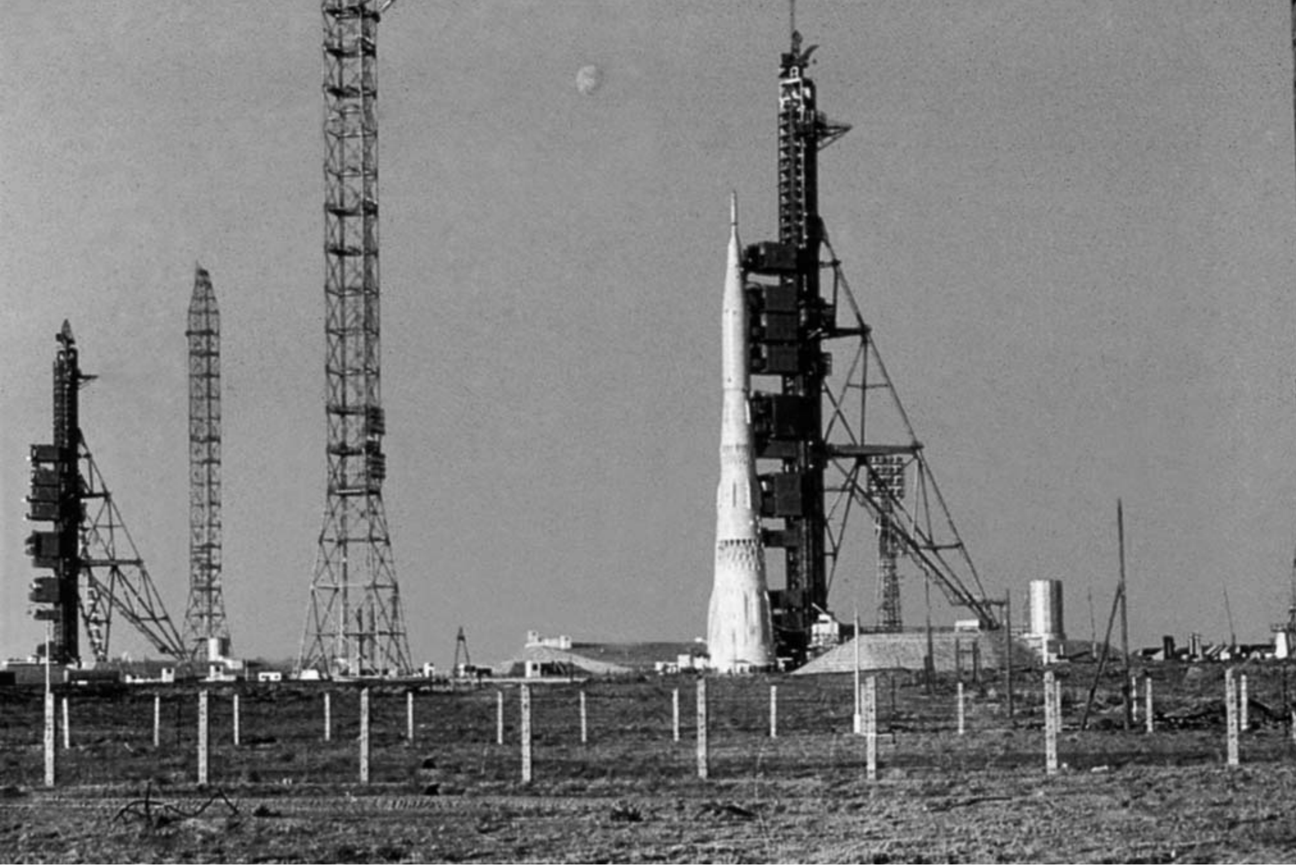
Some kind of protection would be essential, since energetic cosmic radiation and particles ejected by solar storms would break apart DNA, damage genes, and destroy cells. Predisposition to radiation would considerably increase the risk of cancer; after a 3-year trip to Mars the probability of having cancer has been estimated to be 20–24% higher than on average. However, an ongoing study by NASA seems to indicate that the situation is not quite as bad as it has been assessed to be. Space radiation simulations have been done at Brookhaven National Laboratory's booster accelerator since 2003. One preliminary result is that the problem is not with the high-energy protons but with the low-energy ones, that is, with particles moving slowly; these tend to cause more damage to living tissue. Other factors influencing the risk are the health of the astronauts and measuring the effects of the radiation on each organ instead of on the whole body.

All this would mean that the risk to the health is possibly only half of what has previously been expected. Thus the astronauts on a Mars mission might not need any treatment with protective drugs such as retinoids or other substances that slow down cell division so that the cells being damaged have time to repair themselves.

A somewhat surprising problem is people's adaptability to almost any environment. The Soviet cosmonaut Georgi Gretchko recounted how one of the most difficult things to remember after a long stay in weightlessness is that things like dishes do not stay in the air anymore. On Earth this is simply annoying, but on the surface of Mars a preoccupation like this might prove to be fatal – even though Martian gravity is only some 40% of that on Earth.

Off we go, but how?

● Most of the plans for a flight to Mars are based on the same principle as the one used on *Apollo* flights and other manned missions: everything the astronauts would need will be taken onboard the ship whether it is fuel or air, food or drink. In the case of a flight to Mars this principle would boost expenses to literally astronomical figures.



The gigantic Soviet N-1 launch vehicle was supposed to take the nation to Mars, but it failed to take it to the Moon.

To have enough room for everything needed, the ship would have to be big. And big ships are very difficult – if not impossible – to get into space in one go. The United States, Russia, and Europe do not have a rocket or even plans for one big enough so that a "classical" Mars ship could be launched into Earth orbit in one piece.

One solution that has been given much thought would be taking the ship into space in components, and assembling it in orbit. This would take several flights of the space shuttle or some future launch vehicle, and the building of a "space dock" for the actual assembly work. Another problem would be the storage of liquid hydrogen and oxygen. Handling a liquid with a temperature of −250°C is not easy on Earth, let alone in the weightlessness of space.

A flight to Mars and back would require enormous quantities of fuel. This in turn would limit the amount of equipment that could be taken onboard, so a visit to Mars would be very short – a visit for a visit's sake. For a flight of more than a year to be in any way sensible, there should be something meaningful to do at the destination and the time to do it.

Battlestar Galactica

● The German-American Wernher von Braun, who developed the Saturn rocket used in the *Apollo* program, outlined plans for a manned flight to Mars at the end of the 1940s. His "Marsprojekt" received a lot of publicity because of a series of articles published in *Collier's* magazine and a television program produced by Disney. These excited the public at large. It seemed that man would go to Mars even before reaching the Moon.

Von Braun did think big. As it would take a gigantic rocket to get to the Moon – the final version of the Saturn rocket had a mass of over 2,000,000 kg at launch – a trip to Mars would require an even bigger rocket, preferably several of them. And the size of the crew would be reminiscent of the Antarctic expeditions of a hundred years ago: 10 ships would have a total of 70 crew members. Later, von Braun's megalomanic vision was called "Battlestar Galactica" after the science fiction television series broadcast at the end of the 1970s. Great ships would be thundering through empty space toward an unknown – or in this case known – destination. Magnificent, mighty – and costly.

The Soviet Union had plans almost as noteworthy as the United States. The original purpose of the N-1 rocket developed for a manned flight to the Moon was to carry components of a Mars ship into Earth orbit. According to a plan prepared under the guidance of "Chief Designer" Sergei Korolev, the "von Braun of the Soviet Union," a flight to Mars would be undertaken by a ship with a mass of 1,500 m tons, the assembling of which would require 25 launches of the N-1 rocket. This is quite a lot even in itself, but especially in light of the complete failure to make the rocket work. All the test flights ended up in the destruction of the rocket.

Atomic power in space

● Thanks to preparations for the *Apollo* missions, knowledge on spaceflight and its requirements increased tremendously. Long before the "small step" it was realized that carrying out a flight to Mars using chemical rockets fueled by hydrogen and oxygen would be difficult. In those days atomic power was considered to be the solution to almost any problem, including this one.

Atomic energy was to be used as a power source for a trip to Mars. The Orion spaceship would have used nuclear bombs.

One of the nuclear rocket programs was called Orion, which was made public only in the beginning of the 2000s. The planned ship would have had a mass of thousands of metric tons, and it would have carried thousands of nuclear bombs, which would have been set off continuously less than a second apart. A massive, suspended shield at the back of the ship would have transmitted the energy of the explosions to the ship and made it speed up, while at the same time it would have protected the crew from the radioactive radiation. The motto of the project was "Saturn by 1970." On the way there, sort of as a pit stop, would have been a couple of years' visit to Mars. Faith in the omnipotence of technology was amazingly robust.

As the project advanced, Saturn was dropped from the itinerary, but there was an exact schedule for the flight to Mars. It would take 258 days to get there, 454 days of being there, and another 258 days to get back: a total of 2.5 years. To be on the safe side the flight was to be carried out "only" in 1965, so that there would be no haste. The plan was conceived in 1959, with the first manned spaceflight still more than 2 years in the future.

The project was completely canceled in the mid-1960s, when the superpowers signed a treaty banning any nuclear tests in space. A flight to Mars would not be boosted by the fission of atoms. In addition to space research, the project left some permanent marks in the history of cinematography. In Stanley Kubrick's mystical movie *2001: A Space Odyssey*, the ship *Discovery,* which took astronauts to Jupiter, was originally supposed to be an Orion-type rocket powered by nuclear explosions.

The idea of nuclear power was revisited in the early 1990s when the White House "Synthesis Group" convened by NASA and led by the Apollo astronaut Thomas Stafford decided that nuclear rockets were the most practical means of sending astronauts to Mars – and the only possible vehicles for visiting other planets. It was estimated that the travel time to Mars with nuclear propulsion could be as short as 60–90 days compared to almost 200 days with the traditional chemical propulsion. At that time the target date for a manned mission to Mars was set to 2015–18. As we know now, this will not happen.

The Mars Society, founded by Robert Zubrin, has "Mars Stations" in Utah and in northern Canada. The Finnish scientist Sini Merikallio from the Finnish Meteorological Institute spent 2 weeks at the Utah station in 2002.

Express Mars

● Fortunately a flying atomic bomb, a speeding nuclear reactor, or a gigantic Mars project with interplanetary cruisers are not the only options for getting to the Red Planet. In the beginning of the 1990s the American Robert Zubrin published a plan called "Mars Direct." The core of the plan was that not everything would have to be taken aboard the ship; instead, the mission would make use of the resources on Mars.

At first there would be an unmanned chemical laboratory and an empty return ship sent to Mars. Launching them would take only one big rocket, since fuel would be needed only to get there. After arriving at Mars the laboratory would start manufacturing the fuel needed for the way back from the carbon dioxide in the Martian atmosphere. With a small supply of hydrogen transported from Earth an automatic "factory" would produce enough methane in 6 months for the return trip. A year after the launch of the laboratory the time would be right to send a manned ship to Mars. It, too, would only need enough fuel to get there, since there would be a refueled return ship waiting on Mars.

In the mid-1990s Zubrin outlined a schedule with the first humans on Mars as early as 2008. According to all other plans humans on Mars would be reality only in the 2030s. This disparity is quite large, even if Zubrin's original goal has been postponed by the ten or so years that have passed since he came up with the plan.

The difference in cost would be even more dramatic. A traditional flight to Mars would easily carry a price tag with 12 figures: the total cost would be hundreds of billions of dollars. Mars Direct could – in principle, at least – be realized with one-tenth of that sum. And it would not be just a quick visit to the Red Planet, but a systematic research program with a manned ship launched to Mars every other year.

Ecology in space

● Rocket power, also used in Zubrin's plans, is not the only means of propulsion in space. It would be possible to sail from one planet to another, although it would take time – just as sailing does here on Earth. It would be most poetic if the ships set their sails in the continuous solar wind blowing from our central star to leisurely wend their way across our planetary system. However, ships using solar sails would not exploit the solar wind but instead the radiation pressure caused by photons, the tiny particles of light. At the distance of Earth the intensity of the solar wind is only 1/5,000th of the solar radiation pressure, which makes it practically insignificant.

The use of solar sails, especially on flights to the inner planets, Mercury and Venus, has been studied by Viacheslav Koblik who earned his Ph.D. at the University of Turku in 2003. This type of "eco ship" could be sent to the outer Solar System, too, for example to Mars – if there is no hurry. The radiation pressure of the Sun, just like the intensity of radiation, decreases rapidly, inversely proportional to the square of the distance. In doubling the distance the intensity would drop to one fourth. At the distance of Mars the radiation pressure of the Sun is less than half of that at the distance of Earth.

There is no solar sail ship in space yet, but calculations, plans and even experiments have been made. One of the objects of research in the Cosmic Vision science program of the European Space Agency is solar sail technology, and the Planetary Society financed *Cosmos 1*, a satellite testing a solar sail. This was launched

LYING DOWN TO MARS

● European Space Agency ESA has arranged several studies on the effects of a long spaceflight to human body. In a series of test called WISE (Women International Space Simulation for Exploration) weightlessness was simulated with a total bed rest of 60 days. Twelve test subjects – all of them women – at a time lied down for 2 months in beds tilted 6° with their heads down. This kind of position makes the blood distribute the same way it does in weightless conditions and it imitates the effects on the atrophy of the muscles and the weakening of the bones.

in 2005, intended to go into Earth orbit, but it never reached it. The rocket carrying the satellite malfunctioned and exploded destroying the satellite with it.

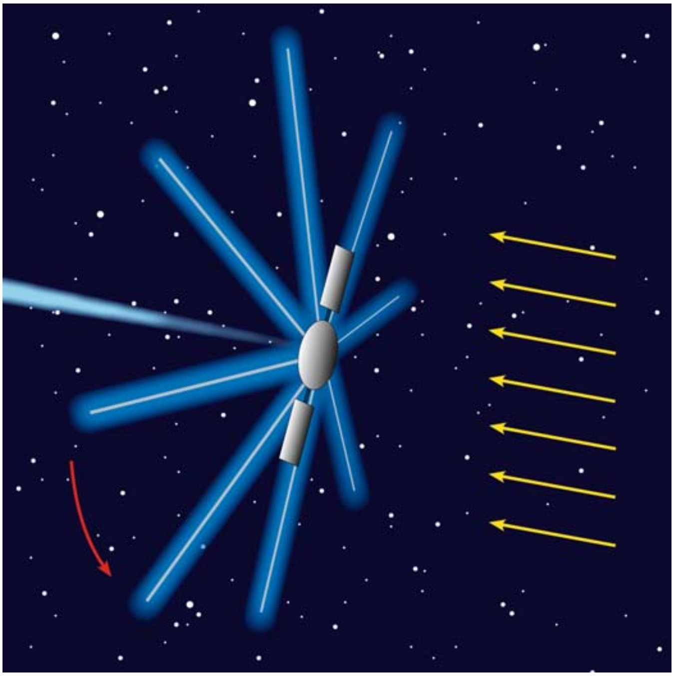
But then again . . .

● With traditional propulsion systems a flight to Mars would take about 6 months, but sailing to the Red Planet would take from less than a year to almost 2.5 years. It seems likely that solar sails will be used to propel only unmanned probes to Mars, as they are able to take a longer route than the ships capable of keeping humans alive.

In theory it would be feasible to sail to Mars in just 1 month. The American physicist and science fiction writer Gregory Benford, with his brother James, who runs a technology company, has been developing a new kind of solar sail, the principles of which caused somewhat of a sensation in the magazines and on the Internet in 2005.

At the root of the idea is a special paint covering an extremely thin sail. A traditional rocket would be used to launch a ship into space, where the solar sail would unfold. After that a powerful microwave ray would be aimed at the sail raising the temperature of the paint to thousands of degrees centigrade. Evaporation of gas molecules from the hot paint would create propulsion, which would speed up the ship with acceleration far greater than that gained with only the radiation pressure of the Sun. As the result of one hour's irradiation the velocity attained would reach 60 km/second, or over 200,000 km/hour, which would break all the earlier records in interplanetary flights. So far the biggest problem is that there is no microwave transmitter powerful enough.

Another novel idea involving sails in space is an electric solar wind sail that was invented by the Finnish scientist Pekka Janhunen in 2006 at the Kumpula Space Centre in Helsinki. The electric sail uses the solar wind's momentum for producing thrust. The spacecraft based on the idea would look like a huge, rotating spider; it would have 50–100 "legs" instead of just 8. The legs, or tethers, made of conductive material would be 20 km or so long, have a thickness of some 20 μm (20 thousandths of a mil-



limeter), and a mass of only about 250 g each. The “body” of the spider would contain a solar-powered electron gun that would maintain the craft and the tethers in a high positive potential. This would create an electrical field in the tethers extending some tens of meters into the solar wind plasma, so from the point of view of the ions in the solar wind, each tether is about a 50-m wide “obstacle” against which the ions would be continuously pushing. Thus, the total area of a sail with 100 tethers would be almost 100 km^2, with the inevitable overlapping in the central area of the sail.

The newly proposed electric solar sail would utilize the interaction between the electromagnetic field created with long conductive tethers and the charged particles of the solar wind. The light blue “cone” is the electron beam of the gun, and the dark blue glow the field around the tethers. The solar wind acting on the tethers would make them bend a little.

This kind of an electric sail could produce an acceleration that would give a spacecraft with a mass of 200 kg a speed of at least 30 km/second in 1 year. Compared to the “Benford Sail” and other beamed-energy designs, the electric sail would have some significant benefits: it would be self-sufficient, lightweight, and low-cost. One disadvantage would be that the electric sail would not function in a planetary magnetosphere where there isn’t any solar wind blowing, but because Mars has practically no magnetosphere at all, this wouldn’t be a problem.

Both of these new ideas are in a very early stage of development and upon realization would be of help only with small payloads. Nevertheless they have already proved that despite the long history of space research, there are still new areas to be studied and new approaches to be tried.

Back to the future

● President Bush – both the son and the father – tried to do what President Kennedy did in the beginning of the 1960s, when he declared that the nation would go to the Moon. The dream of returning to the Moon and carrying on to Mars announced by Bush Senior in 1989 was crushed by a price tag of $450 billion. As to the dream of Bush Junior it is too early to say anything definite. The basic idea of going to Mars via the Moon is not too promising. It is more or less like going to the Antarctic via the Arctic.

In principle the Moon would be an ideal base for Martian research. Gravity on the Moon is much weaker than gravity on Earth, so it would be a lot easier to launch ships into space from there. If it were to yield all the benefits – and also the economic ones – the facilities required should already be there. But they are not. There is not that much sense in first returning to the Moon and establishing a base. No matter what the final destination in the Solar System would be, most of the energy will be consumed in getting from the surface of Earth into low Earth orbit. It does not matter that much where one continues from there. If the point of departure to Mars would be either Earth or the Moon, the latter has obvious advantages. But if the alternatives are to depart from Earth either to the Moon or Mars, it seems to be a waste of time, money, and energy to make a pit stop at the Moon.

However, that is exactly what the current plans call for. Initially, robotic probes reminiscent of the rovers currently roaming the surface of Mars would be sent to the Moon before 2010. Some 10 years later there would be the first manned flights to the Moon – about 50 years after the first *Apollo* landing. After establishing a Moon base the destination would be shifted to Mars, which is supposed to be reached at the end of the 2020s.

The first landing on the Moon happened only some 8 years after President Kennedy's famous "not because they are easy" speech.


NASA

Humankind may once be heading again for the Moon – and this time also for Mars. The American Ares rocket and Orion craft could pave the way for the next stage of the "conquest" of space.

Now it would take 15 years to get back there and a quarter of a century until the first flight to Mars. However, it is of no use to compare the current or any other space program with the *Apollo* project. In the 1960s the Cold War was at its hottest, and the Soviet Union had to be beaten no matter the costs – and they did not matter.

Nowadays there is no motive for going to Mars other than scientific research. It is by far a good enough motive, but unfortunately science has never carried much weight, unless there were political purposes as well. It is possible, though, that these purposes will emerge, what with both Europe and China aiming at Mars, and Russia contemplating it, too. The Americans are surely not too thrilled about the European or Russian rivalry, but perhaps the Chinese will be an even bigger threat. In the 1960s there was the fear that the Moon would turn red. Now the Red Planet might become redder still.

From the Moon race to Martian combat

Back to home. An artist's impression of the lift-off of a spacecraft from the surface of Mars.

● In 2001 the ESA launched the Aurora Program, whose goal is to send a manned flight to Mars in the early 2030s. Just like NASA, the Europeans plan to go first to the Moon and only after that to Mars.

The goal of the European Space Agency's Aurora program is a manned flight to Mars.


esa

In the mid-2010s there will be the first manned flights into Earth orbit and the Moon would be reached during the first half of the 2020s. However, ESA's program does not count the Moon as an actual way station, but more like a whistle-stop used to test the technology needed on future Mars flights and to practice working in the smaller gravity of another celestial body.

According to Russian authorities a manned flight to Mars could be feasible as early as at the end of the 2010s, if the financing were sorted out – even though officially their latest plan aims at the mid-2030s. Their mission would go along traditional lines. The Mars craft would be taken into space in parts and assembled in Earth orbit. A flight of 9 months would be followed by a research period of 3 months on the surface of the planet.

The Chinese performed their first manned space flight only in 2003, but plans for further undertakings were revealed already in the 1990s. Moon probes to be launched by 2010 would be followed by a manned flight to the surface of the Moon by 2020. The schedule for the flight to Mars has not yet been revealed, but it is reasonable to assume that the same kind of strategy will be used there: first unmanned probes, then a manned ship. Around 2030 Mars will be a crowded planet.

All men are equal . . .

● In addition to the technical problems accompanying a flight to Mars the Russians have been thinking about the difficulties caused by having humans aboard. To guarantee the welfare of the crew during a flight lasting a couple of years it would take more than just air, water, and food.

Surprisingly, one of the problems connected with a flight to Mars is considered to be – women. Anatoli Grigoryev, the director of an institute studying the medical and biological effects of space-flights said in the beginning of the 2000s that the presence of women would cause tensions and conflicts between the male cosmonauts, so the crew should consist solely of men. It seems that according to Grigorijev women should know their place even in the Space Age, without any concrete role in the most challenging project of all humankind. However, this idea could very well be

Geraldyn "Jerrie" Cobb *was the first of the Mercury 13, a group of women who underwent the same testing as the final group of Mercury astronauts. And that – unfortunately – was it . . .*

turned upside down. If the real problem is squabbling between men, perhaps the crew should consist solely of women.

Surprisingly enough, as an unofficial and secret part of Project Mercury, which sent the first Americans into space, there was a group of women called the *Mercury 13*. In 1961 they underwent the same physiological tests as the astronauts who eventually flew into space. The arguments behind the testing were that women are in general smaller and lighter than men, they require less oxygen than men, and – what was most important – they handle stress better than men. The members of *Mercury 13* proved themselves as good as the male candidates, but the social climate of those days was such that none of them ever made it to the actual training, not to mention into space.

But times do change. The first man in space was a man. What if the first man on Mars was a woman?

12

GREEN THUMBS OF THE RED PLANET

What if the nanotech reaction gets out of hand?

– Bruce Balfour: *The Forge of Mars* (2002)

Terraforming Mars, to change the planet into something more like Earth, has been one of the recurrent themes in science fiction ever since the early years of the 1950s. It was as early as 1946 that the Swiss-American astronomer Fritz Zwicky expressed his ideas on making the Solar System a more habitable place. In the case of Mars it would require changing the atmosphere – one way or another – so that the climate would warm up and the frozen water would melt. The Red Planet would become a place suitable for life, "a second Earth." In 1994 *New Scientist* magazine gave a simple recipe for terraforming Mars:

> First heat your planet by at least 60°C. Then use sunlight to remove carbon dioxide. Wait 100,000 years and add humans . . .

Step by step

● At the moment we do not possess the abilities to change a whole world – at least not in the way we want it. We do not even possess enough knowledge about Mars, so that we could begin changing it to suit our purposes. We have managed to upset the balance on our home planet, but it is something else to raise the temperature of a warm planet by a few degrees – which in itself is devastating

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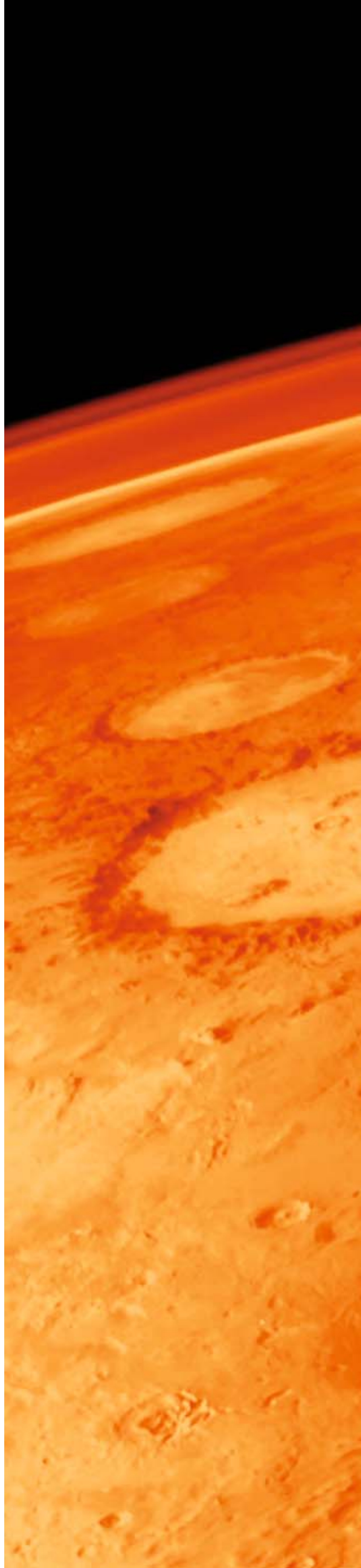
and, in the case of Earth, harmful enough – than to make a comfortable place out of frozen Mars surrounded by a thin atmosphere. However, this has not prevented the most eager enthusiasts from creating models on how to undertake such a monstrous effort, if we had the means, the money – and the time.

In the least lofty fantasies terraforming Mars would proceed in stages. First something should be done with the atmosphere. It has to be made thicker and its composition has to be changed, so that the temperature of the planet will begin to rise. Next the water contained in the polar caps and in the permafrost should be released to flow on the surface, so that Mars will not become – after a good start – a warm but arid place.

The rise in temperature will be of help, but not quick enough so that the third stage – an increase in the amount of oxygen in the atmosphere – would start in any reasonable time. But then again, what is "reasonable time?" Estimates are as numerous as the people who give them, but terraforming Mars would take at minimum hundreds, most probably thousands, of years. Not one of us would see the outcome of the project, perhaps not even the start of it. However, one day the Red Planet might turn green.

Environmental engineering on a planetary scale

● There are several alternatives for terraforming Mars, and these could be applied together or separately. The density of the atmosphere and thus the pressure could be increased by releasing carbon dioxide contained in the southern polar cap. This could be done with a large mirror situated in orbit around Mars reflecting sunlight to the pole. A mirror with a diameter of 250 km would cause the temperature in the southern polar areas to increase by 5°, which would suffice to initiate the sublimation of carbon dioxide ice into gas. The greenhouse effect would strengthen and the temperature would increase even more, which would speed up the release of carbon dioxide into the atmosphere. This in turn would accelerate the greenhouse effect, and so on; it would be a kind of climatic chain reaction.



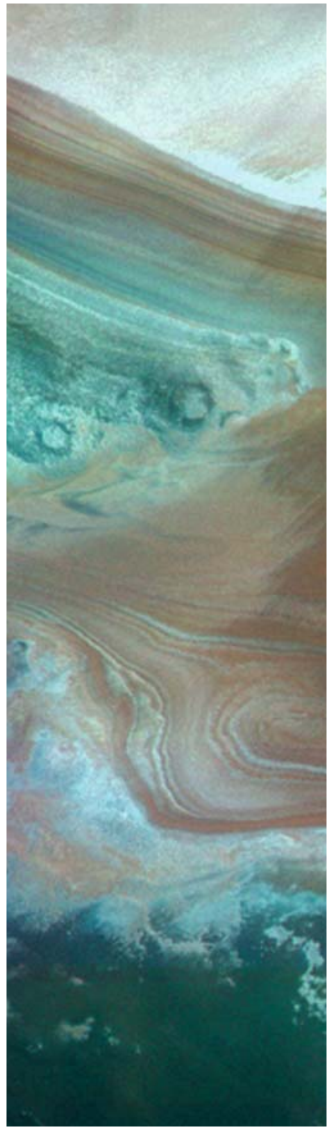
Mars has an atmosphere, but it is very thin and not suitable for humans.

Carbon dioxide could also be released from the ground with the aid of nanotechnology. The greenhouse effect could be accelerated more and more by developing small, self-replicating "nanites," which would spread into the carbonate strata of Mars and break it up into carbon and oxygen. At the moment it is still uncertain, though, whether there are any carbonate strata extensive enough – or any at all. So far none has been found.

In addition to carbon dioxide there are other greenhouse gases, such as ammonia. However, there is no ammonia on Mars, so it would have to be brought there from someplace else. The icy asteroids or "iceteroids" wandering in the outskirts of the Solar System are mainly made of frozen gases, and ammonia is thought to be one of them. It would only have to be transported to Mars.

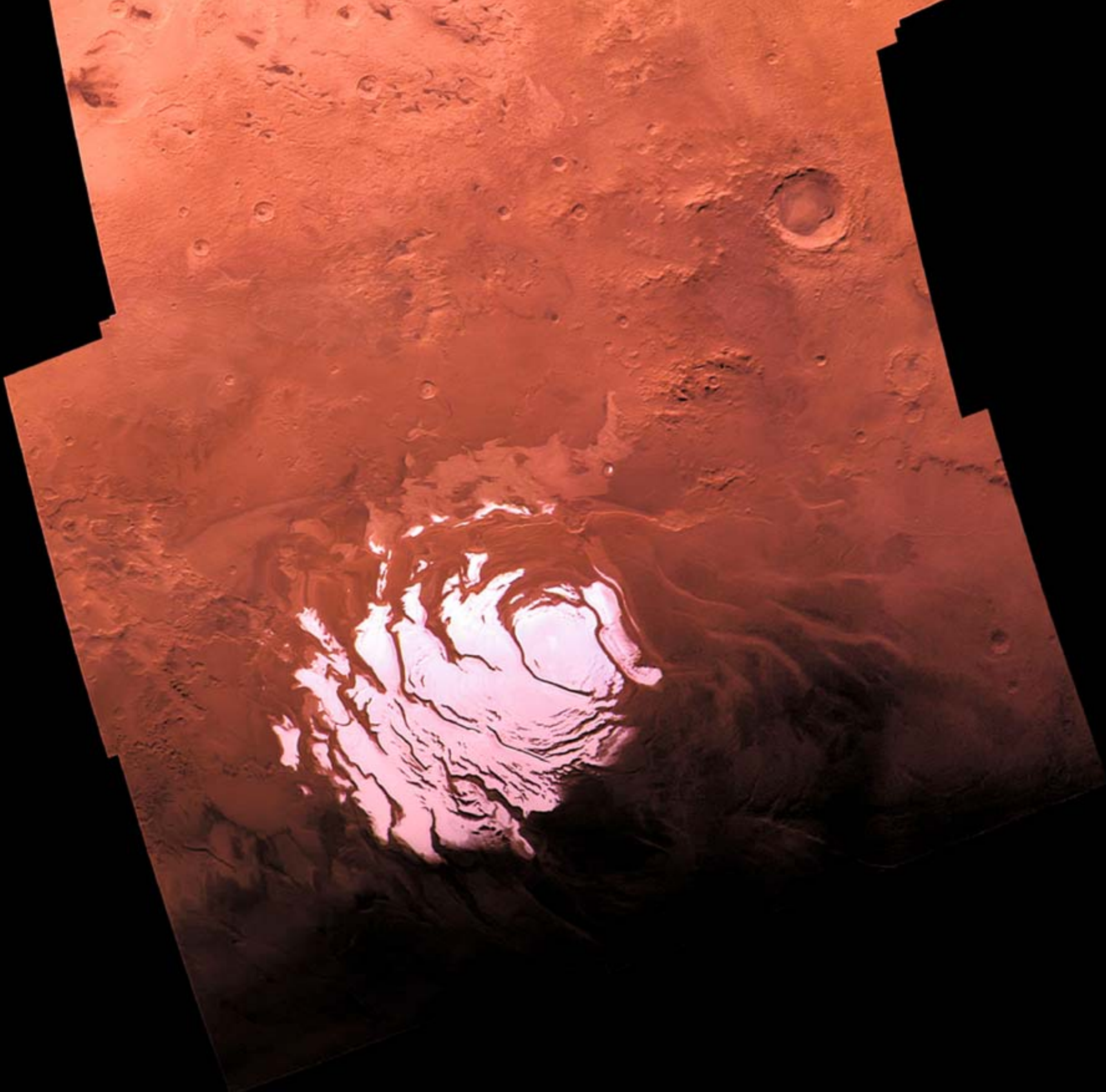
In fact, moving an asteroid from the outer reaches of the Solar System to the central regions would be easier than hauling them from the Asteroid Belt – although "easier" in this case is as relative a concept as possible. The orbit of a suitable asteroid could be altered with nuclear rockets, which would exploit the frozen gases of the asteroid. In some tens of years the package would arrive, ready to hit the surface of the Red Planet.

The amount of ammonia in an asteroid with a diameter of 3 km could be billions of metric tons, which would be enough to raise the temperature of Mars by several degrees. As a bonus, the heat released by the impact would melt a trillion metric tons of water. One asteroid would not be enough, though, since the ammonia would break up in the atmosphere of Mars in about 20 years. With some 40 asteroids the climate of Mars could be made temperate and at the same time the amount of liquid water would be enough to wrap the whole planet in a blanket some 30 cm thick.



The ingredients for terraforming Mars might be hidden in the ground layers of Mars.

The greenhouse effect on Mars could be accelerated also by releasing chlorofluorocarbons, or CFCs, which cause ozone depletion on Earth, into the atmosphere. To establish a production rate high enough to increase the temperature significantly – by at least 5° – would require a number of nuclear reactors and an even larger number of industrial plants with thousands of employees. The problem is that CFCs are not stable – which, from the point of view of



Carbon dioxide at the polar caps could be used to enforce the greenhouse effect on Mars.

Earth, is good news. At the moment it is not yet known, though, how fast they would break up in the atmosphere of Mars. Estimates range between a few days and some 200 years. Thus, the CFCs would have to be produced at a rate of at least 100,000 metric tons a year for them to have any real importance.

It is quite obvious that terraforming Mars is not something suitable for tinkerers. However, with the methods mentioned it would be possible to make the atmosphere of Mars thick enough for humans to survive on the surface without a pressure suit. Some kind of respiratory device would still be needed, because a mere increase in the density of the atmosphere and of the temperature would not yet make Martian "air" breathable. It would still almost completely lack oxygen.

More water and oxygen, please!

● Getting the water hidden in the Martian ground to go into continuous circulation, which would give life a chance, could be done with the same methods and more or less at the same time as increasing the greenhouse gases: with asteroid impacts and large mirrors in space. Increasing oxygen in the atmosphere would require some additional measures. In principle it could be done with genetically modified plants, which would survive in the harsher conditions of Mars and would release oxygen at a quicker pace.

Although plants use carbon dioxide in photosynthesis, advanced vegetation also requires nitrogen and some oxygen, which somehow would have to be released into the atmosphere. The solution could be – once again – mirrors situated in space. There are superoxides and nitrates in Martian soil that, with the help of warmth, would give up so much nitrogen and oxygen that the plants could be put to work. After that it would only take some thousand years, and Mars would be more or less a habitable planet.

Is there something missing?

● All the mammoth-like plans for terraforming Mars tend to have a fatal flaw; some important detail is forgotten. Permafrost could be melted with asteroid impacts, which would also release gases that would accelerate the greenhouse effect. However, asteroid impacts are extremely devastating, which can easily be deduced from the past mass extinctions in the history of life on Earth – though there were other factors, too, such as exceptionally active volcanism.

A big cosmic collision creates a vast cloud of dust, which effectively prevents the solar heat from reaching the surface. On the other hand even a normal amount of dust in the Martian sky warms up the atmosphere by absorbing solar radiation. But do we know for sure whether tricks of this magnitude would have the desired effect?

Another problem would be the CFCs, the release of which into the atmosphere of Mars would likewise strengthen the greenhouse

effect. However, at the same time they would destroy the ozone layer protecting the surface from the strong ultraviolet radiation. Mars has an almost nonexistent ozone layer to begin with, but terraforming would increase the amount of oxygen, which in turn would increase the amount of ozone – unless the CFCs would break it up as soon as it was formed.

This leads us to the next hardship: increasing the amount of oxygen in the atmosphere. Done mainly with vegetation it would be a kind of natural solution, since plants release oxygen at the same time as they bind up carbon dioxide. As a result of the photosynthesis of plants the amount of oxygen would increase, but the amount of carbon dioxide accelerating the greenhouse effect would decrease, and Mars would begin to cool down again. Unless . . . by releasing more CFCs the greenhouse effect would be given a new boost, which in turn would be harmful to the ozone layer. And so on.

Unless we had much more massive resources – technically and economically as well as intellectually – terraforming Mars will be just a dream. Perhaps it would be better to stay that way, because a process this complex would be extremely difficult to control. Nobody would be capable of predicting the exact outcome, but it could very well turn out to be something completely different from what it was supposed to be. Mars would not become a new home planet swarming with intelligent life but a dead world turned – if it were possible – even more dead.

The essential question, which is usually left unanswered – in case it was asked in the first place – is why? For what purpose should we tackle a whole planet and try to force it into a utopia-like condition unsuitable for it? We do not need any more room: all 6 billion Earthlings could easily fit on a circular piece of land with a radius of some 45 km, and it would not be more crowded than the subway during an average rush hour.

Even though we are already upsetting the ecosystem and climate of one planet, some people insist that we have a moral obligation to change Mars into a planet suitable for life. That is quite a strong state-

The conditions on Mars could be altered by steering asteroids to hit the planet.

CORGI BOOKS
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PUZZLE OF THE SPACE PYRAMIDS
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COOPER
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13

LITTLE GREEN PERSONS

They don't shed tears.

– C.S. Lewis: *Out of the Silent Planet* (1938)

Apart from Earth, Mars is the most populated planet in the universe – at least if the weight of science fiction as evidence is to be believed. Inspired by their imagination the penmen of Mars have colonized the Red Planet with living, dying, or dead civilizations with which humanity usually is on a collision course with devastating consequences. Interplanetary space is crammed with ships dashing between the two planets. Preparations for a major battle or a peaceful coexistence are made on both sides. We – after all – are not alone.

Victorian Mars

● Science fiction associated with Mars – or in general – can be said to have its real beginnings in the late nineteenth century, although it has been said that the first credible novel on space travel was published in 1744 by the German astronomer Eberhard Christian Kindermann, who also "found" a Martian satellite. The book has the lengthy title *Die geshwinde Reise auf dem Luft-schiff nach der obern Welt, welche jungsthin funf Personen angestellet* ("Swift Journey by Airship to the Upper World with Five Youngsters Onboard"), but in short it tells about a trip to Mars.

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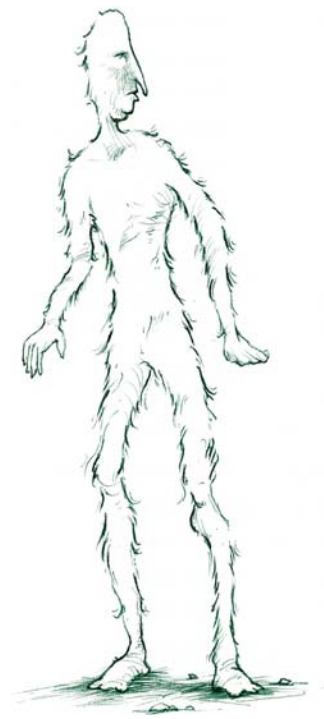
What kind of a world did the fantasists of those early years begin to populate? An excellent characterization is to be read on the opening pages of H.G. Wells' *War of the Worlds*, but how is it related with the reality of today?

> It must be, if the nebular hypothesis has any truth, older than our own world; and long before this earth ceased to be molten, life upon its surface must have begun its course.

Immanuel Kant's and Pierre Simon de Laplace's theory on the formation of the Solar System is correct when it comes to its basis, but the details are erroneous. All the planets were formed at the same time, not in succession according to their distances. Thus, Mars is not "older than our own world."

> The fact that it is scarcely one seventh of the volume of the earth must have accelerated its cooling to the temperature at which life could begin.

With this Wells almost had it right. Because of its smaller size Mars did cool down faster than Earth, but it has continued to do so. There is just a hint left of past volcanism, so the interior of the planet is most probably almost completely solidified. The lack of a magnetic field also points to this, giving free access for the harmful cosmic radiation to reach the surface of the planet.



> It has air and water and all that is necessary for the support of animated existence.

There has been air and water on Mars all right, but later on the air diminished and the water froze. Besides that there are lots of things on the surface of Mars preventing the continuation of life, if it ever got started there.

The broad spectrum of Martian science fiction is no coincidence, but not as evident as it seems to be from our vantage point in the twenty-first century. One of the first more or less modern science fiction stories was Achille Eyraud's *Voyage to Venus*, published in 1865. In those days people were more interested in our closest planetary neighbor than in Mars. Since Venus is about the same size as Earth, it was thought to be similar in many other ways to our home planet, too, like a planetary twin. Nevertheless, Venus

One of the classics of Martian science fiction is C.S. Lewis' Out of the Silent Planet *(1938). The world and especially its inhabitants depicted in the novel are completely different from the invaders in H.G. Wells'* The War of the Worlds: *friendly, helpful, and – as becomes evident with the unfolding story – more humane than most humans. The Red Planet is home to the Pfifltrigg (upper left), Sorn (lower left), and Hross (above).*

was forgotten in no time after the planet-wide network of canals was found on the surface of Mars in 1877. The interest in Venus based on mere guesswork was replaced with a giddiness in Mars founded on – as they were imagined to be – solid facts. Venus just might be inhabited, but Mars was populated for sure!

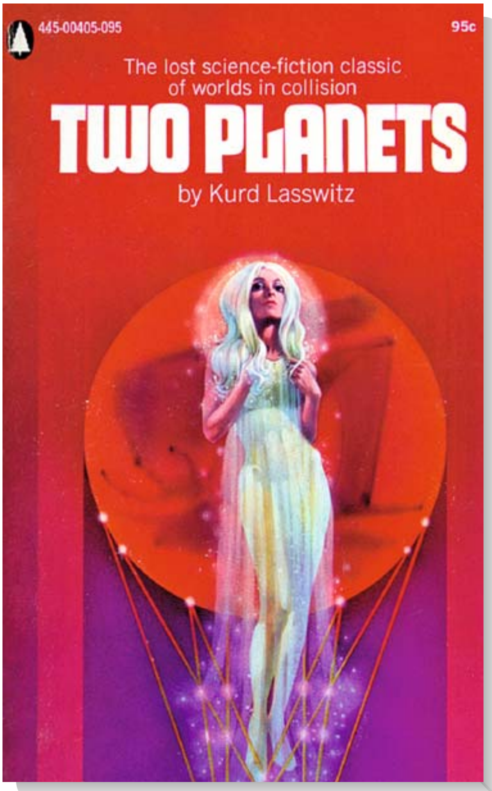
Fantasies or realities?

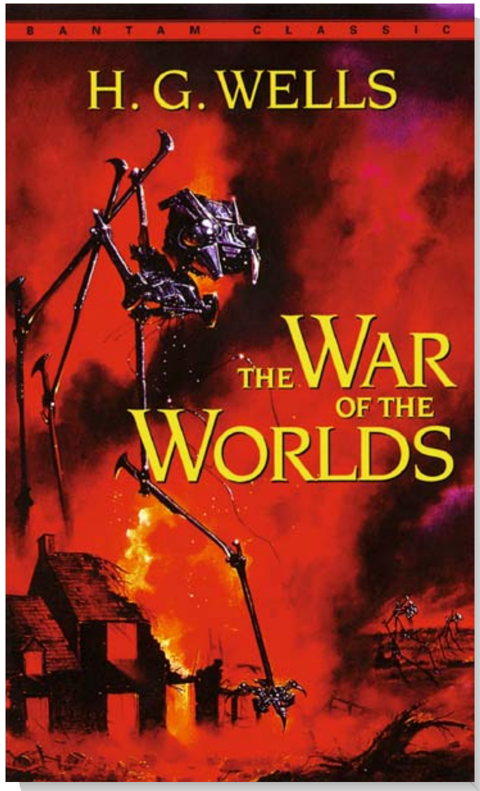
● Science fiction is by nature often predictive. The stories make predictions on technological innovations, new kinds of social structures, the evolution of humans as a species. But similarly science fiction can drag behind. It reflects prevailing conditions, beliefs, and facts. The scientific study of Mars has been kind of an oscillation, with the opposite ends being a living and a dead world.

Science fiction has followed this swinging. Since the end of the nineteenth century Mars was generally considered to be an inhabited planet. Even after conditions on Mars were revealed to be very harsh, for a long time it was thought to harbor primitive life.

The Mars of science fiction has been very similar. Since the 1910s Edgar Rice Burroughs' Mars series recounted the struggles of John Carter with the creatures living on Barsoom, which was riddled with dry deserts. Burroughs' heritage in depicting interplanetary adventures was cherished as early as the 1930s by Otis Adelbert Kline, whose sword-men saved the Martian civilization; since the 1940s by Leigh Brackett (later showing her versatility also in writing screenplays for movies like *Rio Bravo*, *Hatari!*, *The Long Goodbye,* and *The Empire Strikes Back*), whose leading character, Eric John Stark, gets to witness the clash of an ancient Martian civilization with a Terran empire; in the 1950s by John Russell Fearn, whose "Famous Mars Quartet" was an unscrupulous attempt to make money in the wake of Burroughs; and as late as the 1960s Michael Moorcock's – writing under the pseudonym Edward P. Bradbury – view on the Red Planet, which was very similar to that of his predecessors.

Science fiction reflects itself, too. New writers are influenced by older stories and refine the ideas further. Even the creator of the Mars series had his model: Edwin Lester Arnold. In Arnold's novel *Lieut. Gulliver Jones: His Vacation* (1905), a Navy officer ends up on Mars on a flying carpet, and in the course of his adventures there he managed to rescue a Martian princess. Arnold's story in turn has





references to earlier literature in the name of the leading character – in addition to the fact that Gustavus W. Pope had sent an officer of the U.S. Navy to rescue a Martian princess as early as 1894 in his novel with the unforgettable title *Romances of the Planets, No. 1: Journey to Mars, the Wonderful World: Its Beauty and Splendor: Its Mighty Races and Kingdoms: Its Final Doom.*

Classics of war and peace

● The first science fiction novel situated on Mars is considered to be Percy Greg's *Across the Zodiac: The Story of a Wrecked Record,* published in 1880. The book is an exhaustingly long and, to be honest, boring account of a civil war on the Red Planet. If the future of Martian science fiction had depended on this work, it would have been very gloomy – and short.

Another lesser known pioneer of science fiction associated with Mars is Kurd Lasswitz, who published a novel *Auf Zwei Planeten*

("Two Planets") in 1897. In the best Lowellian fashion he described the Martians as a race much older, much more advanced and much more intelligent than ours. However, they came here not to conquer but to share their vast knowledge with their siblings on Earth, wishing to have in return only breathable air and solar energy. Traditionally this kind of Samaritanism has never augured anything good, and it all comes down to war and tyranny – with a happy ending, of course.

Herbert George Wells, allegedly the "father of science fiction," might have been influenced by Lasswitz's book, even though it wasn't published in English until 1971. Nevertheless, Wells' significance in the field of science fiction is indisputable. In the German-speaking countries Lasswitz's novel has been regarded a classic comparable to Wells' novels. It awoke Wernher von Braun's, the developer of the Saturn rocket, interest in spaceflights – but the language barrier prevented it from reaching an esteem equal to Wells' works.

Thus, the most popular Martian story is H.G. Wells' *War of the Worlds*, published in serial form in *Cosmopolitan* magazine in 1897 – not *that* Cosmopolitan – and as a book the next year. It begins with astronomers observing strange flashes on Mars, and before they get to know anything conclusive the vanguards of nasty Martians invade the British Isles with destructive consequences. Obviously Wells' attitude towards the Martians was exactly the opposite to Lasswitz.'

The story was continued in Garrett P. Serviss' novel *Edison's Conquest of Mars*, which was published the same year. This time it was made known to the Martians what will come out of an invasion of a planet with a Great Power like the United States of America. The title refers to the space fleet attacking Mars, the armory of which was developed by Thomas Alva Edison himself.

Science fiction writers have every now and then returned to the world created by Wells. George H. Smith published the novel *The Second War of the Worlds* (1976), a sort of parody situated in a parallel universe with characters such as "Mr H" and "Dr W" from Baker Street; Christopher Priest published the novel *The Space Machine* (1976), which tells about the background of Martian invasion; and Eric Brown authored the short story "Ulla, Ulla" (2002), which reveals how Wells managed to get the detailed information on the Martian vessels and equipment.

Reality radio

● A large part of the fame of the *War of the Worlds* is due to Orson Welles, who created a kind of "reality radio" program based on the novel on the CBS channel in October 1938. The radio play, with fake news reports and interviews of eyewitnesses, caused a nationwide panic. Hundreds of thousands of people hid themselves or fled their homes. Almost the whole nation was convinced that the United States had really been attacked by Martians.

Welles' Halloween prank has been regarded ever since as a textbook example of mass hysteria. But is it possible that a single radio program – which, before and during the broadcast, was emphasized to be fiction – could make large crowds go off the rails? In fact, millions of people were not horrified out of their minds, nor were thousands or even hundreds of people hurt in the chaos. For example, the *Toronto Star* reported the next day that

> One woman said she had collided with furniture in her haste to get into the street, blackening both her eyes.

The real damage caused by the radio show was actually minimal. The CBS channel was sued, but the case never made it to the courtroom.

Only for men

● In addition to their motifs, several of the Martian stories written in the 1920s and 1930s are interesting because of their archaic attitudes. Something extremely naïve can be found in John Wyndham's (alias John Beynon) novel *Stowaway to Mars* (1935), with its strong faith in technology. In the 1930s spaceflights were still very straightforward. It took more than just falling asleep or standing in the middle of a field with arms spread out, but it was almost that simple to get to Mars: build a rocket and launch it into space.

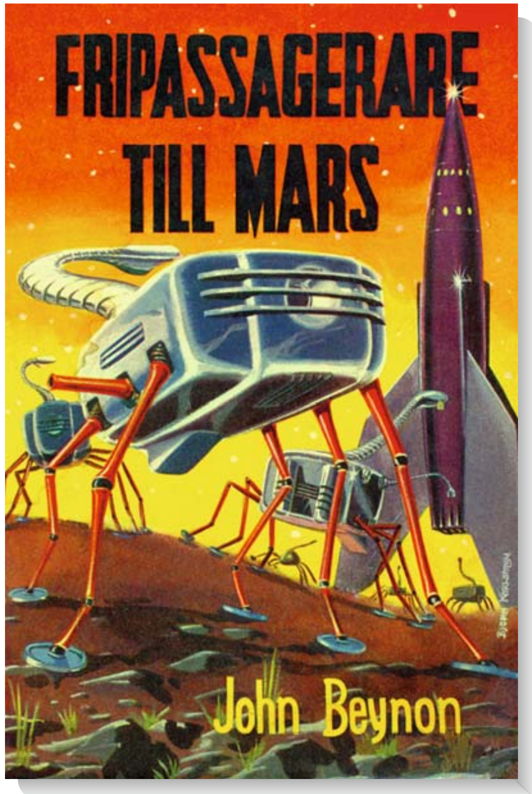
In Wyndham's novel the spur for the trip was a large sum of money, which would be awarded to the first crew to fly to Mars and back, much the same way as in real life with the first trans-Atlantic solo flight in the 1920s, or the first private spaceflight a couple of years ago. Naturally the winners were fellow countrymen of the British author.

Eando Binder's *Puzzle of the Space Pyramids* (1937) is an equally typical product of the time: touchingly childish, excessively optimistic and an honestly romantic adventure. The strange first name

COMIC MARTIANS

● Mars is the home of Marvin the Martian or Commander X-2, one of the members of *Looney Tunes* family created by Warner Bros studios. The character was created in 1948 by the legendary animator Chuck Jones, the father of Bugs Bunny and Duffy Duck. The small Martian with a Roman helmet was determined to blow up Earth because it obscured his view of Venus. Marvin the Martian was aided with a green space dog called Commander K-9, a snowman Hugo and an instant army of 10,000 Martians ("just add the water . . . ").

In the world of comics "Martian Manhunter" J'onn J'onzz was a menace to all the bad guys – just like his close friend Superman. J'onn J'onzz was "born" in 1955, when a story in *Detective Comics* written by Joe Samachson and drawn by Joe Certa told about Doctor Erdel teleporting the green superhero from Mars to Earth to fight the villains.

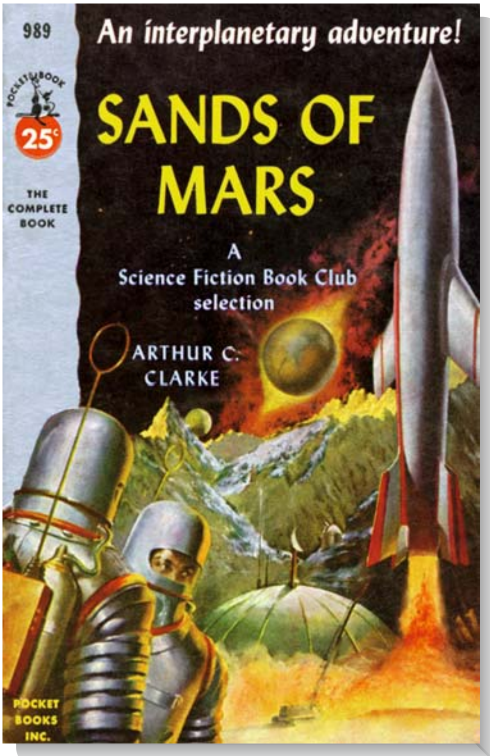


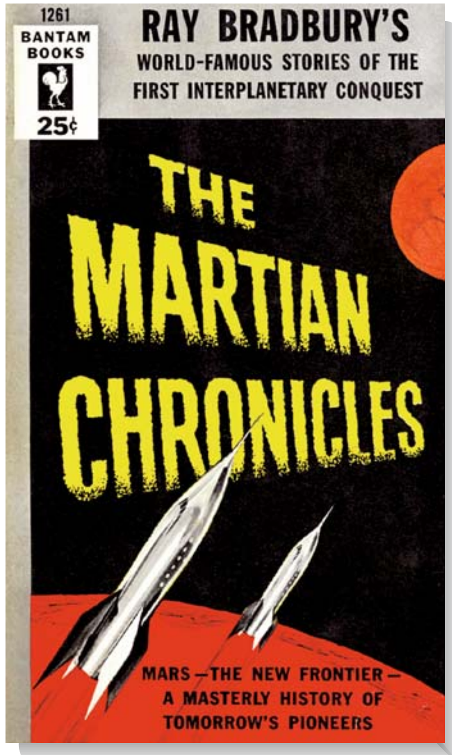
of the author conceals the Binder brothers Earl and Otto, "E and O." The tone of the novel is also chauvinistic without any scruples, which was not that odd in those days. After one of the crew members turns out to be a woman, she has to take care of the cleaning up, the washing of the dishes, and the preparing of the food – not to mention baking "coffee-cakes" – for the rest of the trip.

In addition to Mars the crew travels to Venus, Mercury, Jupiter, and two of Jupiter's satellites, Ganymede and Callisto. Flying is a bit too technical a term to use for how they got there, since moving around in interplanetary space does not seem to be a much more amazing feat than sailing on the oceans. The astronauts get stuck in almost every place they land on, but still their biggest worry is that they do not have any music to listen to as a pastime!

From B to C

Gradually the romantic sword-man and princess tales and space adventures accompanying them in the first half of the twentieth





century gave way to more realistic stories. These have humans struggling not so much with the Martians but with Mars and often with themselves, too. One of the most famous and perhaps most significant works situated on Mars is Ray Bradbury's *The Martian Chronicles.* The book came out in 1950, but some of the stories had been published in magazines already by the end of the 1940s. In those days it was easy to think of Mars as a place where people could live without any technical aids. The air was thin, the wind was dry and the sand was dusty, but the conditions were essentially more or less similar to those in deserts or highlands.

In light of the current knowledge, *The Martian Chronicles* is an awkward depiction of a future we have caught up with, but 50 years ago the outlook was very different. It was only a few years since the end of the war, and humankind had collective nightmares on mushroom clouds engulfing our planet. The first flight to space was still more than 10 years in the future.

It is futile to evaluate science fiction, whether old or new, based on its reality, though. Between the lines, science fiction – just like literature in general – recounts something fundamental about us as humans. The central idea of *The Martian Chronicles* is crystallized in a short story entitled *Interim*, in which it is February 2003:

> It was as if, in many ways, a great earthquake had shaken loose the roots and cellars of an Iowa town, and then, in an instant, a whirlwind twister of Oz-like proportions had carried the entire town off to Mars to set it down without a bump . . .

The almost instant "terraforming" could be regarded as a manifestation of the author's deep pessimism on the future of humanity. No matter where we go, we carry with us our deep-seated habits, customs, and foolishness. We will never adapt to the new environment, but we will try to make the environment adapt to us – no matter what.

The Martians of Sands of Mars *are kangaroo-like marsupials like Squeak, adapted to the dry climate. They get the oxygen they need by eating the "air plant"* Oxyfera.

Arthur C. Clarke's novel *The Sands of Mars* is comparable to Bradbury's work, since it was published in 1951, only a year later than *The Martian Chronicles.* In Clarke's story the Red Planet has already been "conquered," and there are as many as two cities built under protective domes. Clarke's Mars is not inhabited by creatures like Bradbury's ethereal beings, glowing in the colors of precious metals, but kangaroo-like animals with intelligence close to that of dogs.

The Sands of Mars is not great literature, but it is one of the first science fiction novels to have terraforming Mars as one of its themes. *Oxyfera*, an "air plant" found on the surface of the planet is capable of releasing oxygen contained in the minerals of the soil. An even more crucial role is given to Phobos, the larger satellite of Mars. It is ignited to become a "meson bomb" which shines for about a thousand years. It gives light and heat to the surface of the planet, creating more favorable conditions for the plants. Characteristic of Clarke's faith in humankind's ability to control the universe, the atmosphere of Mars would become so dense and oxygen-rich in only 50 years that no respiratory devices or special overalls would be needed anymore.

While Bradbury's work is a kind of meditating morality, Clarke's novel is hard-boiled science fiction, a straightforward narrative of the conquest of space with the aid of technology. Both of them have their basis in the same and similarly scanty knowledge of the time on the conditions of the Red Planet. But it is still justified to ask whether the images of Mars created by the books are further apart from the reality or each other.

The Red Planet on the silver screen

The history of science fiction films situated on Mars is nearly as long as that of science fiction stories. The first Mars movie was *A Trip to Mars*, a short film with a length of four minutes produced in 1910 by Thomas Alva Edison. A nutty professor, later to become an archetype in science fiction, invents a powder that neutralizes gravity, and accidentally it flings him all the way to Mars. According to the film – and the general belief of those days – there is life on Mars despite the fatal blows dealt to the canal theories.

After that the route to Mars and back has been traveled countless of times at a speed of 24 frames per second. Some of the early movies were especially straightforward adventures in the spirit of Edgar Rice Burroughs. The Red Planet has been visited as well as by Flash Gordon (*Flash Gordon's Trip to Mars*, 1938), Abbott and Costello (*Abbott & Costello Go to Mars*, 1953), and Robinson Crusoe (*Robinson Crusoe on Mars*, 1964). Sometimes the humor in the movies is deliberate, but often it is also unintentional, brought about by the passage of time. The worst damage is suffered by special effects, which usually reveal the decade in which the film was made.

Time takes it toll also on movies that aim at depicting realistically the Red Planet and the survival of humans in the conditions on its surface. The trouble is that the "realism" is always based on the knowledge of both the destination and how to get there at the given time. The information it is based on might by tomorrow or at latest in a few years time be obsolete. For example, *Conquest of Space* (1955) was based on the dreams of Wernher von Braun soon found to be much more difficult to realize than they were thought to be. And later on it became evident that the "conquest" promised by the title of the movie was an exaggeration – as it still is.

On the other hand, realism will not save a movie if the movie in other areas is weak. A typical example is *Mission to Mars* (2000) with a cast of famous actors and actresses. Brian de Palma, the director of the movie, hired a distinguished

Mars scientist Matt Colombek as the scientific advisor. The planet looks good in the film, but that is nearly all that does. Sometimes the people behind a movie are not too proud of their accomplishment. *Battle Beyond the Sun* (1963) is credited to Thomas Colchart, but actually it was directed by Roger Corman and Francis Ford Coppola.

Capricorn One (1978) could be said to be hyper-realistic. In the film the crew is trying to reach Mars with spacecraft inherited from the *Apollo* project. In reality the astronauts are firmly on the ground, and the television transmissions from "the surface of Mars" are shot in a studio – much the same way some people still claim the flights to the Moon were shot in the 1960s and 1970s.

Several science fiction films related to Mars are pure "marsploitation." Mars is just a metaphor or a lure in the title of a movie. The story could just as well be situated on some other planet – even on Earth. *Aelita* (1924), an early Soviet propaganda film, had the good news of communism taken to our neighboring planet, which was mired in the chains of a capitalistic dictatorship. In the same way Mars and its aggressive inhabitants get to symbolize fear of communism in many American science fiction b-movies made during the Cold War. *Invasion from Mars* (1953) led the way for various "invasion movies" such as *Missile Monsters* (1958), *Angry Red Planet* (1959), and *The Day Mars Invaded Earth* (1962). Of the more recent films John Carpenter's *Ghosts of Mars* (2000) is most probably situated on the Red Planet only because of Mars had gained renewed popularity due to the successful probes a few years earlier.

Several of the old Mars movies have been re-filmed. In many cases these are much worse than the original, perhaps partly because – as the saying goes – memories grow sweeter with time. Suspense and special effects once regarded as something really special lose most of their fascination in remakes.

Some of the more recent remakes are *Invaders from Mars* (1986), *Mars Attacks!* (1996), based on popular chewing gum cards of the 1950s, *My Favorite Martian* (1999) updating the television series broadcast from 1963 to 1966, and *Santa Claus Conquers the Martians* (2002), with the original made in 1964.

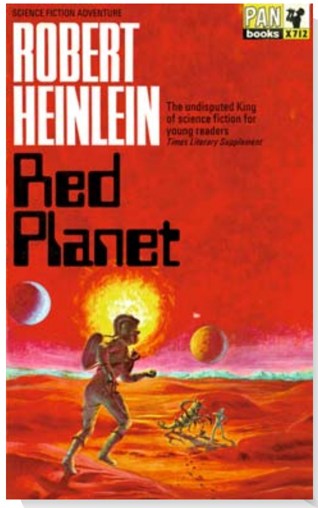
There is no sign that interest in Mars and in remakes of Mars movies will fade. Quite the contrary. In 2005 a total of three – though very different – versions of *War of the Worlds* premiered, which was filmed for the first time in 1953.

Teen planet

● Mars has been the stage for numerous novels intended for youths, with an emphasis on an excitement and adventure. The characters are often as thin as paper, and the logic of the pivotal events not always watertight.

In Robert A. Heinlein's novel *Red Planet* (1949) the colonists of Mars migrate with the seasons from one hemisphere to the other – except for the pupils of the boarding school in Syrtis Minor at the equator of the planet. Jim and Frank, the heroes of the story, learn accidentally about "a great conspiracy." The Company administering the colony is planning to put an end to the continuous and expensive traveling between the hemispheres and force the colonists to settle themselves. With the aid of enigmatic Martians the boys manage to inform the inhabitants of the colony in time and the denouement is – as easily could be anticipated – happy for the good ones, not so happy for the bad ones.

James Blish's *Welcome to Mars* (1967) is one of the last, if not the last, post-Lowellian novel. It was written just before the *Mariner 4* mission to Mars, and the book came into print just as the probe was sent on its way. Just like Heinlein's novel, *Welcome to Mars* is an adventurous youth book. Dolph Haertel, a kind of proto-nerd, finds out how to nullify gravity and secretly leaves for the Red Planet in a hut he had built in a tree. This "MacGyver of Mars" is handyman enough to build useful gadgets like an air pump, a radio transmitter, and a "wine-press" to extract nutritious fluid from the Martian vegetation. The novel could, of course, be read as a parody of all those space operas in which the marooned heroes get out of insurmountable dangers without a scratch.



One of the characters in Red Planet *is the spherical "bouncer" Willis, who is able to grow all kinds of sense and prehensile projections. It can also repeat everything it hears, like an authentic recording.*

Metaphorical Mars

● The space probes changed both the scientific reality and the realm of science fiction. Almost the last hope of life was ruined with the results of the *Viking* landers; most scientists regarded them as conclusive evidence that there is no life on Mars. In addition to Martian research this piece of information partly paralyzed Martian science fiction, too. Even though science fiction is not true, it is often an extrapolation of facts, stretching the truth – as Groucho

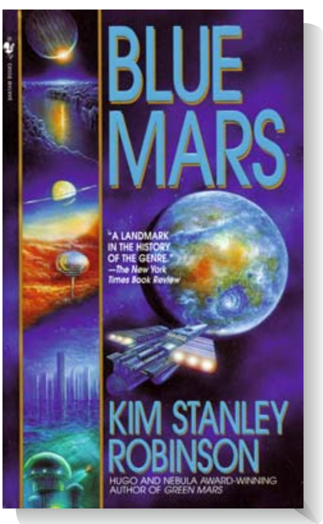
Marx put it in his quasi-autobiography *Groucho and Me* – "from here to Finland." However, a dead planet is a dead planet, not nearly as fascinating as a place with even the slightest possibility for life.

That is why Mars has often been a metaphor, a familiar yet distant enough background against which different social dramas could be played out. In several science fiction stories situated on Mars or associated with it the central theme is a utopia built on a new world, a new start for the migrants. The basis of the utopia could be religious, economical, or political. However, in many cases the color of Mars has had a certain influence on the political system adopted in the utopia. Unfortunately the result is often obvious, and in fact it is not essential where the story is situated but who the leading characters are – imperfect humans.

A Martian Earth

● In science fiction anything is possible, even resurrection. A new direction for the fantasies was given by the megalomaniac plans to terraform Mars, make it more Earth, with a warmer and wetter climate. Since the 1980s the methods proposed have been more realistic than the meson bombs of earlier times.

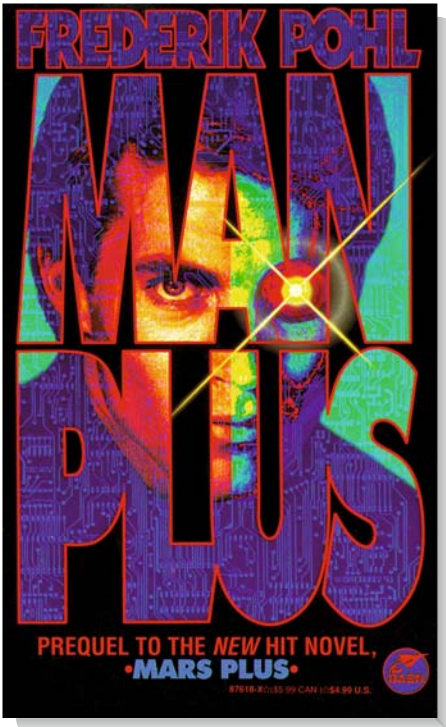
One of the cornerstones – if not brick stones – of contemporary Martian science fiction is Kim Stanley Robinson's massive trilogy *Red Mars, Green Mars, Blue Mars* (1993, 1995, 1997). An expedition with a hundred members – which, despite strict requirements and the careful screening of applicants, seems to be an unbelievable bunch of paranoids and neurotics – travels to Mars and begins a really long-term project. Their goal is to turn the rusty planet at first into the green of life and finally the blue of water.



There is a strong ethical aspect to the trilogy: Do we have a right to tamper with another planet without knowing with certainty what we are doing? The dispute is focused on two blocs: "reds," who maintain that Mars should be left as it is, and "greens," who advocate changing the planet into a habitable world that humanity would then be able to move to after it had destroyed its planet of origin.

Of Mars and men

● There are several Martian stories in which attempts to change the Red Planet are given up and the new subjects are humans, who are



"marsformed" so that they are capable of surviving in the extremely thin atmosphere and freezing cold temperatures of the Red Planet.

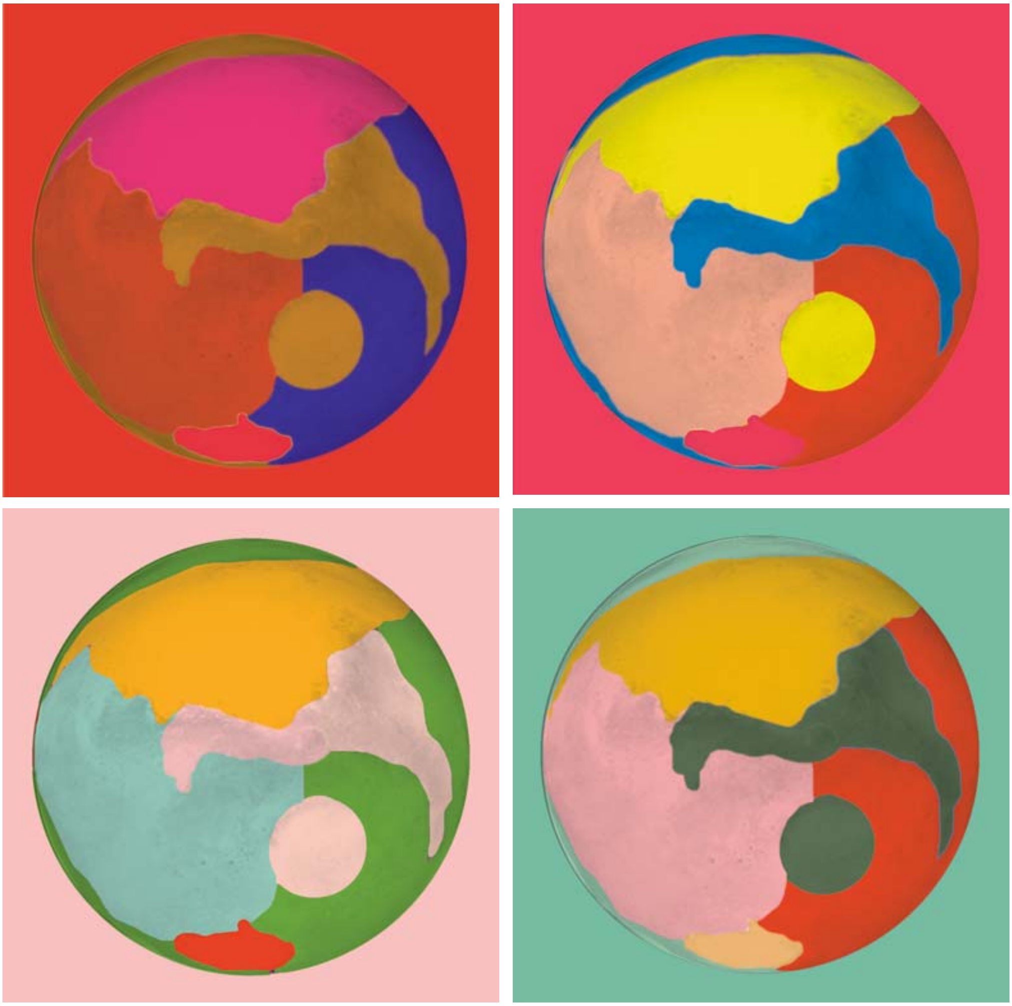
One of the classics in this genre is Frederik Pohl's *Man Plus* (1976). Roger Torroway is turned into a cyborg, a combination of man and machine. The goal is to create a creature that could operate in the harsh environment of Mars without any external aids. Torroway is altered both inside and out so much that finally all that is left of the original human being is the mind – and even that can be controlled by the artificial intelligence of the artificial body by shutting away the last shred of humanity into an isolation chamber with no connection to the outer world. Pohl's novel could be regarded as some kind of proto-cyberpunk, a genre probing the relationship between human and machine, and gaining more popularity in science fiction only in the 1980s.

In Kevin J. Anderson's novel *Climbing Olympus* (1994) the people play it safe and alter both the living and nonliving: in the short term human, in the longer term Mars. The scientists of a remote

One of the classics of Finnish science fiction – with an obvious influence from Flash Gordon – is a comic strip Maan mies Marsissa *("Earthman on Mars"). This was originally published in* Seikkailujen maailma *("World of Adventures") magazine as a serial at the beginning of 1940s and as an album in 1947.*

Siberian research institute have at first created *adins*, "first ones," and after that *dvas*, "second ones." The rest of the world is let in on the secret only after the adins land on Mars. Terraforming the planet was already on the way, but the conditions would be suitable for humans – or "ordinary humans" – only in the distant future. Adins did not have any difficulties in working on the Red Planet. Problems arose only when the dvas and ordinary humans arrived and slowly began changing Mars. Dvas survived with less radical alterations than adins, but ordinary humans still needed spacesuits and pressurized habitats. But did they need adins anymore? The ever warming and thickening atmosphere made the adins as uncomfortable as the presence of "former" fellow species, so they had to climb higher and higher up – thus the title.

What is the message here? Is it that if humans one day really do encounter another intelligent civilization, will the consequences be disastrous, as long as we are unable to encounter ourselves? Or is it that if there is intelligent life in the universe, is it to be found only out there, not here on Earth?



14

MARS ROCKS!

The most beautiful planet in the world.

– Kim Stanley Robinson: *A Martian Romance* (1999)

> A small silvery rover makes it way cautiously on the red sand of Mars. A gentle breeze plays with the dust raised by the tiny wheels. The tracks left by the rover go way back towards the salmon pink horizon. A wheeled robot the size of a microwave oven gazes confidently ahead and relays yet another image to the ground control.

Is this a scene in a science documentary on Mars exploration? Could be, but the correct answer is no. It is a commercial advertising Hewlett-Packard's ink jet printers.

Marketplace Mars

● Mars is so deeply seated in the collective unconscious introduced in the early twentieth century by the Swiss psychiatrist Carl Jung that it can be used to sell almost anything. For a long time the Red Planet has not been the private property of scientists, and likewise amateur astronomers have been compelled to give up their privileges on Mars. Our neighboring world has become the common cultural heritage of all people. It is a planet known by everyone, and everyone has some kind of mental image of Mars. It is not just a point of light to be seen in the sky if one only happens to know its exact location. It is a world we all are familiar with – one way or another.

M. Hotakainen, *Mars*, DOI: 10.1007/978-0-387-76507-5_14,
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Using the pretense of Mars the most natural things to sell are telescopes, binoculars, and other equipment related to sky gazing. Before the perihelic opposition of 2003, astronomy magazines were filled with ads using Mars as an eye catcher and its record-breaking short distance from Earth as literary bait. But this continued after the opposition, too. For example, Canon advertised its image stabilizer binoculars and digital SLR cameras in the December 2004 issue of *Sky & Telescope* magazine with the catchphrase "Mars hadn't been this close to Earth in 60,000 years. Yet it's amazing how many people missed it." Talking about hindsight . . .

This ad of Hewlett-Packard explains why the Martians have not yet been found.

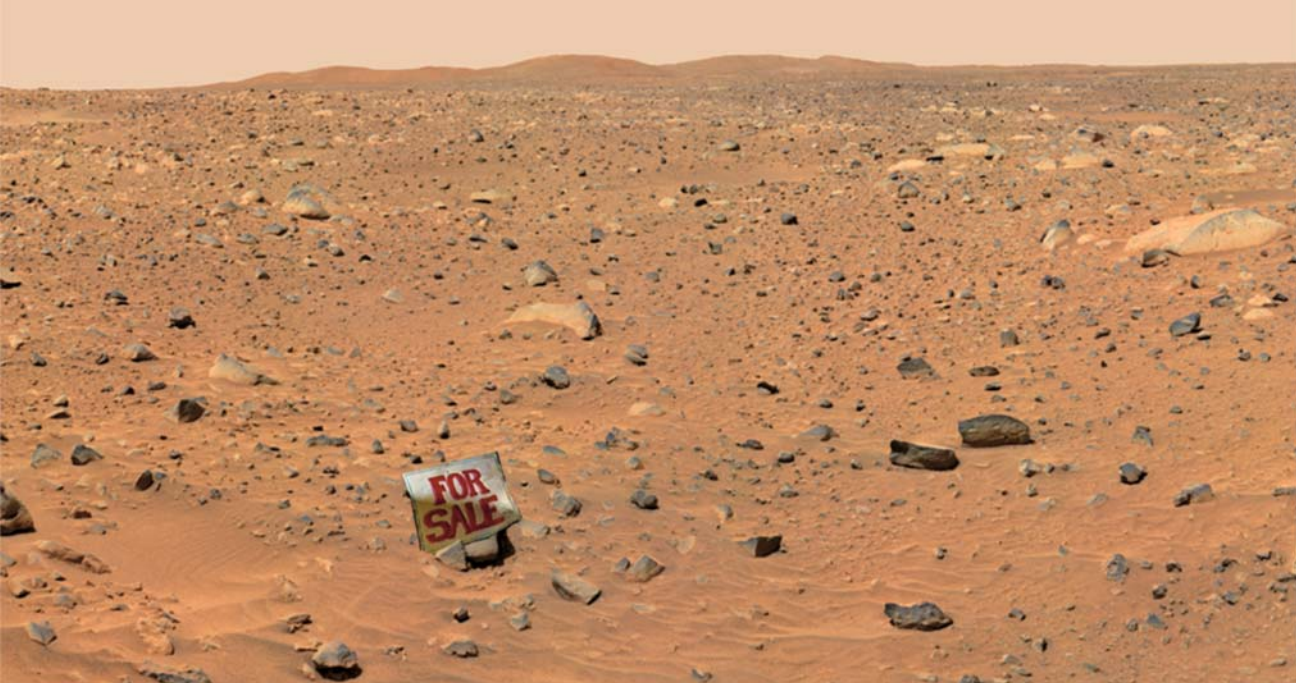
Martian real estate

Anyone interested in buying land on Mars has been able to do so for the past 25 years, and at a very low price. The American Dennis Hope thought in the early 1980s that he had found a loophole in the international treaty controlling the exploitation of outer space. According to Hope the treaty only limits the property rights of nations, not those of private persons. He declared unilateral ownership of all the planets and their satellites, founded a company called Lunar Embassy, and began to make money.

A piece of land of 4,000 m^2 on Mars as well as on the Moon and Venus is for sale for less than $20 ($19.99), on top of which there is Martian tax ($1.51) – whatever the criteria for that might be – and the postage and handling of the documents ($10.00). It is not possible to choose the location of the lot, but the exact site will be marked on a map enclosed with the sales contract.

Lunar Embassy has several branch offices around the world and authorized dealers, too. For example, MoonEstates.com is the only British company licensed by Lunar Embassy to carry on with the cosmic real estate business. For wealthier customers they offer Martian plantations of 10 acres. MoonEstates.com only sells land on our three closest neighbors, but Lunar Embassy also has Mercury and Jupiter's satellite Io on their list.

On the website of MoonEstates.com, Francis Williams, the Lunar Ambassador of Great Britain, greets potential customers. He says the company has purchased the land from Hope in "good faith" and is selling it to prospective buyers in equally "good faith."



Would you like to buy some Martian property? Too bad, because no one has a right to sell it.

The success of the business depends naturally on the "good faith" of the customers. And there seems to be quite enough of that sort. Through its branch offices and authorized dealers such as MoonEstates.com, Lunar Embassy has sold Martian sand to millions of happy proprietors, among them more than a thousand companies apparently aiming for tax evasion by moving their head offices – at least on paper – to another celestial body.

This is not the first time someone is asking for a good price for something not in his or her possession – and not the last. And this certainly is not the first time someone is willing to pay that price – and most probably not the last, either.

Children's playground

● The year 1999, the dark year of Martian research, marked the loss of two probes within a few weeks. Shortly after that the models of those probes, the *Mars Climate Orbiter* and the *Mars Polar Lander,* disappeared from the shelves of toy stores. The American company Mattel, which has the exclusive right to manufacture scale models of NASA's probes, hit the jackpot in 1997 by introducing a Hot Wheels 'Sojourner Mars Rover' Action Pack set with both the *Pathfinder* lander and the tiny rover.

The new 'JPL Returns to Mars!' Action Pack consisted of detailed models of both *Climate Orbiter* and *Polar Lander* with the

Oskari Hellman's series of photographs Matkalla Marsiin *("On a Way to Mars") won the third prize in the Advertisement Photograph of the Year competition in 2005.*

Deep Space 2 microprobes. The set was launched only a week before the landing of the *Polar Lander,* but after the probe was lost, Mattel withdrew it from the stores. Sudden action and a limited quantity of only 10,000 to begin with guaranteed that the models became a wanted item. Only a week after the loss of the *Polar Lander* the price of the set on internet auction sites was ten times the original.

The Danish company Lego in turn produced two kits, *Mission to Mars* and *Mars Exploration* – out of stock for years now – in cooperation with the Discovery science channel. The latter was a large-scale model of the Spirit/Opportunity rover, the former a smaller version of the same rover with the *2001 Mars Odyssey* probe and Delta launch vehicle. Prior to that Lego had a *Life on Mars* series with Lego people terraforming Mars together with Martians of different colors, not just the traditional green.

In the world of Lego Mars has been terraformed for a long time.

Lego is involved in the real rovers, too. Both Spirit and Opportunity carry two Lego Astrobots with them, Biff Starling and Sandy Moondust – even if only as images. They were named by Cindy Rossetto whose suggestion won a naming contest with over 1,100 entries. This time Lego cooperated with the Planetary Society, whose website follows the adventures of the tiny astronauts in *The Astrobot Diaries.* At the moment, Lego is selling the *Mars Mission* series with command bases, spacecraft, ground vehicles and evil aliens trying to steal crystal energy from the human miners on Mars.

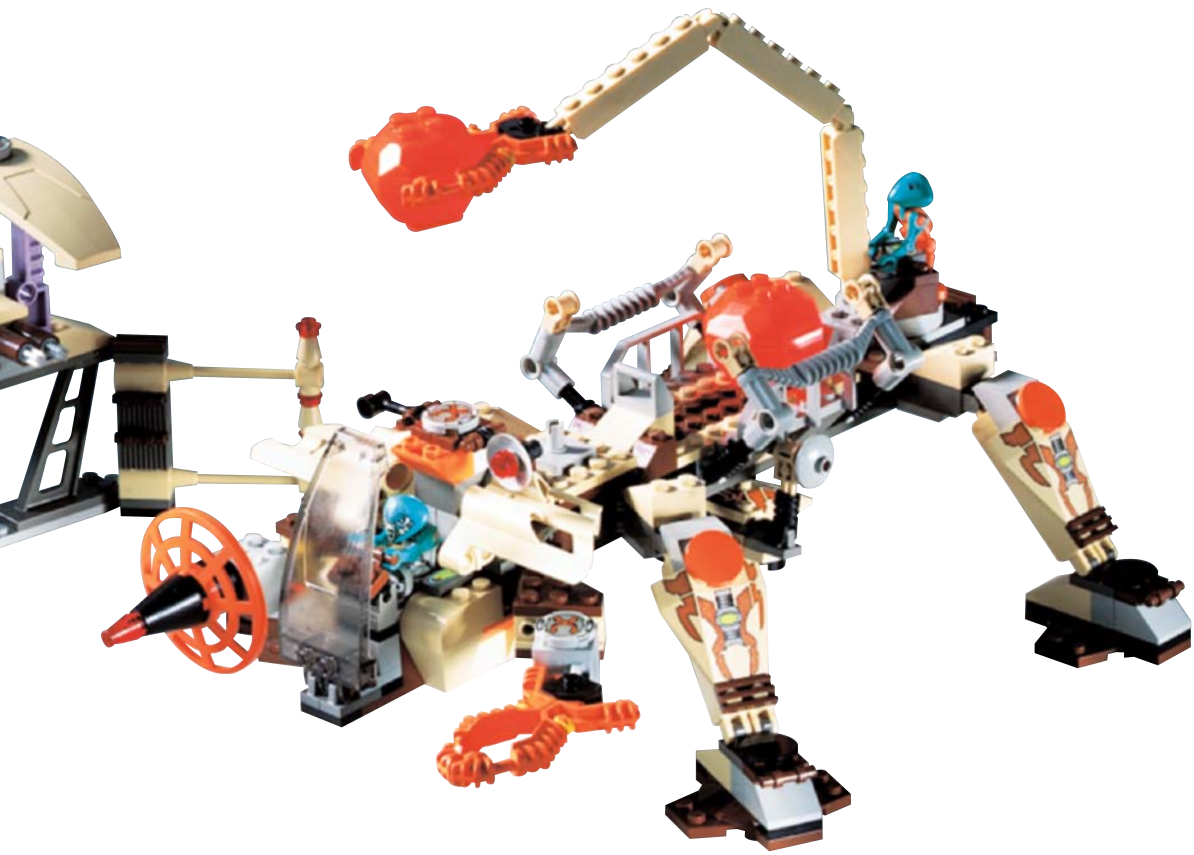
Heavenly chocolate

● All chocolate lovers are familiar with Mars as a candy bar. The trademark originally had no connection with the Red Planet; it is derived from the last name of the founder of the company, Frank C. Mars. He started the candy business in the early 1910s. He thought of exploiting the space theme connected with his name, and the cornerstone of his success came to be a chocolate bar named *Milky Way*, which is still in production. Frank developed the bar with his son Forrest in 1923. By the end of the 1920s Frank Mars had made a fortune, and he established an estate in Tennessee called Milky

Mars is also a large family of chocolate consumables.

Way. True to its name, the estate was huge: a total land area of 11 km^2 and a manor with 2,300 m^2 of living quarters.

Later on, Forrest founded a company of his own in Europe and developed the famous Mars bar. The family of products expanded in 2002 with Mars Midnight, which was topped with dark chocolate. It did not succeed, though, so it was withdrawn 2 years later. Another novelty, *Mars Lava*, was launched in Australia in 2004. It derives its name from the orange-nougat filling. In addition to these varieties there are or have been products such as Mars Fling, Mars Pods, Mars Planets and a real Space Age delicacy, Mars Chill: the wrapper has Mars written in white, but it turns to blue when the package is cold enough.



Cobwebs on Mars

● The most famous "Martian" in the music business is surely Ziggy Stardust, an androgenous character created by David Bowie, the chameleon of rock 'n' roll. Ziggy performed for a couple of years just at the time that the first detailed information on Mars was obtained and the real nature of the Red Planet was beginning to be revealed. Ziggy Stardust's first British tour started in the small London pub Toby Jug in February 1972, only 3 months after *Mariner 9* reached orbit around Mars.

Bowie's creation toured the world only until July 1973, but fans could search for solace in the album named *The Rise and Fall of Ziggy Stardust and the Spiders from Mars,* released in 1972. It contains such classics as *Starman* and *Suffragette City*, and naturally *Ziggy Stardust*, whose lyrics gave the band its name, which sounds something like the title of a horror b-movie.

Mars has been a recurrent theme during Bowie's career. In 1971 he asked about life on our neighboring planet in a song titled *Life on Mars?* on the *Hunky Dory* album. And in a way Ziggy's album could be considered to be one possible reply to this question, which still has no definite answer.

Ziggy Stardust, a character created by David Bowie, played guitar with the Martian spiders.

Mars, bringer of war

● In classical music Mars is probably best known from the *Planets* symphony by the British composer Gustav Holst, which premiered in 1920. However, Holst was not inspired by the planets as members of the Solar System but as astrological entities. That is why Earth is not represented. The symphony also excludes Pluto, which was discovered only in 1930, 4 years prior to the death of the composer. Holst did not even consider composing the missing part, since he loathed his most famous work and especially the fame he received due to it. Holst gave out typed sheets of paper to people who asked for his autograph stating that he would not give autographs. However, later on the symphony was kind of completed by another Briton, Colin Matthews, who composed *Pluto, the Renewer* in 2000.

Two parts of the symphony, *Mars, the Bringer of War* and *Jupiter, the Bringer of Joy*, have become especially familiar on the sound-

MARS BANDS, . . .
30 Seconds To Mars (USA)
Armchair Martian (USA)
Billy Lee Riley & His Little Green Men (USA)
Boss Martians (USA)
Cydonia (Italy)
Electric Blue Peggy Sue and the Revolutionions from Mars aka EBPSATRFM (Finland)
Hundred Million Martians (Finland)
Lars Mars (USA)
The Laziest Men on Mars (USA)
Little Green Men (USA)
Mars (New Zealand)
Mars (USA)
Mars Electric (USA)
Mars Lasar (USA)
The Mars Volta (USA)
Martian Water (USA)
The Martians (USA)
Mouse on Mars (Germany)

. . . albums, and songs
Jan Amber: *The Little Martian*
Anggun: *Life on Mars*
Avarus: *Mars on paljastanut salaisuutensa*
Bobby Fuller Four: *Our Favorite Martian*
Bon Jovi: *Captain Crash & The Beauty Queen from Mars*
Joe Carson: *Hillbilly Band From Mars*
Cleaning Women: *Aelita*
Alice Cooper: *Might As Well Be On Mars*

Bruce Dickinson: ***Mars Within***
Terry Dunavan and the Earthquakes: ***Rock-It On Mars***
Jackie Fautheree: ***First Man On Mars***
Hank Flamingo: ***Redneck Martians Stole My Baby***
Gackt: ***Mars***
Gas Huffer: ***Beer Drinkin' Caveman from Mars***
Ron Goodwin: ***Martians on Parade***
Grateful Dead: ***From the Mars Hotel***
The Killer Barbies: ***They Come From Mars***
Muse: ***Knights Of Cydonia***
The Orb: ***Mickey Mars***
Butch Paulson: ***Man From Mars***
Jason Ringenberg: ***Honky Tonk Maniac From Mars***
Rocky Sharpe and the Replays: ***Rock It To Mars***
Matthew Sweet: ***Blue Sky on Mars***
Thee Ultra Bimboos: ***Mars Is Rising***
The Vibro Champs: ***Martian Trip***
Daniel Wang: ***Let's Go To Mars***
The Wild Tones: ***The Martian Band***
Robbie Williams: ***Viva Life On Mars***
The Wings: ***Venus and Mars***

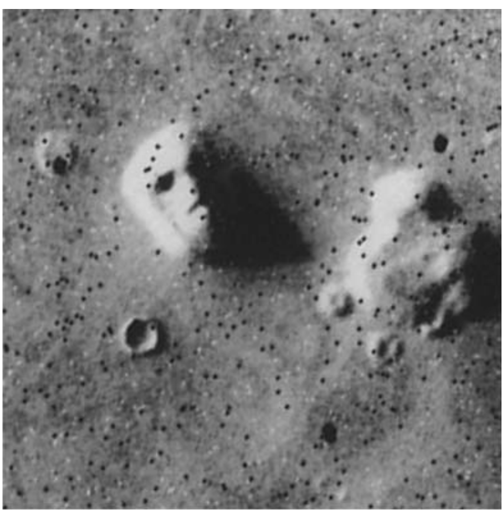
tracks of numerous movies and television programs, as in, for example, Carl Sagan's *Cosmos* (1980), a once-popular series on astronomy. The part on Mars is also found in science fiction. It has the honor of being Mars' anthem in Robert A. Heinlein's novel *Stranger in a Strange Land* (1961).

President of the Red Planet

● In July 1976 the *Viking* orbiter was photographing the surface of Mars to find a suitable landing site for the lander. The image of the plains of Cydonia Planitia exhibited a shape resembling the human face. NASA published the image to show something familiar from the surface of a strange planet to the general public. Perhaps it should not have been done.

The "Face of Mars" has become one of the most famous images from the Red Planet. Some people think that it not only looks like a face, it really portrays a Martian, possibly a local ruler. A huge monument, 2.5 km long and 250 m high, was supposedly built in the ruler's honor. This type of illusion is called pareidolia: a shape vaguely resembling something familiar is clearly seen to represent exactly that figure. In psychology pareidolia is used in the Rorschach test in which a patient is encouraged to see shapes in irregular ink stains.

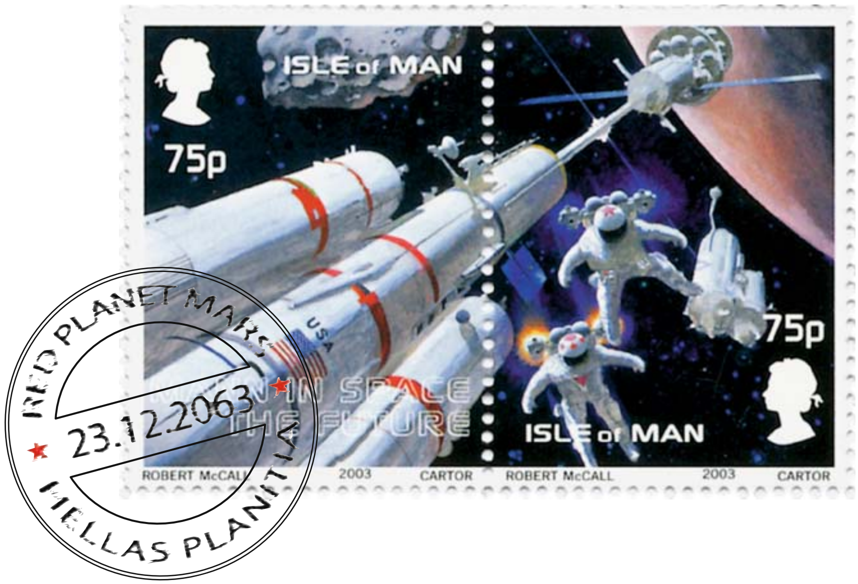
The features so clear in the image taken by the Viking *orbiter had disappeared in the image taken by the* Mars Express *– as a consequence of a conspiracy, some people claim.*



You have mail – from Mars. The most fabulous space stamps are usually issued in countries having nothing to do with spaceflight. Isle of Man has issued a block depicting a manned flight to Mars, the Soviet stamps present the Mars 1, 2, *and* 3 *probes, and a stamp from the Comoro Islands depicts a tracked* Viking 3 *lander. There were plans to build it at the end of the 1970s, but it was canceled because of high costs.*

In April 1998 the *Mars Global Surveyor* photographed the "Face of Mars" with a resolution far exceeding that of the *Viking* probe more than 20 years earlier. And the result? The human face was not there anymore. The most logical and simple explanation is that the "face" was seen only now for what it really was, a natural hill on which the play of light and shadow in favorable conditions creates patterns resembling a face. However, some people think the real explanation lies in a great conspiracy, which was created right after the infamous picture was taken. The landing site originally chosen for *Viking 2* happened to be on Cydonia Planitia, but at the last minute the probe was redirected to Utopia Planitia, thousands of kilometers away from the enigmatic monument.

According to conspiracy theorists, *Mars Observer,* a probe supposedly lost in 1992, was not actually lost, but did exactly what it was supposed to do. It was sent to photograph the "Face of Mars" and other strange structures found in its vicinity. After acquiring watertight proof on the existence of an ancient civilization the probe destroyed the monument with a nuclear bomb. The new images were considered to be much too revolutionary by the authorities and so they were buried in the archives. Images taken of the ravaged face by later probes were used in convincing people that there never was any civilization on Mars.



Public secret

● Where scientists, as the result of several decades' of hard work, have come to the conclusion that there was water on Mars at some stage in the history of the planet, conspiracy theorists are convinced that there has also been life on Mars, and advanced life, for that matter. And they know that the official quarters are well aware of this fact, but they are doing everything they can in order to keep the truth from ever being revealed.

The problem is that there is no consensus on what the truth really is. There are numerous websites in the virtual universe of the Internet dedicated solely to Martian conspiracy theories. Google comes up with about 1.5 million hits for "Cydonia" in one-tenth of a second, and Accoona, which is based on artificial intelligence, comes up with some 70,000. There is also fact in this lot, but most of it is pure fiction. One piece of "conclusive proof" of the truthfulness of the conspiracy claims is – naturally – that the links listed on these websites, which would reveal even bigger secrets on Mars, frequently do not work.

The popularity of conspiracy theories often seems to be based on their absurdity. Usually the claims are so wild that whoever makes them can feel free to demand that the "authorities" attend to them, because no one will ever take any kind of measures. For example, NASA is continuously pressured to perform a detailed scientific study of the Cydonia Planitia in order to verify the artificial origin of the mysterious formations. However, these requirements alone are typically controversial. At the same time that NASA is pressed to undertake these studies, they are claimed to have already done these, but judged the information too devastating and so concealed.

Mars is an excellent site for alleged civilizations and their remains, because it is simultaneously close enough and far enough. It can be seen in the sky with unaided eyes, and its surface can be examined even with a smallish instrument. Thus it is easy to maintain an interest in Mars – or actually it is maintained without any extra effort. Who would be interested in possible habitation on Pluto's satellite Charon?

In principle – but not in practice – it is easy to send probes to Mars, which relay a continuous flow of new, fascinating images. And with a little help from computer design software it is possible to bring out imaginative and extremely conclusive details. On the other hand Mars is so far away that there will be no manned flights anytime soon, with astronauts capable of making in situ studies with much better efficiency and accuracy than robots, which have limited capacity and area of operation. Thus it is more or less safe to make all kinds of claims.

Mystical truths

● Numerology mystics have studied Cydonia Planitia with a ruler and have found several numerical relationships, each more significant than the next one. According to these studies, the angles between the lines connecting different "buildings" and "monuments" are astonishingly often 19.5° exactly. This makes the whole Cydonian complex a cosmic message, the central content of which is just that figure. Can it be a coincidence that the geographical location of Mauna Kea, a Hawaiian volcano rising from the depths of the ocean, at 19.6° northern latitude is almost precisely identical with the 19.3° of Olympus Mons, the highest volcano on Mars and in all of the Solar System? If needed, supporting evidence for the cosmic importance of this figure is given by the location of the Great Red Spot on

HIKING ON THE RED PLANET

● **The highest mountain of Mars and of the whole Solar System was conquered in the summer of 2005 – in Tampere, Finland. A performance called "2,500 km in Space" by a Trans-Mars Group with 13 members won a competition for a work of art to be realized on the Tuomiokirkonkatu street. It was carried out between June 13 and September 6. During that time Eero Yli-Vakkuri, the designer of the performance, walked on a granite pedestal with a length of 4 m 5 hours and 30 km a day for 85 days. The total distance covered was 2,500 km which is the distance between the northwestern corner of Noctis Labyrinthus and the summit of Olympus Mons. The progress of the journey could be monitored on the homepage of the project with a travelog, images and information on the planet. The performance was compiled into a video titled "85 Days in 3 Seconds" and it was accompanied by design jewelry called "Olympos Mons – A Desert Rose."**

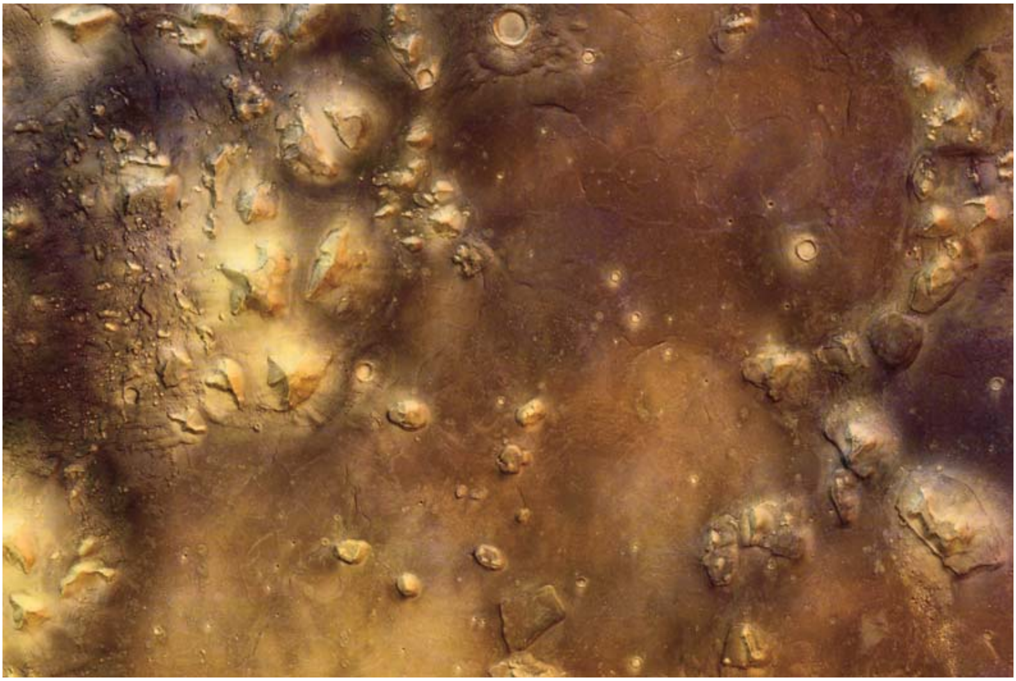
Jupiter, a whirlwind three times larger in diameter than Earth. The Great Red Spot is at 19.5° southern latitude.

The energy of all three "objects" – two volcanoes and one hurricane – is supposed to come from higher dimensions, the total number of which is 27. This energy leaks into our modest three-dimensional universe through surfaces of rotating, spherical bodies – in other words, planets – at a latitude of 19.5°. And here we have the ultimate cause for the conspiracy. This "truth" is so revolutionary that it could not be revealed to humanity as a whole. If anyone could exploit the endless energy of higher dimensions the world economy would collapse. The practical realization of this exploitation could be met with some unexpected difficulties, though, if the energy flow even here on Earth is limited on the top of a mountain several kilometers high.

The "Face of Mars" and the other formations on Cydonia Planitia have been given countless other explanations, but one of the most far-fetched – both in time and space – is based on the religious writings of ancient Sumerians. In addition to some people thinking that the images sent by the probes clearly reveal the artificial nature of the Cydonian structures, the adepts of real knowledge are capable of telling who constructed them. They were not Martians, they were Anunnaki.

Sumerian texts 6,000 years old tell about a total of 12 planets in the Solar System, the tenth being Nibiru. According to the Sumerians, they received this information from the gods, whose name *Anunnaki* means "those who from heaven to earth came," that is, from the planet Nibiru. The ruined city on Cydonia Planitia is a freight depot built by the reptilian Anunnaki through which they transported gold collected on Earth. The precious metal was supposed to help them "repair" the atmosphere of their home planet. The story does not tell how they were supposed to accomplish this and whether they succeeded in it or not.

The Anunnaki did not dig for gold in any vulgar way, such as tunneling underground, but more than 400,000 years ago they extracted it from seawater in the area of the present-day Persian Gulf. Gold was supposed to be stored at the way station on Mars until Nibiru would make the next passage on its elliptic orbit, which



has a period of 3,600 years. Some unknown mathematical formula reveals that the city on Cydonia was built some 250,000 years ago. No wonder that the center of a past culture has crumbled into mere windswept heaps of gravel, which only the most keen-sighted people are capable of recognizing as artificial structures.

Recognizing the ruins of an Anunnaki city amidst the plains of Cydonia Planitia has become increasingly difficult with the new images.

Green residents of the Red Planet

● In the end it might be appropriate – and about time – to ponder the color of the Martians, which has been established to be green. In science fiction the inhabitants of Mars come in many different colors of skin, fur, or feathers, but in contemporary folklore the Martians and extraterrestrials in general are green – and little.

It is a well-known fact that green looks good against red, its complementary color, but aesthetics is surely not the cause for the color of the Martians. One reason could be that green is very different from the spectrum of human complexion and thus makes our imaginary celestial neighbors even stranger. But then again, in this sense blue would be an equally peculiar color for skin.

The origins of the green color are usually linked with the first novel of Burroughs' Mars series, *Princess of Mars* (1917). The story tells about aggressive Martians being green, but they are only one of several races residing on the planet. The white Martians are apelike and the red ones scientifically advanced. Why could not we talk about Little Red Men?

However, ever since the 1920s space heroes saving beautiful princesses struggled on the covers of pulp fiction magazines and books with monstrous green aliens, and this tradition was adopted in the fantasy world of movies. With the UFO sightings in the 1950s stories on "little green men" began to gain publicity and the name – along with the color – became established.

According to one theory the green color refers to old Irish legends. In ancient days the forests of Ireland teemed with small leprechauns dressed in green. The UFOs are considered to be folklore of our times: they have conquered the world of elves, gnomes, and fairies. Perhaps they have also inherited the color of the little folk faded in the mists of history.

AUTHOR'S FINAL NOTE AND ACKNOWLEDGMENTS

Despite my complete lack of belief in – and the total absence of any scientific evidence for – astrology, Mars has been a kind of "planet of fate" to me almost all my life. My first memory of the Red Planet takes me way back to the 1960s, the "Golden Age of Apollo," when my aunt told me that the name "Markus" was derived from the god of war.

At the end of the 1970s I prepared a presentation for a physics class at school on Mars. I would have delivered it if I had not caught a bad flu. In the 1980s – as part of my studies in astronomy at the Helsinki University Observatory – I examined the spectral signature of Martian ozone in observations made with the *International Ultraviolet Explorer*. It was kind of consoling to know that among all the differences between Mars and Earth there are a few similarities, too. At around the same time I covered the Soviet *Phobos* project with a Finnish input for the *Tähdet ja avaruus* ("Stars and Space") magazine of the Ursa Astronomical Association, and made observations of the planet with the instruments of the Ursa Observatory. It was thrilling to see with my own eyes the very same surface features of Mars that the *Phobos* probes were supposed to be soon studying. In the 1990s I participated in organizing a "Mars Day" in Heureka, the Finnish Science Centre, the program of which consisted of short presentations on various aspects of Mars. This gave me – for the first time – a clear insight into the great importance of the Red Planet not only scientifically but also in our culture. And finally, in the beginning of the 2000s, I was looking for – as a managing editor of non-fiction at WSOY, the biggest publishing company in Finland – a book on Mars to be translated and published in Finnish. I did find several very good books, but I also found that none of them treated the Red Planet comprehensively enough to my taste. Being a stubborn and somewhat arrogant person I decided to start writing one myself. I never would have believed that eventually I would write it in English.

John Donne at the beginning of the seventeenth century wrote, "No man is an island" – or, as would be more appropriate in this case, “a planet.” Even though I have typed every single word in this book – as well as in the earlier Finnish edition – with my own fingers, it would not have been born without the strong support and encouragement from a large number of people.

First of all I would like to express my deep gratitude to my parents, Kaino and Olavi, who supported my choice of astronomy for a hobby some 30 years ago (goodness me . . .) and later for a major subject of my studies. They never questioned my decision but trusted my judgment – perhaps more than I did myself.

I thank my wife Helena Sederholm who bravely endured all my miniature lectures on whatever Martian detail happened to be on my mind during the various stages of collecting material for this book and shaping it into an intelligible form. She also read the manuscript and asked some tough questions, the answering of which helped me to – hopefully – clarify what I was trying to say. I am also in great debt to our 4-year-old daughter Tilda Sigrid Meteoora, who made it possible for me to work on “Daddy’s planet” by going to bed without a fuss and sleeping soundly through the night – the time of “day” I did the writing.

Of my colleagues in the publishing business I want to say thanks to managing editor Kaarina Miettinen from WSOY, who persistently demanded clarifications for things treated with too much complexity or superficiality; non-fiction writer Mattias Tolvanen, whose keen-sightedness helped me avoid a large number of literary pitfalls; and especially graphic designer Martti Ruokonen from WSOY, who created the superb layout for the original Finnish edition and the cover used also in this Springer edition. The illustrations made for this book have their origins in the magic pen of graphic designer Mikko Juhola. As a fellow amateur astronomer he managed to find the meaning of my vague instructions and succeeded in bringing to life whole civilizations.

The Finnish manuscript was read in its entirety by Professor Juhani Kakkuri and Docent and science journalist Leena Tähtinen. I am grateful for their advice in making the text clearer and scientifically accurate. The chapters on Martian research and its results were read by Dr. Ari-Matti Harri from the Finnish Meteorological Institute, the appendix on Finnish participation by Professor Risto

Pellinen – who also kindly wrote the foreword – likewise from the Finnish Meteorological Institute – and the chapter on space probes by science and aviation journalist Jari Mäkinen. Thanks to them I managed to correct several embarrassing mistakes and misunderstandings. The English manuscript was read by Dr. Diana Hannikainen from the Metsähovi Radio Observatory who also – as a native English speaker – checked the language, making a number of corrections and giving valuable advice on how to say things in English the way they should be said.

Major thanks go to editorial director Harry Blom and editor Maury Solomon at Springer Science + Business Media. They made the publication of this book possible across the Atlantic, first with Harry's strong faith in a book written originally only in Finnish and then with Maury's patient help in transforming it into a thoroughly updated English edition – actually a completely new book. Kiitos!

I have also received assistance on details of varying size from the following persons deserving my sincere gratitude: Ralph Aeschliman (www.ralphaeschliman.com), Filipe Alves (www.paragrama.net/manalokos), Matti Anttila (Space Systems Finland Ltd.), Bruce Bradley (Linda Hall Library of Science, Engineering & Technology), Jean-Luc Dauvergne, Louis Friedman (The Planetary Society), Kai Heinonen (Military Museum, Helsinki), Jukka Heiskanen (Sanoma Magazines Finland), Oskari Hellman, Petri Hiltunen, Nick Hoffman, Kimmo Hytti, Kaisa Häkkinen (University of Turku), Markus Jokela (Helsingin Sanomat), Kristian Järnefelt (Hewlett-Packard Finland), Marjo Järvinen, Hannu Karttunen (Tuorla Observatory), Marjatta Koivisto, Johannes Kvist (Oy Suomen Lego Ab), Jukka Lehtinen, Martti Lehtinen (Geological Museum, Finnish Museum of Natural History), Arja Lindblad (WS Bookwell Ltd.), Marcel Maltzeff (WSOY), Matti Martikainen, Alice Martin (WSOY), Terry McNeeley (www.nuclearspace.com), Sini Merikallio (Finnish Meteorological Institute), Franck Montmessin (Service d'Aeronomie du CNRS), Veikko Mäkelä (Ursa Astronomical Association), Heikki Oja (University Almanac Office, Helsinki), Teivas Oksala, Ann Pasquini (Malin Space Science Systems), Leena Peltonen, Timo Polari (www.timopolari.com), Jouko Raitala (University of Oulu), Mario Rossi (www.space-graphics.com), Matti Rossi (Heureka, The Finnish Science Centre), Hannu Salmi

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The writing of this book was supported financially by the Board for Grants and Subsidies to Writers and Translators, the Finnish Association of Non-fiction Writers and the Werner Söderström Corporation Literary Foundation. I am thankful for their trust in my abilities in the field of science writing. The result of my efforts was acknowledged in 2006 with a State Award for Public Information by the Ministry of Education and a citation from the Lauri Jantti Foundation for promotion of Finnish non-fiction. That is something I appreciate very highly.

I also want to thank all the anonymous persons participating in the development of the Internet in general and the countless Mars-related websites in particular. Without the benefits of the "triple-w" in searching for information and images the making of this book might not have been impossible, but it would have taken far more time than it did. Equally important are the vast electronic image archives of the various space research organizations, especially those of the National Aeronautics and Space Administration, NASA, and the European Space Agency, ESA.

In addition to all the above-mentioned people there certainly is a large group of individuals who have helped me directly or indirectly in the process of putting all this stuff together. I apologize for not being able – or not thinking of it – to name them all.

Nuuksio, Finland, on a wintry Tuesday, the namesake day of Mars, approaching the Christmas opposition of 2007

Markus Hotakainen

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The image archive of NASA (Planetary Photojournal).
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United States Geological Survey page with a 1:5,000,000-scale map of Mars based on MOLA imagery.
www.esa.int
Homepage of the European Space Agency; links to various space programs.
www.esa.int/SPECIALS/Mars_Express
Homepage of the Mars Express.
www.marssociety.org
Homepage of the Mars Society.
www.msss.com
Homepage of the Malin Space Science Systems; links to the image archives of the Mars Global Surveyor.
www.planetary.org
Homepage of the Planetary Society.
www.solarviews.com
A vast collection of images related to the study of the Solar System.

Appendix A

FINNISH MARS RESEARCH – A COSMONAUT PREVENTION PROGRAM

A party official invited himself for tea to tell cosmonaut Selkokari Mars was dead.

– Ian McDonald: *The Old Cosmonaut and the Construction Worker Dream of Mars* (2002)

Finnish Martian research began because of a political promise that was never kept. In the early 1980s the Finnish government was about to accept a Soviet offer to send a Finnish Air Force fighter pilot to cosmonaut training. The Finnish experts in the field of space research were terrified, since it would have eaten up the scanty resources of real research and would also have meant that Finland would have been compared with countries of the Eastern bloc, which have had their cosmonauts flown into space since the 1970s. To prevent this from happening something equally esteemed but scientifically more sensible had to be come up quickly.

Luckily for the future of Finnish space research at this time the Soviet Union was starting a project on the *Phobos* probes. Due to several coincidences, Finnish scientists were able to participate in the building of the instruments for the probes and the analysis of the measurements. From the Finnish point of view the most important instrument was ASPERA, a plasma spectrometer, which was largely designed and built in the Space Research Department of the Finnish Meteorological Institute, led by Risto Pellinen. The instrument took measurements of plasma – electrically charged particles – in space. Although the success of the *Phobos* probes was modest, ASPERA operated perfectly. It sent information all the way to Mars and even after *Phobos 2* went into orbit around the planet. A research group lead by Esa Kallio used the measurements to determine that the atmosphere of Mars was continuously leaking oxygen into space at a rate of about half a kg per second.

The latest version of the instrument, ASPERA-3, is flying on *Mars Express*. It has verified the observations on the leakage of oxygen of the earlier version onboard the *Phobos* probe and revealed that the atmosphere is losing water, too. Also the unlucky *Beagle 2* piggybacking on *Mars Express* carried Finnish know-how with it. An instrument developed by the Finnish Meteorological Institute based on a pressure sensor made by Vaisala Instruments was supposed to study the pressure variations in the Martian atmosphere with season and time of day. The predecessor of the instrument was onboard the *Mars Polar Lander,* which was destroyed during landing. A similar instrument is a part of the scientific payload of the *Phoenix* lander, the purpose of which is to study the northern polar areas of Mars.

Still no luck

● Finland also participated in the Russian *Mars 94* project, which due to problems with the schedule became *Mars 96*. The postponement did not help: the probe never made it to space.

Mars 96 consisted of an orbiter, two surface stations, and two penetrators designed to impact the surface and send information from below the ground. The instruments on the surface stations would have made observations on the Martian weather and the chemical composition of the surface and photographed it at close range.

Together with Finnish industry, such as Space Systems Finland Ltd., the Finnish Meteorological Institute built the central units controlling the operation of the stations with a computer and power system, and the meteorological instruments. The orbiter was equipped with, among other instruments, ASPERA-C, a follow-up of the successful ASPERA.

Bull's-eye on Mars

● Under the leadership of Ari-Matti Harri the Finnish Meteorological Institute has been developing a completely new kind of lander, a *MetNet* impactor. In the long term the goal is to establish a network of weather stations on the surface of Mars; *MetNet* would be an excellent tool for building that.

The study of the atmosphere of Mars makes use of mathematical models created in the Department of Atmospheric Sciences of Helsinki University and the Finnish Meteorological Institute. The most recent of the models developed by the groups led by Hannu Savijärvi and Tero Siili is based on a Nordic model for weather forecasting, so the research of the atmosphere of Mars benefits from the study of the atmosphere of Earth – and vice versa.

The *MetNet* probe, developed in cooperation with Russian space research institutes, is small. It is about 1 m long and weighs some 16 kg. It can be launched towards Mars on a small rocket or as a sub-probe of a larger one. The descent of *MetNet* onto the surface of Mars will at first be slowed down by an inflatable heat shield. It will be blown out in much the same way as the heat shield of the spacecraft *Alexei Leonov* in the *2010: Odyssey Two* by Arthur C. Clarke and in the film based on the novel while decelerating in the Jovian atmosphere.

After the probe has lost enough of its velocity it will open an inflatable "air brake" that will take care of the final stages of the descent. Upon impact with the surface the tip of the probe will penetrate about half a meter into the ground, but the instrumentation in the back of the probe will stay above it to take measurements. The maiden flight of *MetNet* is planned to take place aboard the Russian-Chinese probe Phobos-Grunt to be launched in 2009.

Maybe It's a Drill . . .

● Even though the total number of probes with a successful landing on the surface of Mars is only six, the main problem – especially in the search for life – has been that the landers have only been capable of scratching the surface. The *Viking* landers had a "shovel" to dig trenches a few centimeters deep, the MER rovers operating at present on Mars have an instrument called RAT, the Rock Abrasion Tool, which can be used to drill a few millimeters into the rocks, and the Phoenix lander has a Robotic Arm with which it can dig some tens of centimeters into the Martian soil. But that is not nearly enough. The essential object of research, Martian water – at least in a liquid state – and possible life exist way deeper. And the only way to get there is by drilling.

A drill technique suitable for Martian research has been studied by Matti Anttila who earned his Ph.D. at the Helsinki University of Technology in 2005. Earlier Anttila had been involved in designing a prototype for a miniature rover called Miro which was capable of taking a sample with a drill from a depth of a couple of meters and bringing it to the lander for more detailed analysis or for a return flight to Earth.

In his thesis, Anttila made a detailed analysis on the requirements for drilling equipment to be sent to Mars. Based on the analysis, theoretical calculations, and laboratory tests, he has developed a new kind of drill called MASA, which would be suitable, for example, for the future Mars rover of the ESA. The drill could reach a depth of 2.5 m and could be used to take samples of all imaginable surface materials on Mars: soft soil, hard rock, and water ice.

Deciphering the Images

The technique is only one part of the research undertaken by space probes. Jouko Raitala is leading a planetology group at the University of Oulu with Mars as one of their main objects of interest. An important tool for their research is the Nordic Regional Planetary Image Facility (NRPIF), the archives of which are continuously expanded by the wealth of imagery from the various Mars probes. Despite the fact that there are two rovers and one lander at present operating on the surface of Mars, they can make the observations only very locally. The images taken from orbit give a broader view of larger areas and, on the other hand, they are used to select the sites for future landers, sample return missions and before long manned flights.

The imagery is used at the University of Oulu to study the structure, tectonics, volcanism and marks left by water on the surface of Mars. The aim is to find out the geological history of Mars: what has happened on the surface of the planet at different times and how these events were related to each other. One important area of research is the impact craters and how their creation affected the surface of Mars, but this also works the other way around: how Mars has affected the phenomena and structures in the craters. The ultimate goal is to form a coherent picture of the different geological processes, the result of which is present-day Mars.

Appendix B

Mars Probes 1960–2008

Probe	Nation	Launch	Arrival*	Notes
Marsnik 1	Soviet	October 10, 1960		Flyby; launch failure
Marsnik 2	Soviet	October 14, 1960		Flyby; launch failure
Sputnik 22	Soviet	October 24, 1962		Flyby; launch failure
Mars 1	Soviet	November 1, 1962		Flyby; contact lost
Sputnik 24	Soviet	November 4, 1962		Lander; missed Earth orbit
Mariner 3	US	November 5, 1964		Flyby; launch failure
Mariner 4	US	November 28, 1964	July 14, 1965	Flyby
Zond 2	Soviet	November 30, 1964		Flyby and lander; contact lost
Mariner 6	US	February 24, 1969	July 31, 1969	Flyby
Mariner 7	US	March 27, 1969	August 5, 1969	Flyby
Mars 1969A	Soviet	March 27, 1969		Orbiter; launch failure
Mars 1969B	Soviet	April 2, 1969		Orbiter; launch failure
Mariner 8	US	May 9, 1971		Orbiter; launch failure
Cosmos 419	Soviet	May 10, 1971		Orbiter; missed Earth orbit
Mars 2	Soviet	May 19, 1971	November 27, 1971	Orbiter, lander, and rover; landing failure
Mars 3	Soviet	May 28, 1971	December 2, 1971	Orbiter, lander, and rover; landing failure
Mariner 9	US	May 30, 1971	November 14, 1971	Orbiter
Mars 4	Soviet	July 21, 1973		Orbiter; missed the planet
Mars 5	Soviet	July 25, 1973	February 12, 1974	Orbiter
Mars 6	Soviet	August 5, 1973		Flyby, lander, and rover; contact lost during descent
Mars 7	Soviet	August 9, 1973		Flyby, lander, and rover; lander missed the planet
Viking 1	US	August 20,1975	June 19, 1976/ July 20, 1976	Orbiter and lander
Viking 2	US	September 9, 1975	August 7, 1976/ September 3, 1976	Orbiter and lander

Probe	Nation	Launch	Arrival*	Notes
Phobos 1	Soviet	July 7,1988		Orbiter and Phobos-lander; contact lost
Phobos 2	Soviet	July 12, 1988	February 8, 1989	Orbiter and Phobos-lander; contact lost in the Mars orbit
Mars Observer	US	September 25, 1992		Orbiter; contact lost
Mars Global Surveyor	US	November 7,1996	September 12, 1997	Orbiter
Mars 96	Russia	November 16, 1996		Orbiter, landers, and penetrators; launch failure
Mars Pathfinder/ Sojourner	US	December 4, 1996	July 4, 1997	Lander and rover
Nozomi	Japan	July 3, 1998		Orbiter; missed the planet
Mars Climate Orbiter	US	December 11, 1998		Orbiter; destroyed in the Martian atmosphere
Mars Polar Lander	US	January 3, 1999		Lander and penetrators; landing failure
2001 Mars Odyssey	US	April 7, 2001	October 24, 2001	Orbiter
Mars Express/ Beagle	ESA/GB	June 6, 2003	December 25, 2003	Orbiter and lander; landing failure
Spirit	US	June 10, 2003	January 3, 2004	Rover
Opportunity	US	July 8, 2003	January 25, 2004	Rover
Mars Reconnaissance Orbiter	US	August 12, 2005	March 10, 2006	Orbiter
Phoenix	US	August 4, 2007	May 25, 2008	Lander

*Only successful probes (highlighted with red)

About the Author

Markus Hotakainen studied astronomy, physics, and geophysics at the University of Helsinki in Finland. He has worked since 1983 as a science journalist and was Science Producer of Educational Programs for the Finnish Broadcasting Company from 1993 to 1999.

More recently, he has worked for Werner Soderstrom Corporation, the biggest publisher in Finland, as Managing Editor for nature and science books, and at the moment he is Publishing Manager for Karttakeskus – Map Center. He co-authored a high school textbook on astronomy and wrote a book on observing celestial objects with the naked eye and binoculars, a "pocket atlas" of constellations, and a children's book on stars and planets. He has translated and edited over 40 books on astronomy, space exploration, physics, and mathematics.

This book was first published in Finnish, and Markus translated it himself into English. He has also written many articles for magazines and given numerous public lectures on stellar topics. An observer of Mars since the 1980s, Markus currently uses three telescopes to continue his observing and his research.

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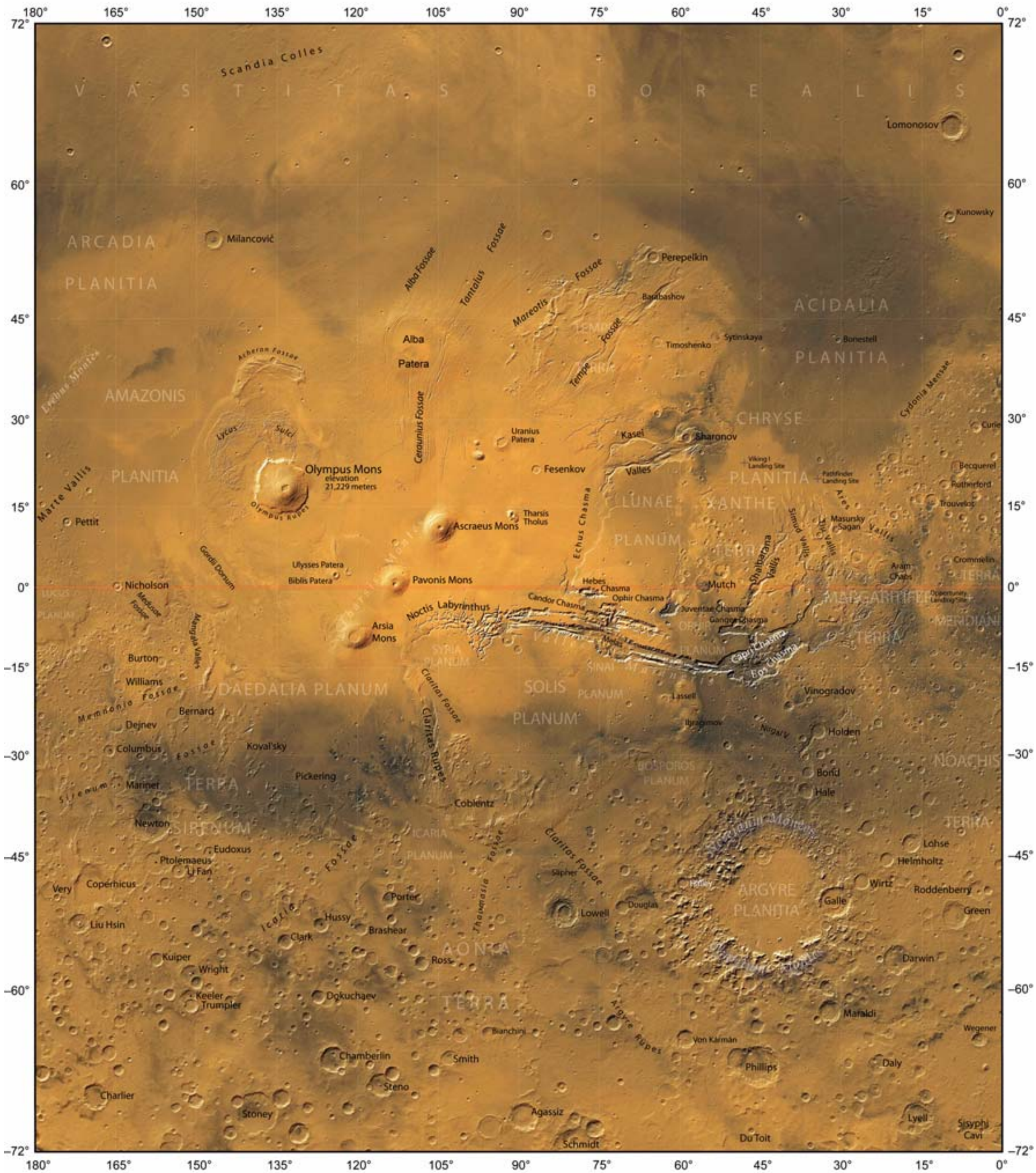
For Tilda and Helena, with love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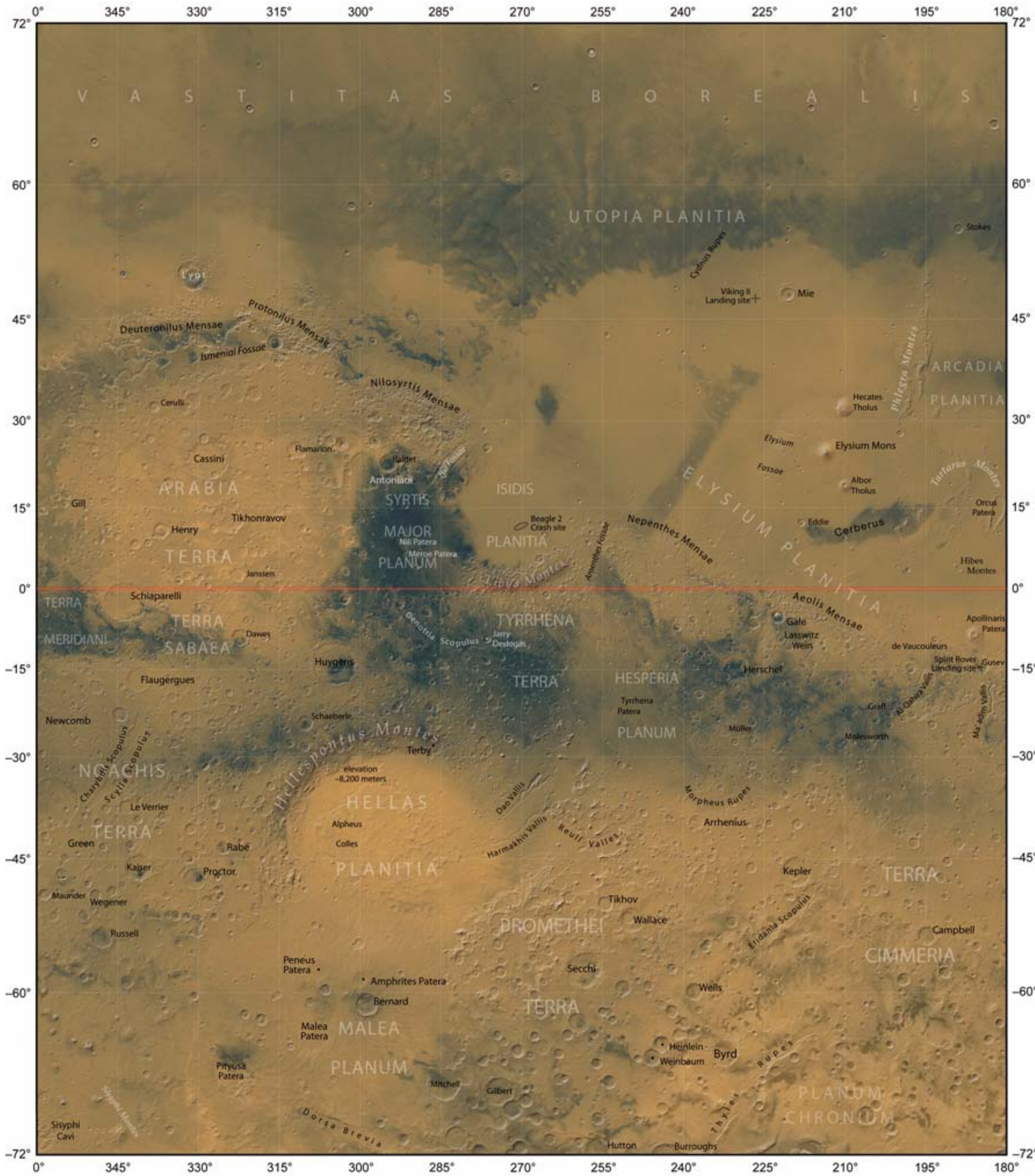
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