Mars

For the musically inclined: Gustav Holst “Mars” Link:
https://www.youtube.com/watch?v=Jmk5frp6-3Q

- **Mars** is the fourth planet from the Sun – a rugged, dusty, cold, desert world with a very thin atmosphere.
- Mars is referred to as the "Red Planet" because of its reddish appearance, due to iron oxide prevalent on its surface.

Size comparison
Mass = 0.107 Earths

- Mars is a terrestrial (rocky) planet with a thin atmosphere, having surface features reminiscent both of the impact craters of the Moon and the volcanoes, valleys, deserts and polar ice caps of Earth. Its solid surface has been altered by volcanoes, impacts, winds, water, crustal movement and chemical reactions.
- Unlike the Earth, Mars is now a geologically inactive planet with no tectonic activity, but was very active in the past with a bigger atmosphere and free water. It still has seasons, clouds, wind, and dust storms.
- It is the site of Olympus Mons, the highest known mountain in the Solar System, and of Valles Marineris, the largest canyon. The smooth Borealis basin in the northern hemisphere may be a giant impact feature covering 40% of the planet.

Credit : NASA/JPL-Caltech

Link:
https://www.youtube.com/watch?v=vdk3iIlSaeM

Mars

- Facts
- Exploration of Mars
- Map
- Clouds
- The night sky of Mars
- Moons
- Colour of the sky
- Canyons
- Meterorites and craters
- Structure and Composition
- Wind and dust storms
- Water
- Magnetic Fields
- Geological History
- Humans on Mars

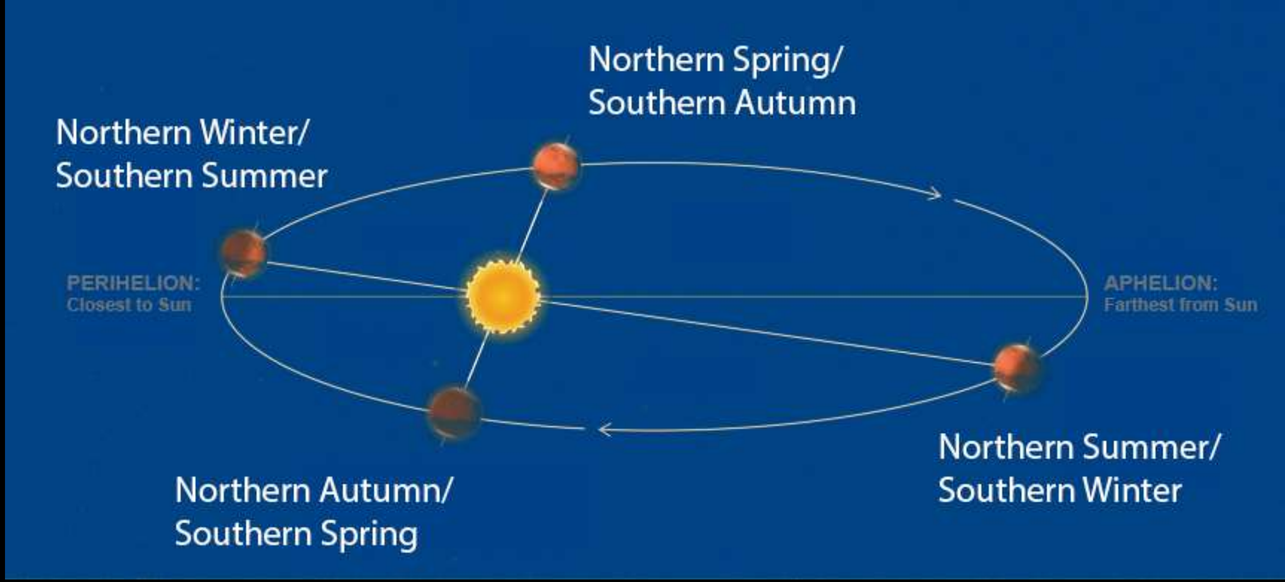
Mars rotational period and seasonal cycles are similar to those of Earth.

- Orbital period 668.5991 sols (Martian day) or 686.971 earth days (1.8808 Julian years).
- Av. orbital speed 24.077 km/s (Earth 29.78km/s)
- Axial tilt 25.19° (Earth currently 23.44 °)
- Sidereal rotation period 24.62296 hr
- Equatorial rotation velocity 868 km/h (241m/s) vs Earth 1,674 km/h (465m/s).
- Surface temp. Min −128 °C Mean −53 °C Max 27 °C
- Density 3.9 gm/cc (compared with Earth's 5.5 gm/cc)
- Mass approximately 1/10th of Earth's
- Gravity 38% as strong as Earth's
- Sunlight 44% of earth
- Atmosphere Surface pressure 0.61 kPa (less than 1% of earth sea level atmospheric pressure)
- Atmosphere composition 95.72% Carbon dioxide

Royalty Free KSNewSpace
This is not meant to be photorealistic nor physically correct but to showcase the ground features of Mars.
Link: https://www.youtube.com/watch?v=rpjQ9aL8PLs

SEASONS ON MARS

The planet experiences all four seasons that the Earth does, but, since the year is longer on the planet (1.88 years), the axial tilt is different, and Mars has a more eccentric orbit than Earth, the seasons are not the same length as each other or the same in each hemisphere



The southern hemisphere has "harsher" seasons than in the north. During Southern winter, Mars is farthest away from the Sun in its elliptical orbit around the Sun. That's different from Earth, because our planet has a near circular orbit. Winter in the southern hemisphere is worse, because Mars is the farthest away from the Sun and moves more slowly in its orbit. The Martian year in the northern hemisphere consists of Spring 7 months, Summer 6 months, Autumn 5.3 months, and Winter just over 4 months.

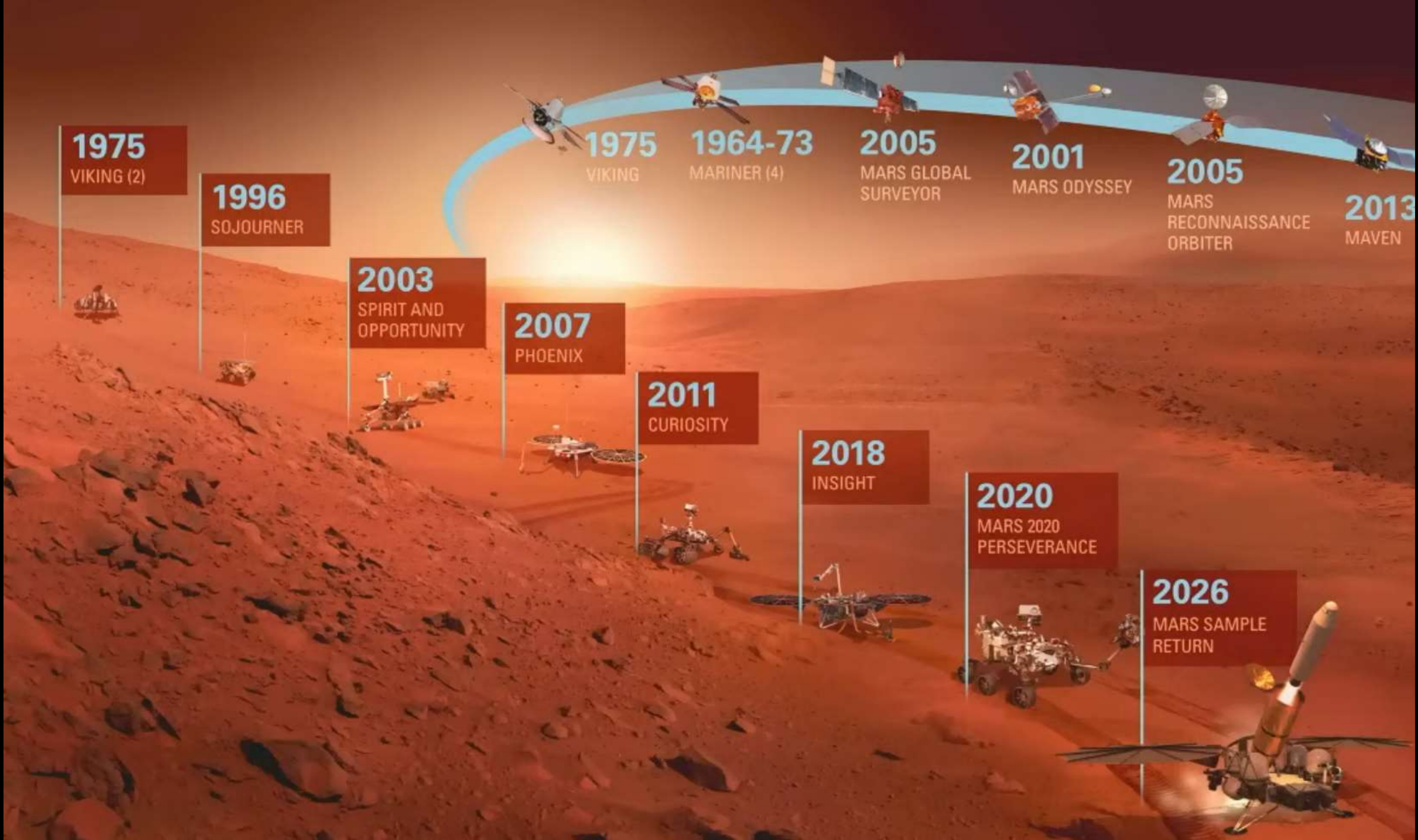
Even in the summer months it is very cold. Temperatures at the height of the season may not top -20 C. In the south the temperatures can be as much as 30 C warmer during the same season. The great fluctuations in temperature and the difference in warmth between hemispheres can cause huge dust storms. Some can affect just a small area, while others can cover the entire planet. The larger storms usually occur when the planet is near its aphelion (closest point to the Sun), the Northern hemisphere Spring.

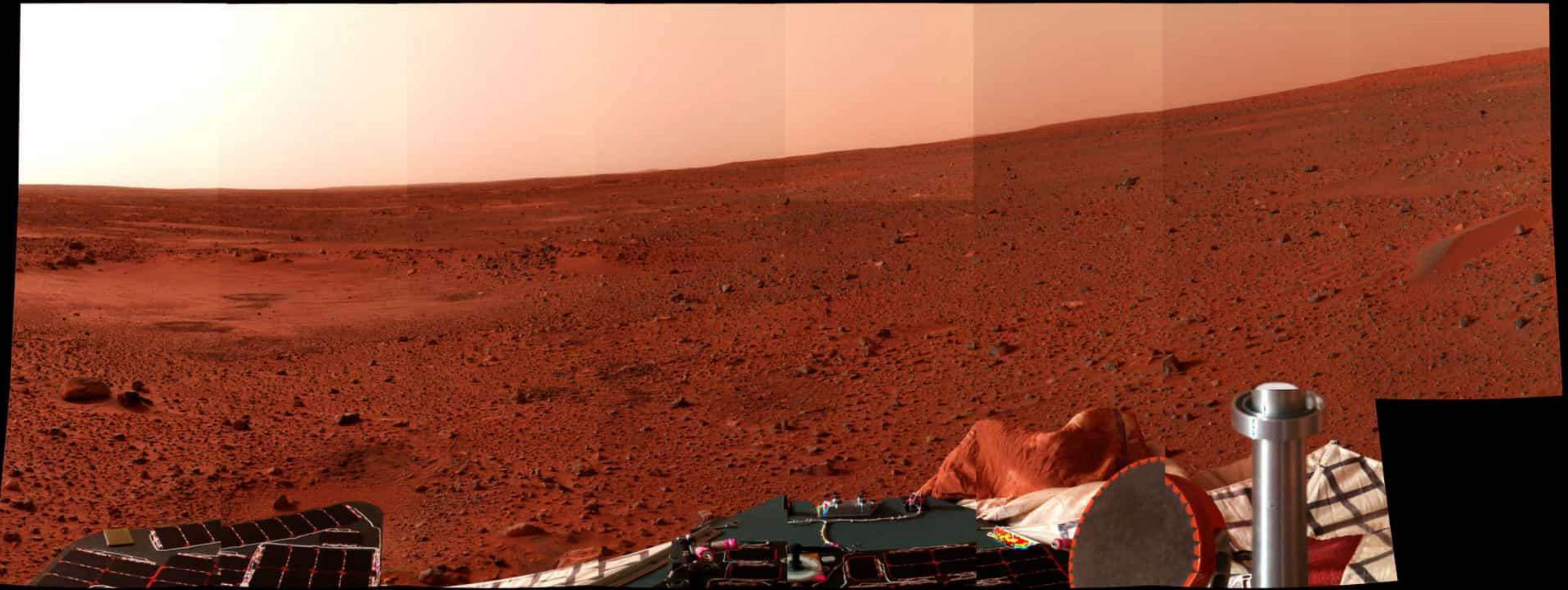
Credit: NASA/JPL-Caltech July 01, 2016

The Martian Landers, Rovers & orbiting reconnaissance satellites

- Initial Fly-By Missions
  - Mariner IV flyby of Mars in July 1965 returned more accurate atmospheric data about Mars and much closer views of its surface than previously achieved
  - Mariner 6 and Mariner 7 flyby of Mars in 1969. The Mariner 6 & 7 infrared radiometer results showed that the atmosphere of Mars was composed mostly of carbon dioxide (CO_2) & detected trace amounts water on the surface of Mars.
- The successful Martian Landers
  - Mars 3 – 1971
  - Viking 1 and Viking 2 – 1976
  - Mars Pathfinder and its Sojourner rover – 1997
  - Spirit and Opportunity rovers – 2004
  - Phoenix lander – 2008
  - Curiosity rover – 2012
  - InSight lander – 2018
  - Tianwen-1 lander and Zhurong rover– 2021
  - Perseverance rover – 2021

Mariner !V 1965: NASA


1975
VIKING (2)
1996
SOJOURNER
2003
SPIRIT AND OPPORTUNITY
2007
PHOENIX
2011
CURIOSITY
2018
INSIGHT
2020
MARS 2020 PERSEVERANCE
2026
MARS SAMPLE RETURN
1975
VIKING
1964-73
MARINER (4)
2005
MARS GLOBAL SURVEYOR
2001
MARS ODYSSEY
2005
MARS RECONNAISSANCE ORBITER
2013
MAVEN



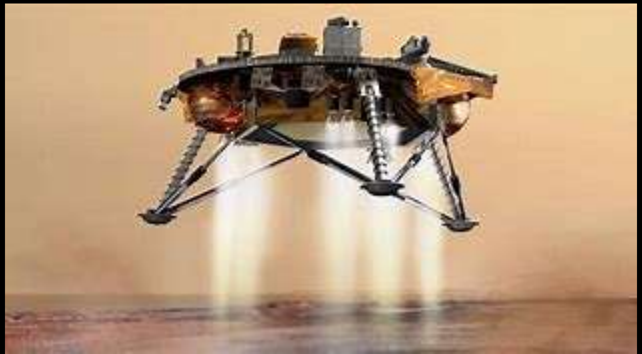
Martian Surface at an Angle

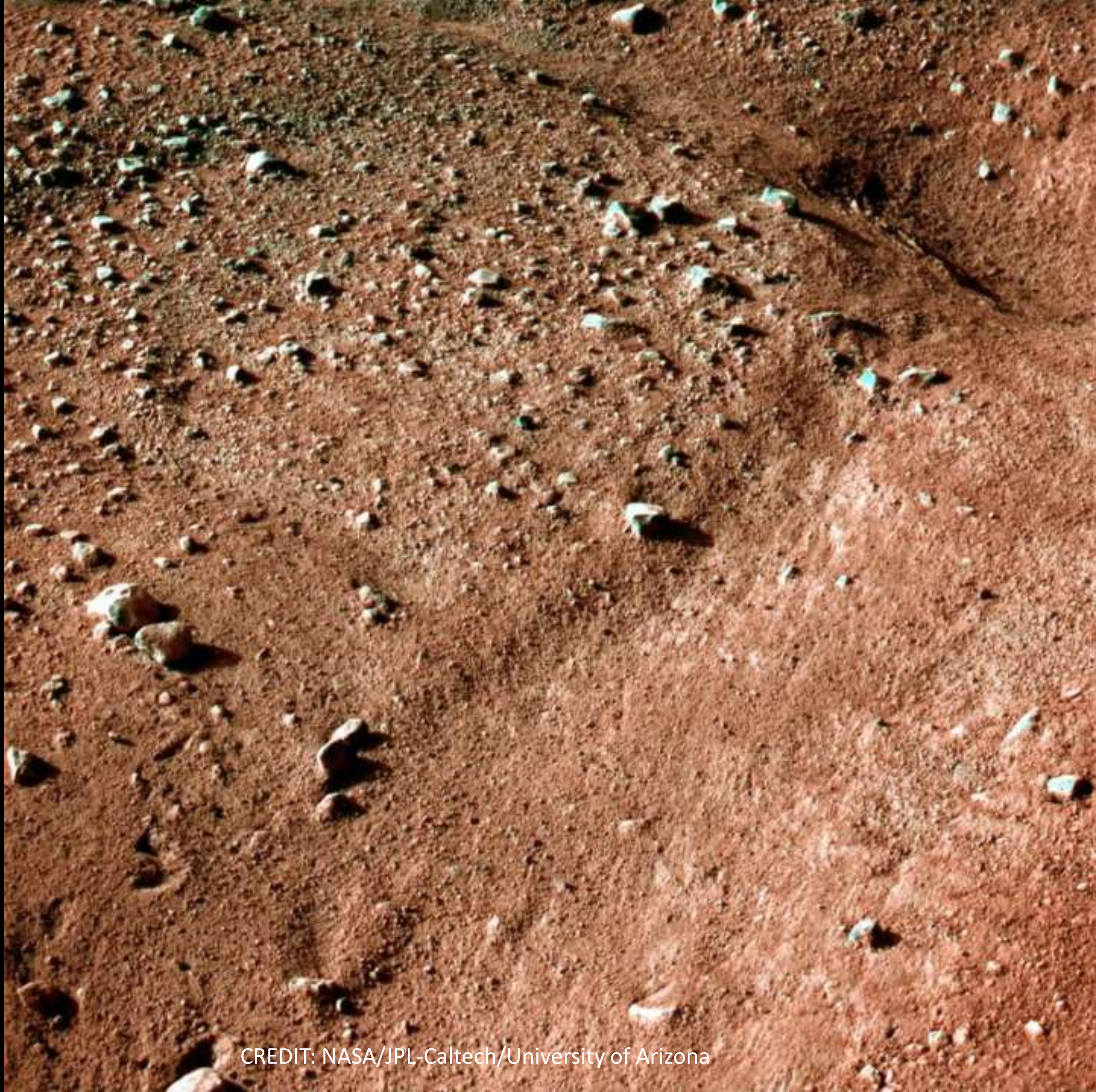
This 2004 "postcard from Mars," taken of the Gusev crater by the panoramic camera on the Mars Exploration Rover Spirit, looks to the north. The apparent slope of the horizon is due to the several-degree tilt of the lander deck. On the left, the circular topographic feature dubbed Sleepy Hollow can be seen along with dark markings that may be surface disturbances caused by the airbag-encased lander as it bounced and rolled to rest. A dust-coated airbag is prominent in the foreground, and a dune-like object that has piqued the interest of the science team with its dark, possibly armoured top coating, can be seen on the right.

The Columbia Hills are a range of low hills inside Gusev crater on Mars. They were observed by the Mars Exploration Rover Spirit when it landed within the crater in 2004. They were promptly given an unofficial name by NASA since they were the most striking nearby feature on the surface. The hills lie approximately 3 kilometres away from the rover's original landing position. The range is named to memorialize the Space Shuttle Columbia disaster. On February 2, 2004, the individual peaks of the Columbia Hills were named after the seven astronauts who died in the disaster. Spirit spent a few years exploring the Columbia Hills until it ceased to function in 2010

Phoenix 26th May 2008

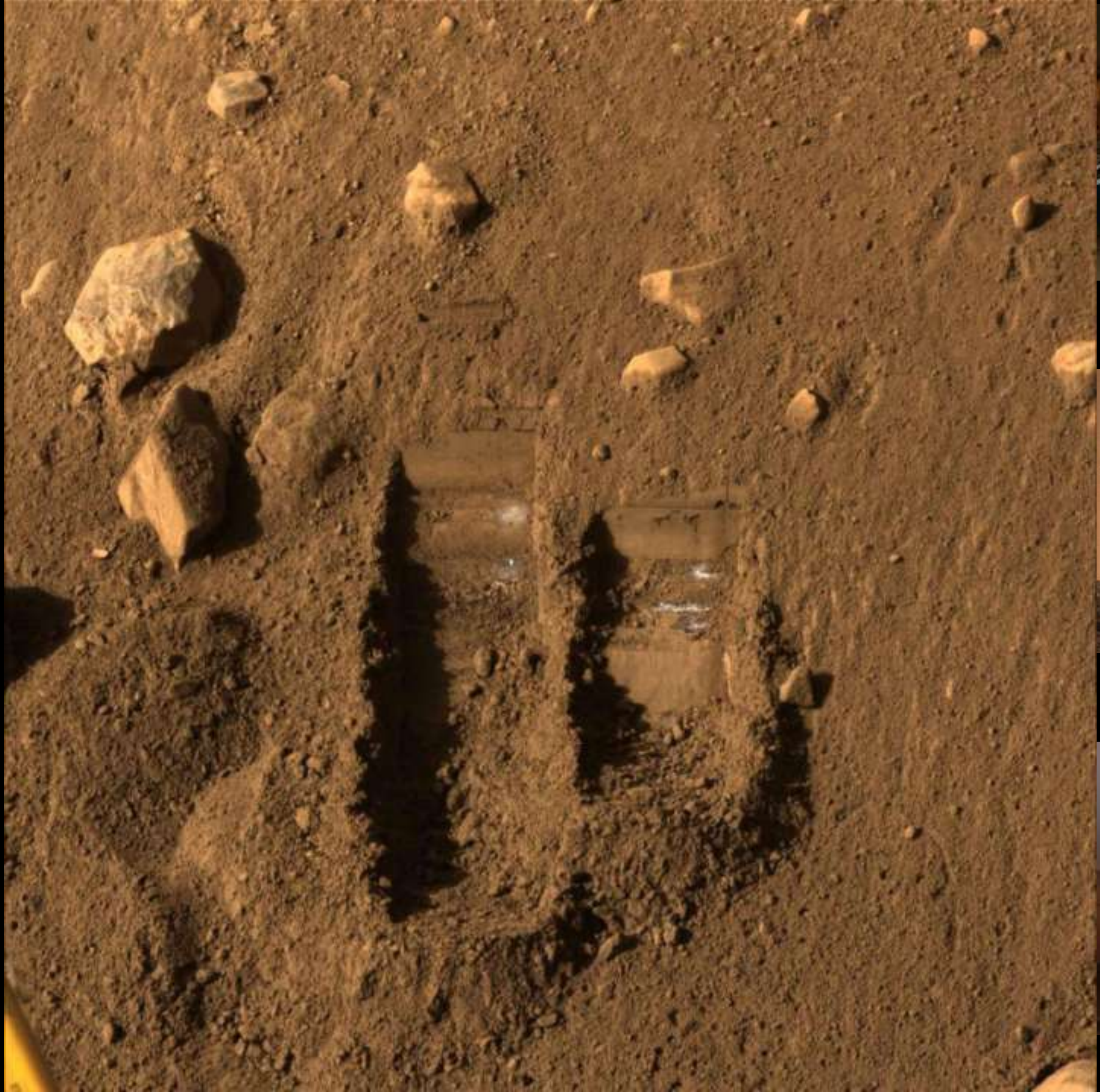
- This flat horizon stretches across the red planet as seen by the Phoenix spacecraft after landing on Mars.
- Touching down shortly after 7:30pm Eastern Time, Phoenix made the first successful soft landing on Mars, using rockets to control its final speed, since the Viking landers in 1976.
- Launched in August of 2007, Phoenix made its landing on Mars in the arctic plains region called Vastitas Borealis which at the time was the farthest north any spacecraft has landed on the Red Planet.
- Its mission was to explore the Martian arctic's potentially ice-rich soil.

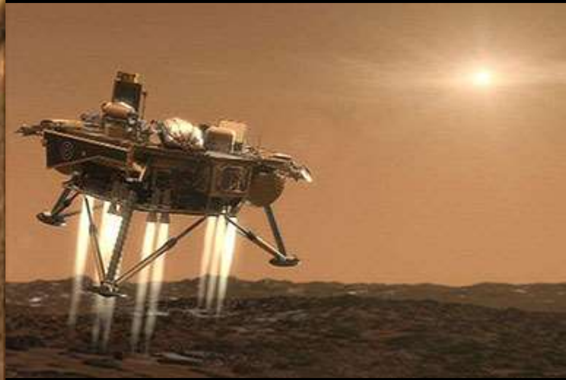




Trenches 2008

These two trenches were dug by the Robotic Arm of the Phoenix lander.
Its robotic arm was the first ever to touch and sample water on Mars. Not only did Phoenix discover ice in the ground but also snow! Its laser instrument, designed to study the planet's atmosphere, detected snow from clouds about 4 km above the spacecraft's landing site, but the snow vaporized before it touched the ground.





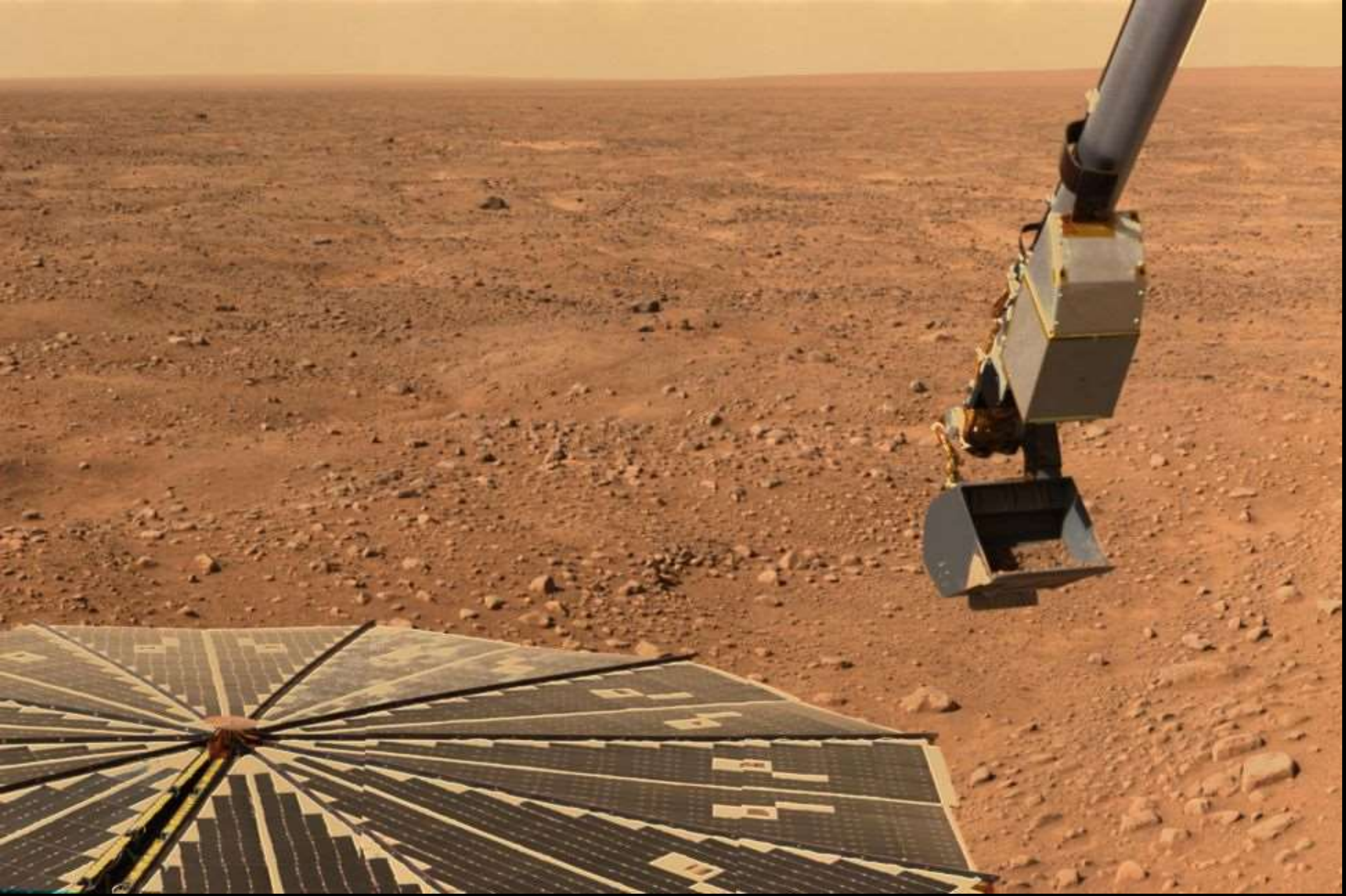


Image credit: NASA/JPL-Caltech/University of Arizona/Texas A&M University

NASA's Phoenix Mars Lander detected perchlorate salts (ClO_4^-) at a concentration of around 0.6%, in all 3 soil samples of the Martian arctic's ice-rich soil it sampled in 2008.

Acting as antifreeze, perchlorate salts lower the freezing point of water, resulting in ice turning into liquid watery brine for a few hours each day during the Martian summer.

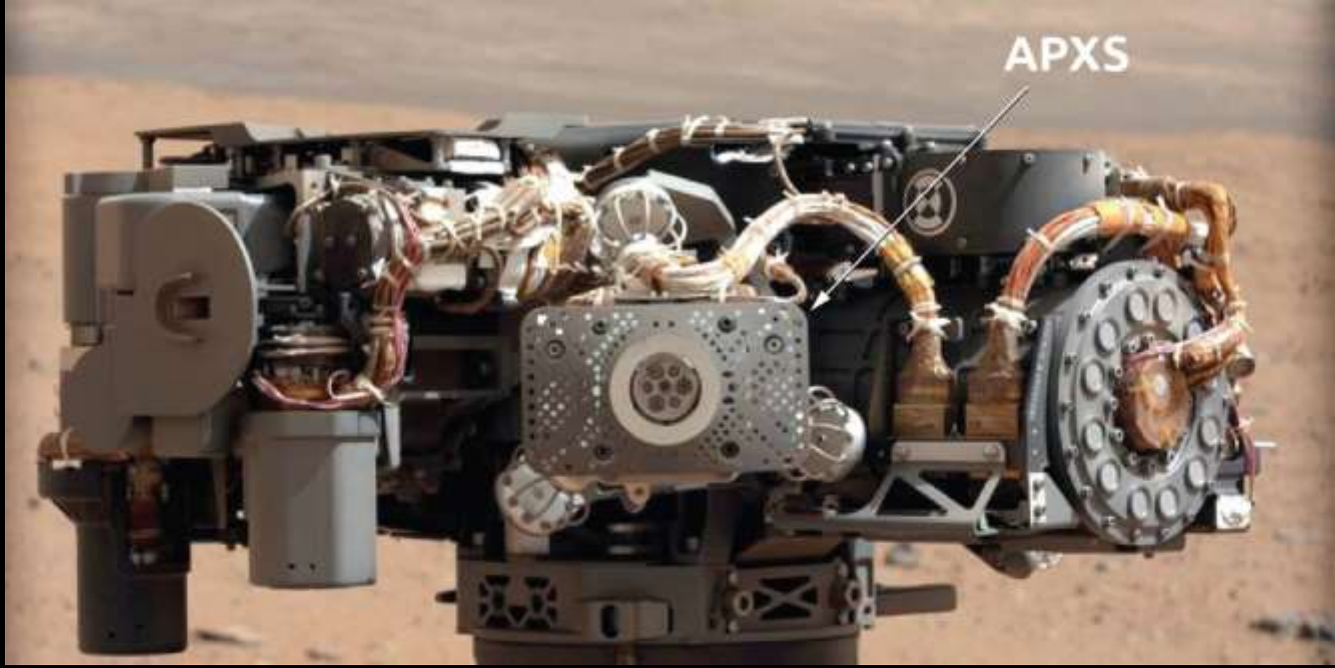
In the lab, perchlorates can be formed by UV light using only NaCl and silicate.

We now know that perchlorates are likely distributed throughout the entire Martian surface.

As concentrations are near 0.5%, these are biologically toxic levels, and would present a serious challenge to human settlement, as well as microorganisms. However, the perchlorates would provide a convenient source of oxygen for the settlements.

Curiosity is a car-sized Mars rover designed to explore the Gale crater on Mars as part of NASA's Mars Science Laboratory mission. Curiosity was launched from Cape Canaveral on 26 November 2011 and landed on Aeolis Palus (Mount Sharp) inside Gale crater on Mars on 6 August 2012

The Bradbury Landing site was less than 2.4 km from the centre of the rover's touchdown target after a 560 million km journey



The Alpha Particle X-Ray Spectrometer will measure the abundance of chemical elements in rocks and soils. Funded by the Canadian Space Agency, the APXS will be placed in contact with rock and soil samples on Mars and will expose the material to alpha particles and X-rays emitted during the radioactive decay of the element curium. X-rays are a type of electromagnetic radiation, like light and microwaves.

Alpha particles are helium nuclei, consisting of 2 protons and 2 neutrons. When X-rays and alpha particles interact with atoms in the surface material, they knock electrons out of their orbits, producing an energy release by emitting X-rays that can be measured with detectors. The X-ray energies enable scientists to identify all important rock-forming elements, from sodium to heavier elements.


Curiosity, 2013
The car-sized rover designed to explore Gale crater appears as a blue dot near the lower right corner of the image.

Late afternoon at Gale - Sol 49 - NASA/JPL-Caltech/D.Bouic - www.db-prods.net

Mount Sharp, 2012
This image shows the base of the Red Planet's Mount Sharp, officially Aeolis Mons, which rises 5.5 km from the valley floor.

Yellowknife Bay, 25th Dec 2012 Image from Curiosity right Mast Camera (Mastcam)
The rough spherical features in an area called Yellowknife Bay are interpreted as concretions, implying they were formed by water that oozed through pores in the sediment.

Image credit: NASA/JPL-Caltech/MSSS

Mount Sharp

Curiosity's view of "Mount Sharp" (September 9, 2015).

Curiosity's view of Mars sky at sunset (February 2013; Sun simulated by artist).

Mount Sharp Sunset

Mount Sharp, officially Aeolis Mons, is a mountain on Mars. It forms the central peak within Gale crater and is located around 5.08°S 137.85°E

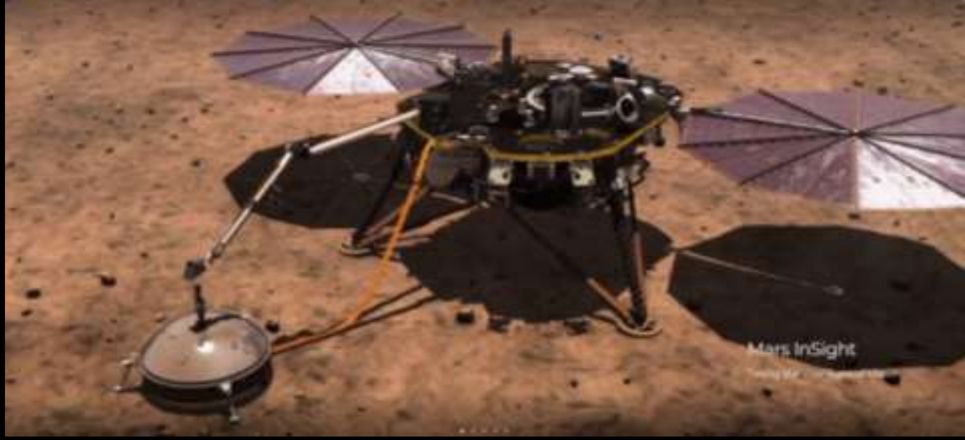
It rises 5.5 km (18,000 ft) high from the valley floor.

Credit: Curiosity's view of "Mount Sharp" (September 20, 2012; white balanced) (raw colour).

Rocks in "Hidden Valley" near the "Pahrump Hills" on the slopes of Aeolis Mons as viewed from Curiosity (September 11, 2014; white balanced).


Gale crater wall

The InSight lander 2018



The Insight Lander began its surface operations the minute it landed at Elysium Planitia on Mars in 2018, but science data collection did not start fully until about 10 weeks after landing. That's because InSight's science goals and instruments were very different from other Mars landers or rovers that have gone before. The lander team had to carefully select where to place the precious science instruments in direct contact with the surface of Mars. These instruments were the first to study the interior of Mars:

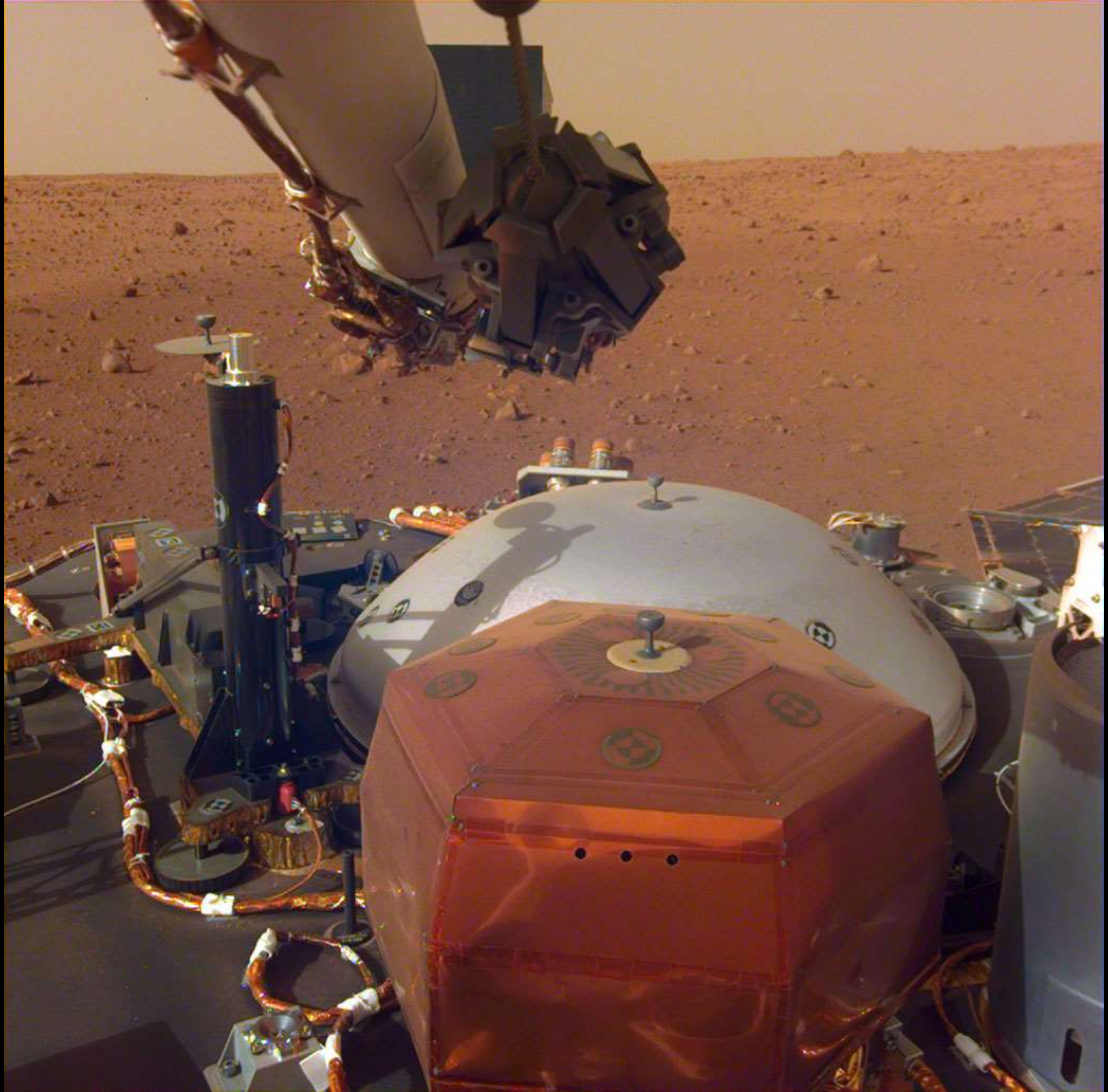
- Rotation and Interior Structure Experiment (RISE). Its job was to stay on the lander deck and trade X-band radio signals back and forth with Earth for an hour or so each day. It had to do this for about two years in order to detect subtle, slow changes in Mars' wobble. Watching the small changes in the signals as seen on Earth helped to answer questions about the nature of Mars' core.
- InSight's Heat Flow and Physical Properties Probe (HP3) "The mole"
  It is a small ground penetrator that implements a string of temperature sensors in the soil measure the thermal conductivity. Unfortunately, the penetrator only reached 40cm because of the presence of a cohesive duricrust of a few tens of centimetres thickness that failed to provide the required friction. To avoid the perturbation caused by annual surface temperature variations, the measurements need to be taken at a depth between 3 m and 5 m
- Insight's seismic Experiment for Interior Structure (SEIS) which has been very successful

Ref: Spohn et al 2022 "The InSight-HP3 mole on Mars: Lessons learned from attempts to penetrate to depth in the Martian soil" Advances in Space Research, Volume 69, Issue 8,2022,Pages 3140-3163,

Source:
NASA/JPL-Caltech
Published: 6th Dec 2018

InSight is a stationary science platform that landed on Mars on Nov. 26, 2018.

InSight's instrument deck and Elysium Planitia as seen from the spacecraft's robotic-arm mounted camera.



The InSight lander

To truly study the larger picture of the deep Martian interior, the radio science investigation and both primary science instruments (the Rotation and Interior Structure Experiment, RISE, SEIS and HP3) had to collect science data for at least one Mars year (about 23 Earth months). Once SEIS and HP3 were placed on the surface of Mars and science operations commenced, they had to remain stationary for the remainder of the mission.

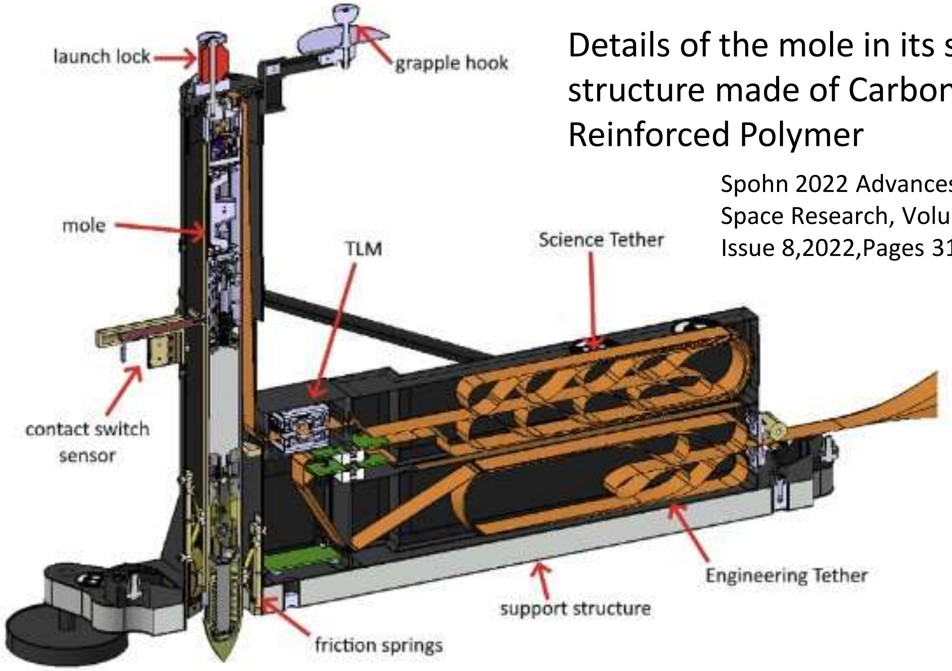
InSight has had both challenges and triumphs. Its burrowing "mole" wasn't able to work itself into the ground. The lander has had to limit science operations this year due to a thick covering of dust over its solar panels. But it has given scientists a new view of the planet's interior and tracked the activity of marsquakes.

The lander received a mission extension through the end of 2022. InSight's ultimate end date will depend on the ongoing dust issues.

Ref: Amanda Kooser https://www.cnet.com/science/space/nasa

Spohn et al 2022 "The InSight-HP3 mole on Mars: Lessons learned from attempts to penetrate to depth in the Martian soil" Advances in Space Research, Volume 69, Issue 8,2022,Pages 3140-3163,

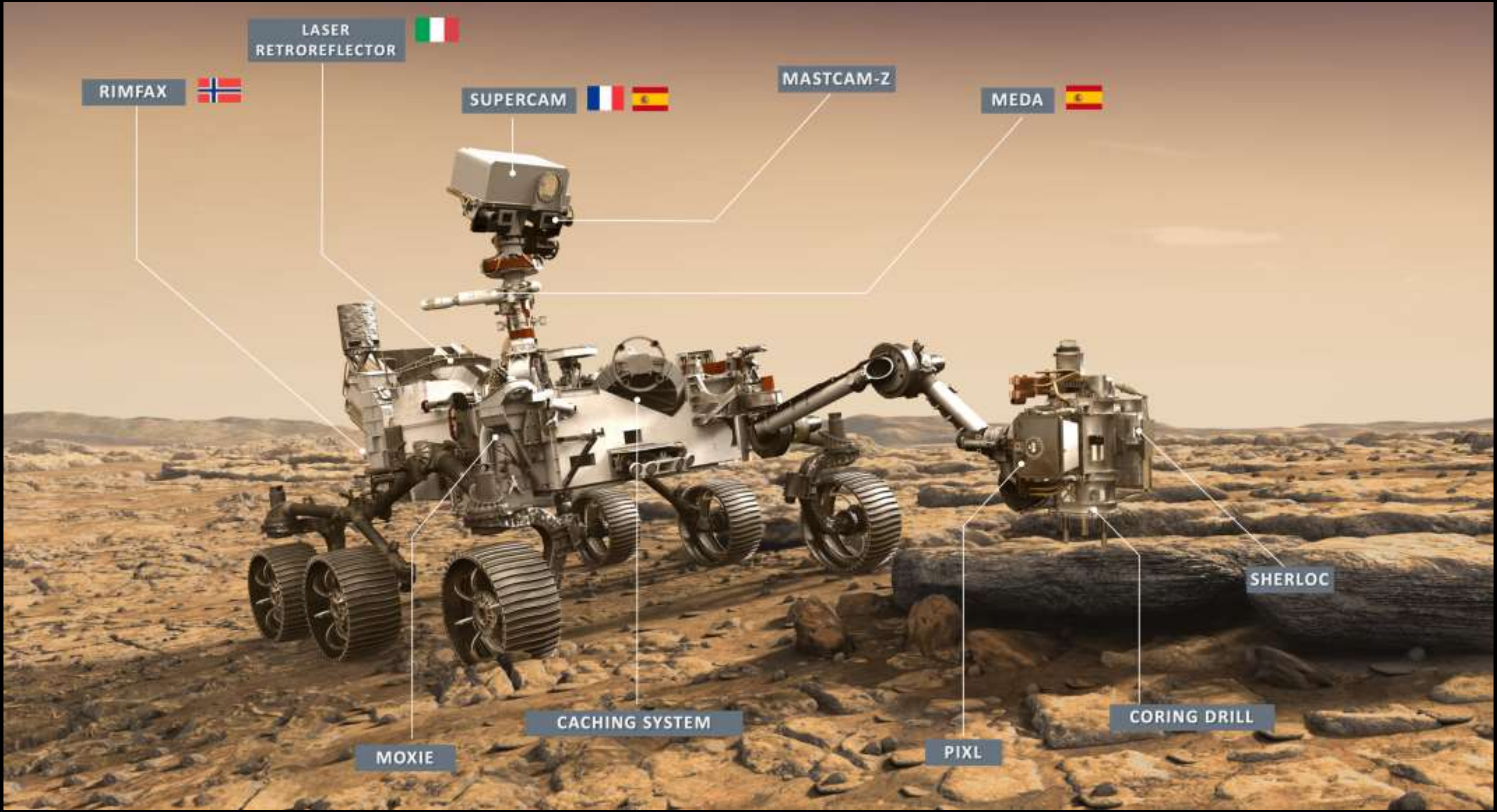
Sunrise image taken by Insight lander on April 10, 2022.
NASA/JPL-Caltech



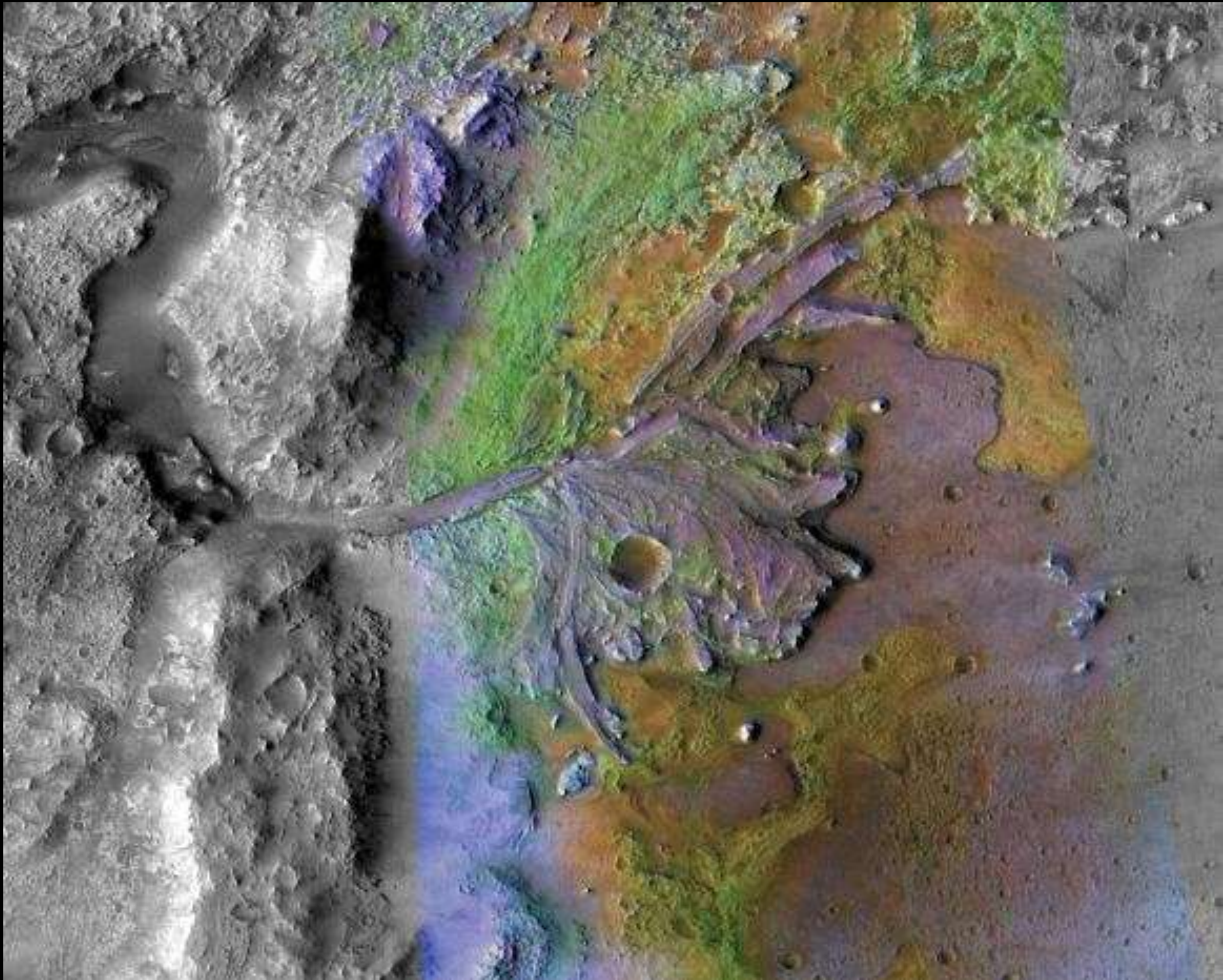
Details of the mole in its support structure made of Carbon Fiber Reinforced Polymer

Spohn 2022 Advances in Space Research, Volume 69, Issue 8,2022,Pages 3140-3163

18th Feb 2021 Perseverance lands on Mars




Credit: NASA/JPL-Caltech



Jezero Crater on Mars is the landing site for NASA’s Perseverance rover.
Credit: NASA/JPL-Caltech/ASU

- Mars is one of the most explored bodies in our solar system, and it's the only planet where we've sent rovers to roam the alien landscape.
- NASA currently has two rovers (Curiosity and Perseverance), one lander (InSight), and one helicopter (Ingenuity) exploring the surface of Mars.
- Perseverance rover – the largest, most advanced rover NASA has sent to another world – touched down on Mars on Feb. 18, 2021, after a 203-day journey traversing 472 million kilometers. The Ingenuity helicopter rode to Mars attached to the belly of Perseverance.
- Perseverance is one of three spacecraft that arrived at Mars in 2021. The Hope orbiter from the United Arab Emirates arrived on Feb. 9, 2021. China's Tianwen-1 mission arrived on Feb. 10, 2021, and includes an orbiter, a lander, and a rover. Europe and India also have spacecraft studying Mars from orbit.
- Mars is a dusty, cold, desert world with a very thin atmosphere. There is strong evidence Mars was—billions of years ago—wetter and warmer, with a thicker atmosphere.

Perseverance, nicknamed Percy, is a car-sized Mars rover designed to explore the crater Jezero on Mars as part of NASA's Mars 2020 mission. It was manufactured by the Jet Propulsion Laboratory and launched on 30 July 2020. Confirmation that the rover successfully landed on Mars was received on 18 February 2021.

As of 30 April 2022, Perseverance has been active on Mars for 424 sols (436 Earth days) since its landing. Following the rover's arrival, NASA named the landing site Octavia E. Butler Landing.

Perseverance has a similar design to its predecessor rover, Curiosity, from which it was moderately upgraded. It carries seven primary payload instruments, nineteen cameras, and two microphones.

The rover also carried the mini-helicopter Ingenuity to Mars, an experimental aircraft and technology testbed that made the first powered flight on another planet on 19 April 2021. As of April 21, 2022, it has made 26 successful flights. Ingenuity's 25th successful flight, which occurred on April 8, 2022, saw the helicopter set new records for highest speed and distance travelled during a single flight.

The rover's goals include identifying ancient Martian environments capable of supporting life, seeking out evidence of former microbial life existing in those environments, collecting rock and soil samples to store on the Martian surface, and testing oxygen production from the Martian atmosphere to prepare for future crewed missions.

March 17, 2022

Credit: NASA/JPL-Caltech/ASU/MSSS

- NASA's Perseverance Mars rover looks out at an expanse of boulders on the landscape in front of a location nicknamed "Santa Cruz" on Feb. 16, 2022, the 353rd Martian day, or sol, of the mission.
- This panorama is made up 24 individual images from the rover's Mastcam-Z camera system stitched together after they were sent back from Mars.
- A key objective for Perseverance's mission on Mars is astrobiology, including the search for signs of ancient microbial life. The rover will characterize the planet's geology and past climate, pave the way for human exploration of the Red Planet, and be the first mission to collect and cache Martian rock and regolith (broken rock and dust).
- Subsequent NASA missions, in cooperation with ESA (European Space Agency), would send spacecraft to Mars to collect these sealed samples from the surface and return them to Earth for in-depth analysis.
- The Mars 2020 Perseverance mission is part of NASA's Moon to Mars exploration approach, which includes Artemis missions to the Moon that will help prepare for human exploration of the Red Planet.

https://mars.nasa.gov/resources/26616/perseverance-looks-toward-santa-cruz/

Perseverance’s Landing Gear

A helicopter surveying Mars for NASA has beamed home an eerie image of the wreckage of the landing gear that protected the drone through its fiery descent to the red planet.

Key points:

•The drones entered Mars's atmosphere at more than 20,000kph

•A parachute acted as a brake and a backshell protected the drones on impact with the surface

•The helicopter and rover are a duo team seeking to return with signs of life on Mars

NASA's Ingenuity helicopter landed on Mars in February 2021 with the Perseverance rover for a combined land-and-sky surveillance mission.

The unprecedented images show the parachute and cone-shaped backshell that protected the equipment as it made its high-speed impact on the surface of Mars.

Looking at the upright backshell and debris that resulted from it impacting the surface at over 120kph, NASA scientists say the backshell's protective coating appears to have remained intact during the 20,000kph entry into Mars's atmosphere.

Mars in 2018

Apparent brightness increases as Mars gets closer to Earth

May

apparent magnitude

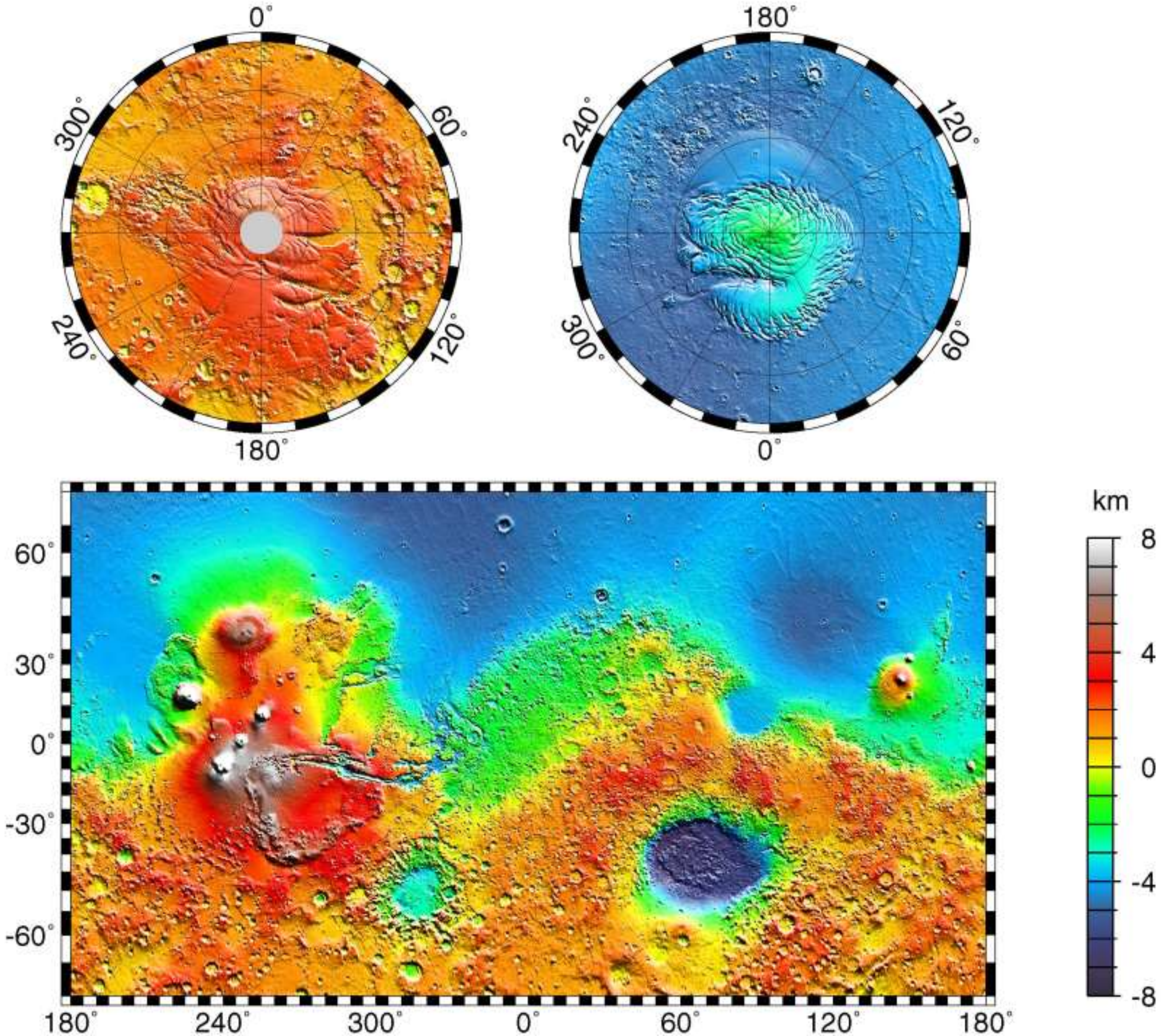
-0.5

July 31 (closest to Earth)

apparent magnitude

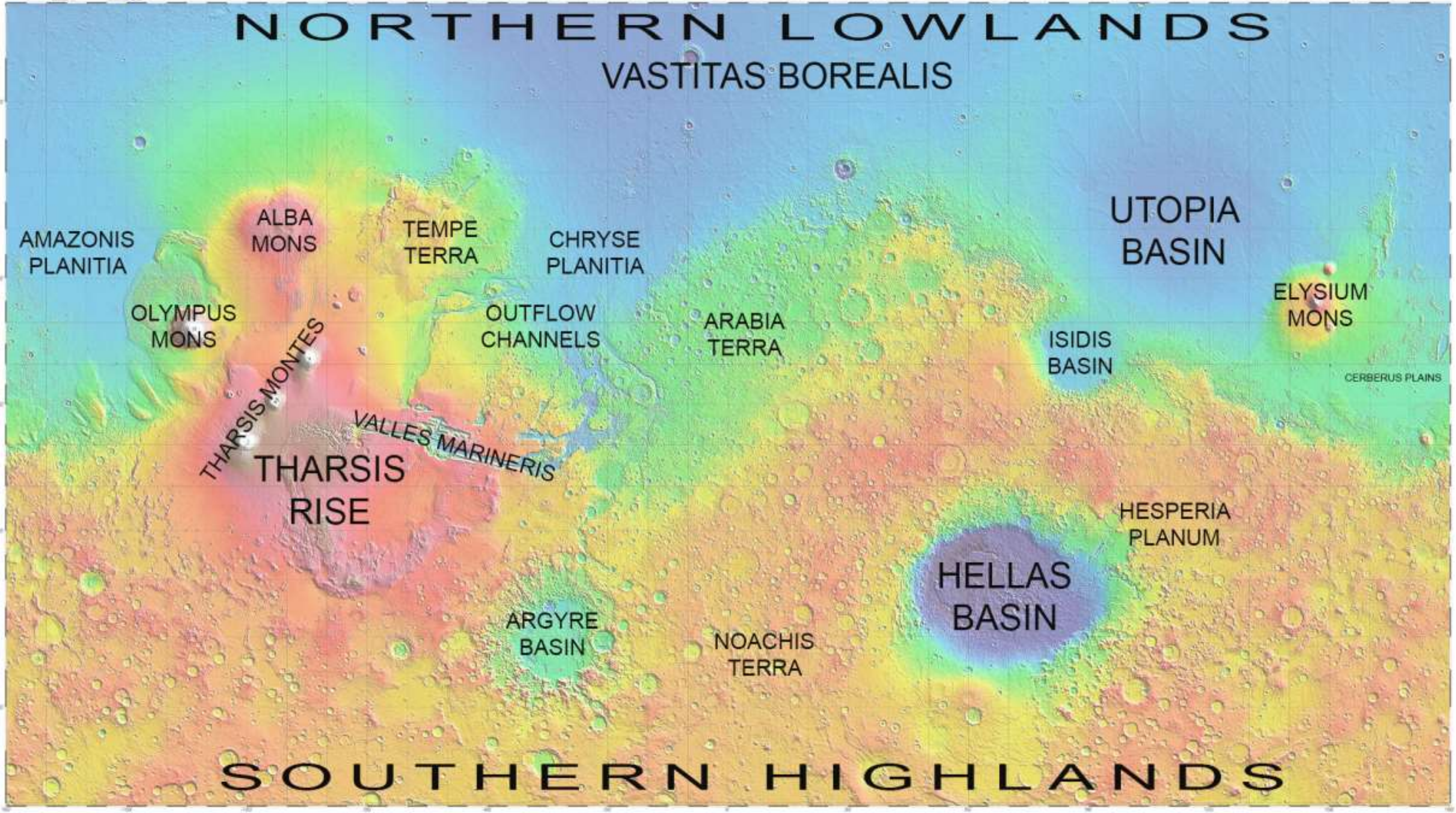
-2.7 (much brighter)

Martian Map



Maps of Mars' global topography. The projections are Mercator to 70° latitude and stereographic at the poles with the south pole at left and north pole at right. Note the elevation difference between the northern and southern hemispheres. The Tharsis volcano-tectonic province is centered near the equator in the longitude range 220° E to 300° E and contains the vast east-west trending Valles Marineris canyon system and several major volcanic shields including Olympus Mons (18° N, 225° E), Major impact basins include Hellas (45° S, 70° E),

THE TOPOGRAPHY OF MARS BY THE MARS ORBITER LASER ALTIMETER (MOLA)



CLOUDS ON MARS

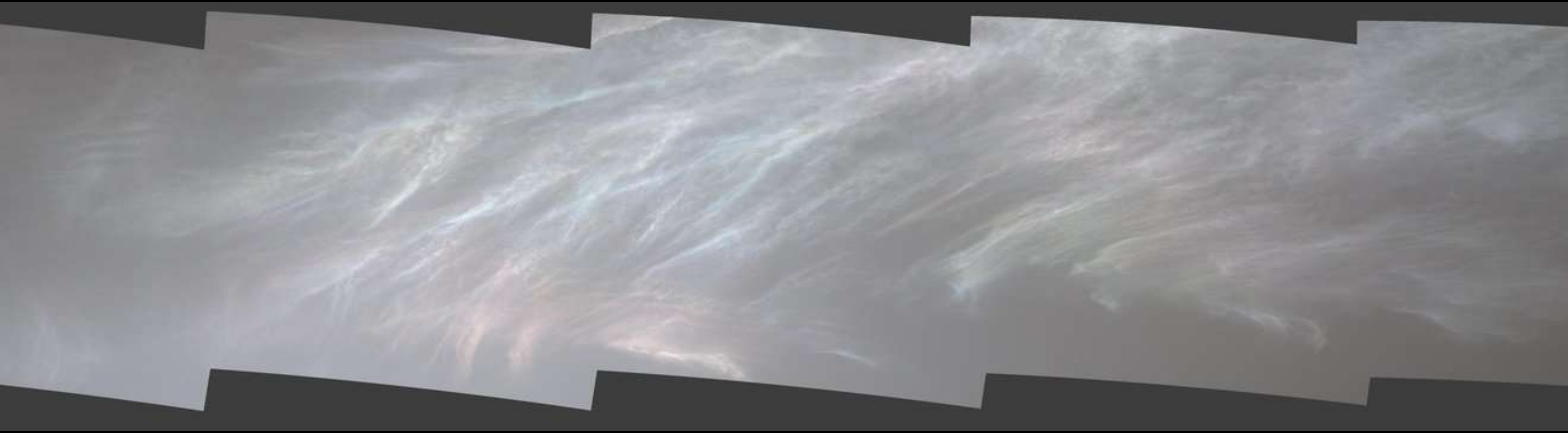
NASA's Curiosity Rover Captures Shining Clouds on Mars
May 28, 2021 Jet Propulsion Laboratory California Institute of Technology

Cloudy days are rare in the thin, dry atmosphere of Mars. Clouds are typically found at the planet's equator in the coldest time of year, when Mars is the farthest from the Sun in its oval-shaped orbit. But one full Martian year ago – two Earth years – scientists noticed clouds forming over NASA's Curiosity rover earlier than expected.

In 2021, they were ready to start documenting these "early" clouds from the moment they first appeared in late January. What resulted are images of wispy puffs filled with ice crystals that scattered light from the setting Sun, some of them shimmering with colour. More than just spectacular displays, such images help scientists understand how clouds form on Mars and why these recent ones are different.

In fact, Curiosity's team has already made one new discovery: The early-arrival clouds are actually at higher altitudes than is typical. Most Martian clouds hover no more than about 60 kilometers in the sky and are composed of water ice. But the clouds Curiosity has imaged are at a higher altitude, where it's very cold, indicating that they are likely made of frozen carbon dioxide, or dry ice. Scientists look for subtle clues to establish a cloud's altitude, and it will take more analysis to say for sure which of Curiosity's recent images show water-ice clouds and which show dry-ice ones.

Credit: NASA/JPL-Caltech/MSSS



NASA's Curiosity Mars rover spotted these iridescent, or "mother of pearl," clouds on March 5, 2021, the 3,048th Martian day, or sol, of the mission. Seen here are five images stitched together from a much wider panorama taken by the rover's Mast Camera, or Mastcam. Credit: NASA/JPL-Caltech/MSSS

Frozen Carbon Dioxide (dry ice) Seasonal Changes on Mars

Sand dune, 2014

These are Mars' northern-most sand dunes and can be seen as they emerge from a winter cover of seasonal carbon dioxide (dry) ice.

CREDIT NASA/JPL-Caltech/Univ. of Arizona


Image credit: NASA/JPL-Caltech/Univ. of Arizona

2017

Being summer for Mars' South Pole, the Sun was low enough in the sky to accentuate shadows over the landscape, making subtle features pop right out. Yet a few rays of light were still able to reveal ice at the bottom of the hole.
Surrounding the pit, patches frozen carbon dioxide could be seen. The circles in the ice were thought to be where the dry ice had sublimated into gas in the summer sunshine, leaving what astronomers have called "Swiss Cheese terrain".

The You'd think NASA's Mars Reconnaissance Orbiter (MRO) has seen everything there is to see on the Martian surface, since 2006 it's orbited our nearest neighbour. This image was taken using the MRO's High Resolution Imaging Science Experiment, or HiRISE camera, which allows researchers to see objects on Mars that are larger than one metre (about 3 feet) in size from about 200 to 400 kilometres (about 125 to 250 miles) above.
That means the pit isn't tiny – at 50 centimetres (19.7 inches) per pixel, we're looking at a feature hundreds of metres across!

The night sky from Mars

2019 NASA's InSight lander used the Instrument Deployment Camera (IDC) on the end of its robotic arm to image this sunset. A small, dim sun hangs near the Martian horizon. This colour-corrected version more accurately shows the image as the human eye would see it.
Image credit: NASA/JPL-Caltech

Credit:
NASA/JPL-Caltech/MSSS
Curiosoty
Night sky
image

This image of Phobos was taken by Mast Camera (Mastcam) onboard NASA's Mars rover Curiosity on Sol 613 (2014-04-28 04:47:18 UTC).

Image Credit: NASA/JPL-Caltech/MSSS

The Martian Moons

Credit: https://mars.nasa.gov/all-about-mars/moons/summary/

The two moons of Mars are Phobos and Deimos. They are irregular in shape. Both were discovered by American astronomer Asaph Hall in August 1877 and are named after the Greek mythological twin characters Phobos (fear and panic) and Deimos (terror and dread) who accompanied their father Ares into battle. Ares, god of war, was known to the Romans as Mars.

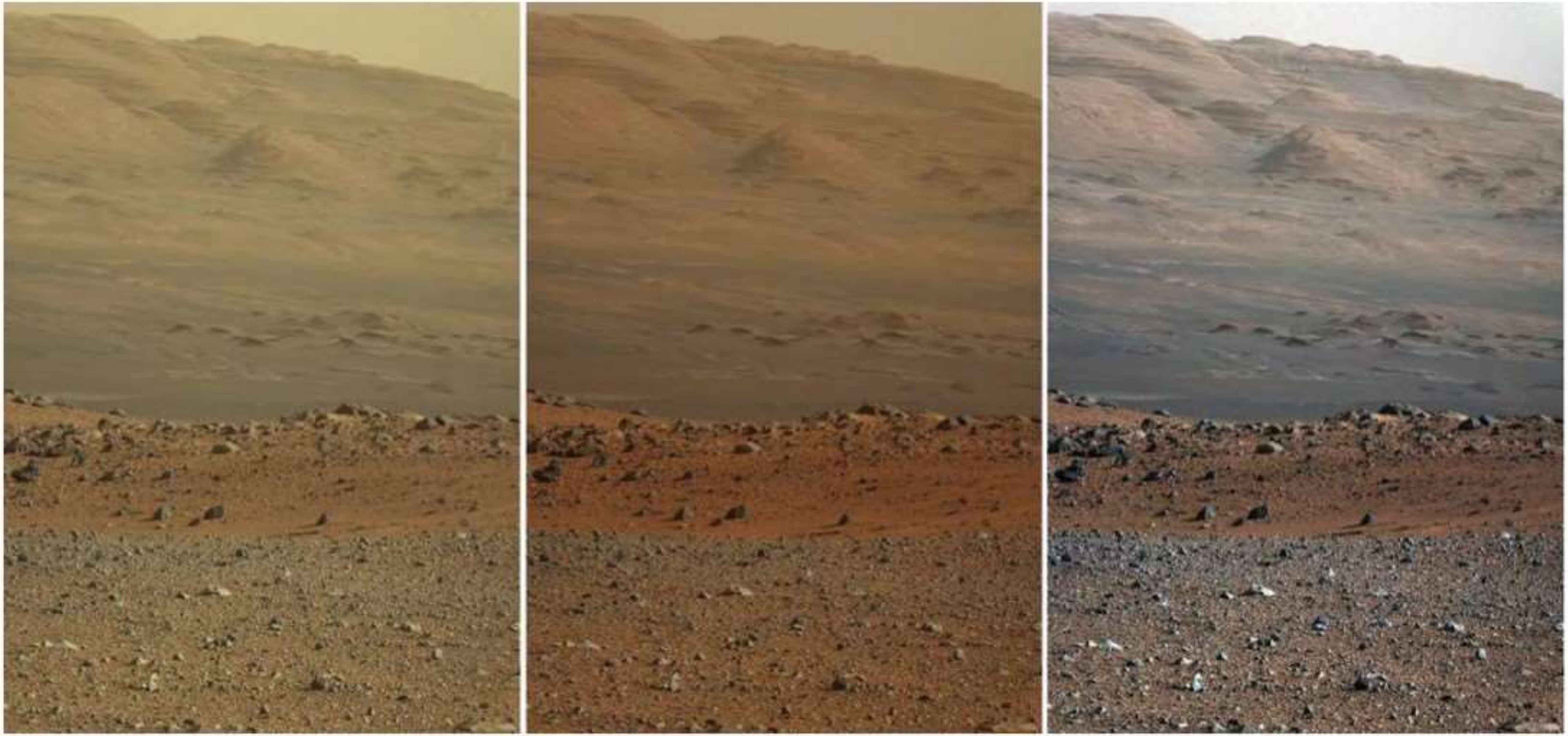
Compared to the Earth's Moon, the moons Phobos and Deimos are small.

- Phobos has a diameter of 22.2 km and a mass of 1.08×1016 kg, while Deimos measures 12.6 km (7.8 mi) across, with a mass of 2.0×1015 kg.
- Phobos orbits closer to Mars, with a semi-major axis of 9,377 km and an orbital period of 7.66 hours, approximately 3x faster than a days rotation of Mars (24.077hours) while Deimos orbits farther with a semi-major axis of 23,460 km and an orbital period of 30.35 hours.

Source: Wikipedia

Detailed view of Phobos, one of the two moons of Mars.
Taken by the HiRISE camera onboard NASA's Mars Reconnaissance Orbiter.

What is the colour of the Martian sky?



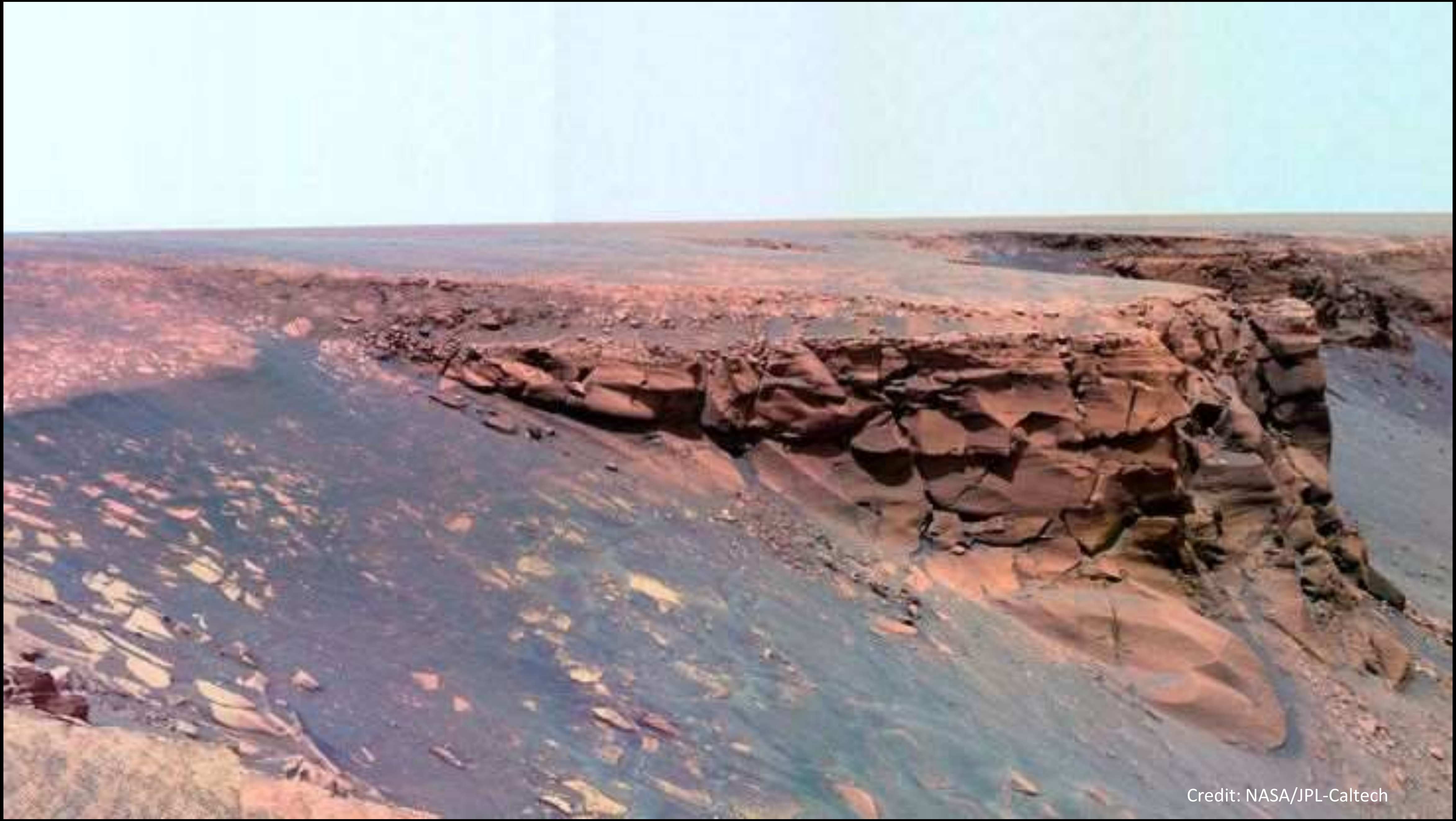
Unprocessed Color (JPL Web site)
(raw data from Mars, uncalibrated)

"Natural" Color
(uses calibrated data)

"White Balanced" Color
(Assumes something in the scene is white)

For explanation see http://serious-science.org/what-color-is-the-sky-on-mars-7310

Credits: NASA/JPL-Caltech/Cornell/Arizona State Univ.


Credit: NASA/JPL-Caltech

Canyons on Mars

The largest canyon in the Solar System cuts a wide swath across the face of Mars. Named Valles Marineris, the grand valley extends over 3,000 kilometers long, spans as much as 600 kilometers across, and delves as much as 8 kilometers deep. By comparison, the Earth's Grand Canyon in Arizona, USA is 800 kilometers long, 30 kilometers across, and 1.8 kilometers deep. The origin of the Valles Marineris remains unknown, although a leading hypothesis holds that it started as a crack billions of years ago as the planet cooled. Recently, several geologic processes have been identified in the canyon.

The image on the left of Valles Marineris, is a 3D image based on satellite data. Perspective view of Melas Chasma, one of the main canyons forming part of Valles Marineris

The image on the right is a mosaic created from over 100 images of Mars taken by Viking Orbiters in the 1970s.

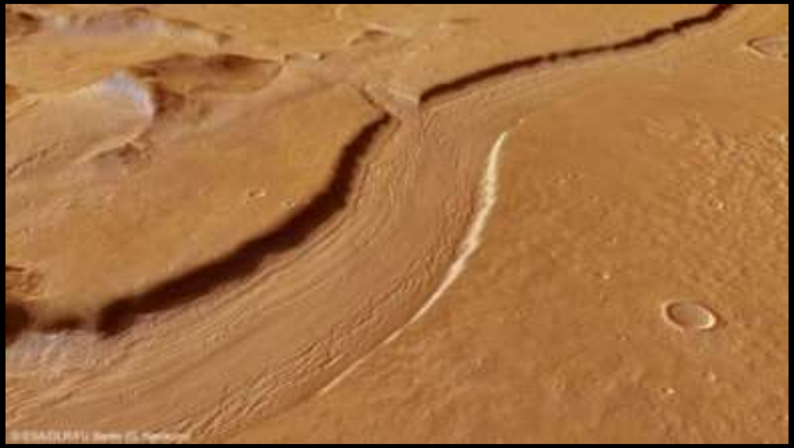
One of the first images taken by Mars Express in 2004 of Reull Vallis.
Credit: Credit: ESA/DLR/FU Berlin (G. Neukum)

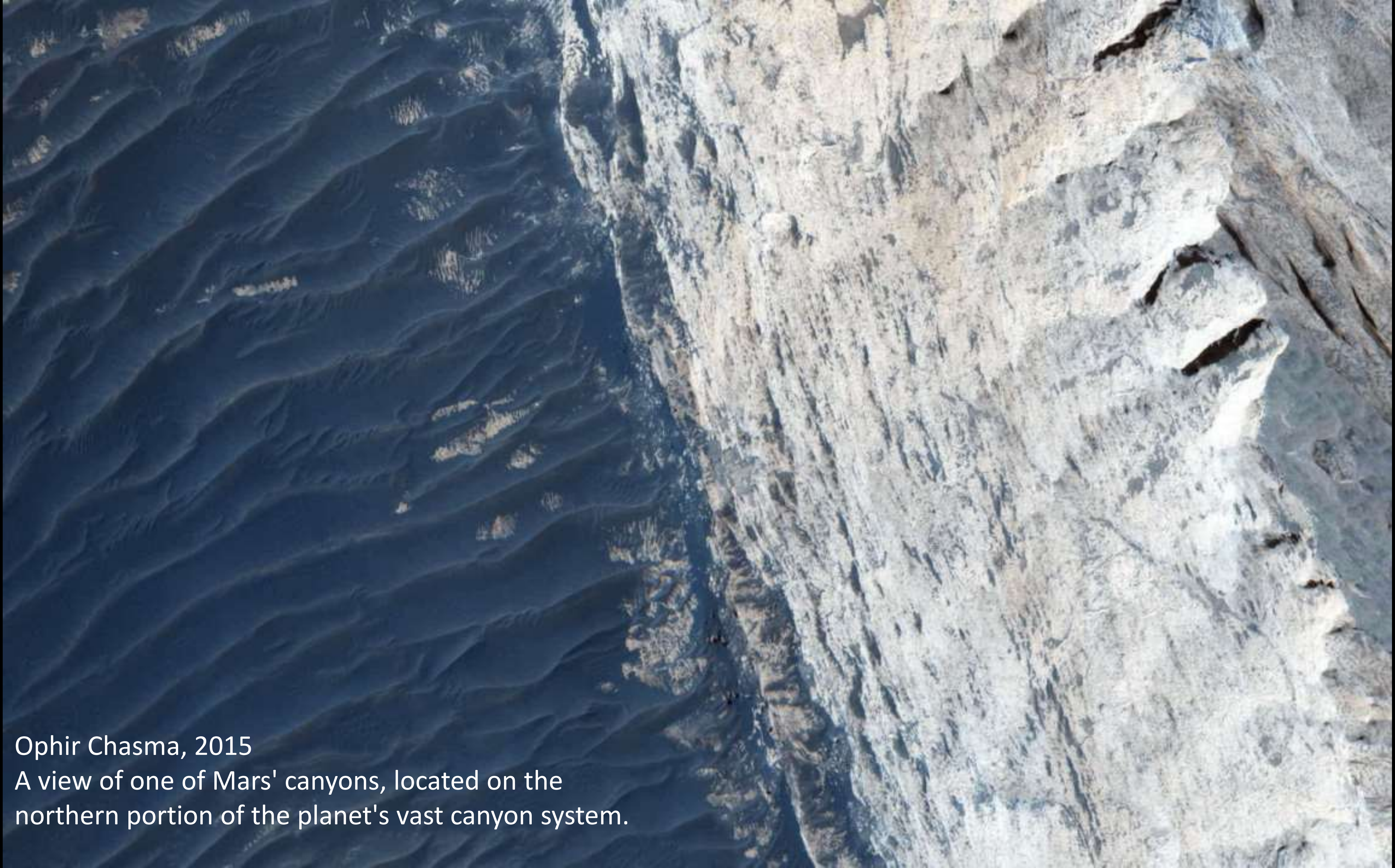
This VIS image shows a short section of Reull Vallis. Reull Vallis starts in Promethei Terra and empties into Hellas Plainitia. On the floor of this channel are ridged and grooved materials that seem to deflect around obstacles. These features are proposed to be ice-rich materials similar to glaciers on Earth. Reull Vallis is 1051km long. This winding depression is 6-10 km wide, and its depth varies from 100-600 meters.

Orbit Number: 83958 Latitude: -40.8313 Longitude: 108.188 Instrument: VIS

Captured: 2020-11-17 09:14

Credit: NASA/JPL-Caltech/ASU





Ophir Chasma, 2015
A view of one of Mars' canyons, located on the northern portion of the planet's vast canyon system.


Noctis Labyrinthus, 2013
Perched high on the Tharsis rise in the upper reaches of Valles Marineris,
this region is notable for its maze-like system of deep, steep-walled valleys.

Meteorites on Mars

January 19, 2005

Opportunity found an iron meteorite on Mars, the first meteorite of any type ever identified on another planet. The pitted, basketball-size object is mostly made of iron and nickel. Readings from spectrometers on the rover determined that composition. Opportunity used its panoramic camera to take the images used in this approximately true-colour composite on the rover's 339th martian day, or sol (Jan. 6, 2005). This composite combines images taken through the panoramic camera's 600-nanometer (red), 530-nanometer (green), and 480-nanometer (blue) filters.

Craters on Mars

- Impact craters generally have a rim with ejecta around them, in contrast Volcanic craters usually do not have a rim or ejecta deposits.
- As craters get larger (greater than 10 km in diameter) they usually have a central peak.
- The peak is caused by a rebound of the crater floor following the impact. If one measures the diameter of a crater, the original depth can be estimated with various ratios.
- Because of this relationship, researchers have found that many Martian craters contain a great deal of material; much of it is believed to be ice deposited when the climate was different.
- Sometimes craters expose layers that were buried. Rocks from deep underground are tossed onto the surface.
- Hence, craters can show us what lies deep under the surface.

Source: Wikipedia

This topographic map was created using Mars Orbiter Laser Altimeter (MOLA) technology on the Mars Global Surveyor spacecraft. This image is a screenshot of RedMapper's website and shows the rim and centre of Escalante crater This map show the relative elevation in 100 meter elevation contour lines (dashed) and 500 meter elevation contour lines (bold) with a total elevation uncertainty of +/- 6 meter

Author: Tyler Ray 2019
Wikimedia Commons, the free media repository

Source: http://photojournal.jpl.nasa.gov/catalog/PIA17932.

A dramatic, fresh impact crater dominates this image taken by the High Resolution Imaging Science Experiment (HiRISE) camera on NASA's Mars Reconnaissance Orbiter on Nov. 19, 2013.

Space rocks hitting Mars excavate fresh craters at a pace of more than 200 per year.

The image from the High Resolution Imaging Science Experiment (HiRISE) camera on NASA's Mars Reconnaissance Orbiter shows a crater about 100 feet (30 meters) in diameter at the centre of a radial burst painting the surface with a pattern of bright and dark tones.

IN 2008 NASA's Opportunity rover returned its first photos of Victoria Crater at Meridiani Planum on Mars. The "Duck Bay" alcove is nearby

The rover relayed tantalizing glimpses of the huge impact crater after a lengthy day-by-day grind across the Martian landscape that ended up being a 20-month journey to reach the destination.

The initial images, stitched into a black-and-white panorama, show rugged walls with layers of exposed rock. The floor is shown to be blanketed with dunes, as researchers already knew. The far wall is about 1 kilometer away.


Acidalia Planitia, 2015
This plain serves as the fictional landing site of a crewed mission named Ares 3 in the best-selling novel and film 'The Martian.'
Image credit: NASA/JPL-Caltech/Univ. of Arizona

Victoria crater, 2006

The impact crater located in the Meridiani Planum plain is roughly 730m wide and named after one of Ferdinand Magellan's five ships, the first to circumnavigate the globe.

Image Credit: NASA/JPL/UA

Victoria Crater from Cape Verde. Original caption from NASA: This true colour composite image taken by the panoramic camera on the Mars Exploration Rover Opportunity shows the view of Victoria Crater from Cape Verde. Since reaching the crater on Sol 951 (September 27, 2006) Opportunity has been making its way around the rim in a clockwise direction. Victoria Crater is roughly 800 meters (one-half mile) wide

It was captured over a three-week period, from October 16 – November 6, 2006.

Source: NASA/JPL-Caltech/Cornell - http://marswatch.astro.cornell.edu/pancam_instrument/991B_cape_verde.html / http://photojournal.jpl.nasa.gov/catalog/PIA09104

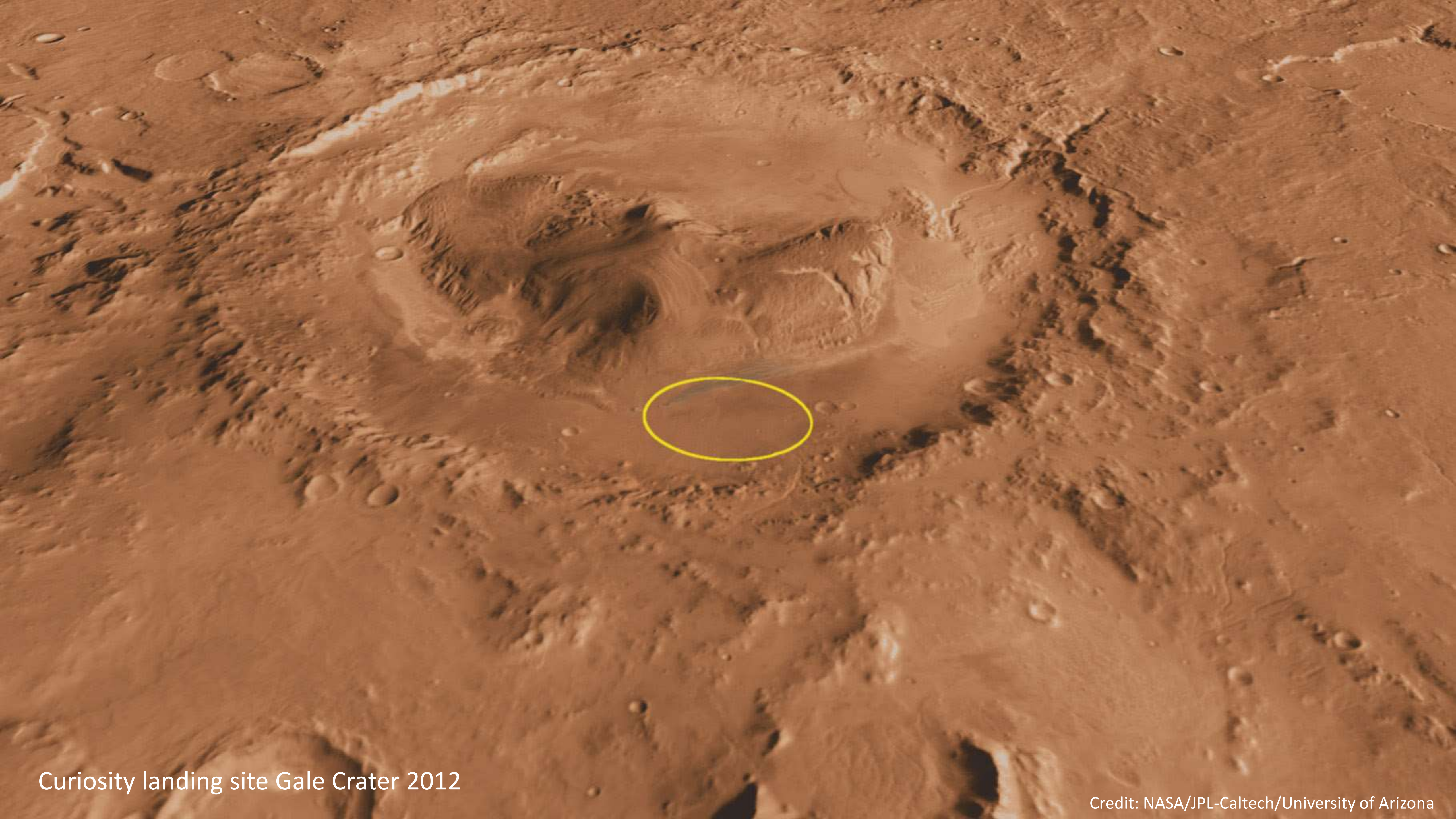
The Gale Crater

Gale Crater formed when a meteor hit Mars in its early history, about 3.5 to 3.8 billion years ago. The meteor impact punched a hole in the terrain.
Gale Crater spans 154 kilometers in diameter and holds a mountain, Aeolis Mons(which is informally named “Mount Sharp”).

At 10:32 p.m. PDT on Aug. 5, 2012 (1:32 a.m. EDT on Aug. 6, 2012), the Mars Science Laboratory rover, Curiosity, landed on Mars at 4.5 degrees south latitude, 137.4 degrees east longitude, at the foot of a layered mountain inside Gale Crater. The crater is named for Australian astronomer Walter F. Gale (1865-1945).

The Curiosity rover landed at the foot of a layered mountain within this massive crater. The portion of the crater where Curiosity landed has an alluvial fan likely formed by water-carried sediments. The layers at the base of the mountain contain clays and sulfates, both known to form in water. Curiosity will go beyond the "follow-the-water" strategy of recent Mars exploration

Credit: NASA/JPL-Caltech


Curiosity landing site Gale Crater 2012
Credit: NASA/JPL-Caltech/University of Arizona

Gale crater, 2013

Estimated to be between 3.5 and 3.8 billion years old, this crater is probably also a dry lake near the north western part of the Aeolis quadrangle.

Gale crater, 2012

Pictured is part of Gale crater's wall where a network of valleys believed to have formed by water erosion enters the crater from the outside.

Hellas Planitia

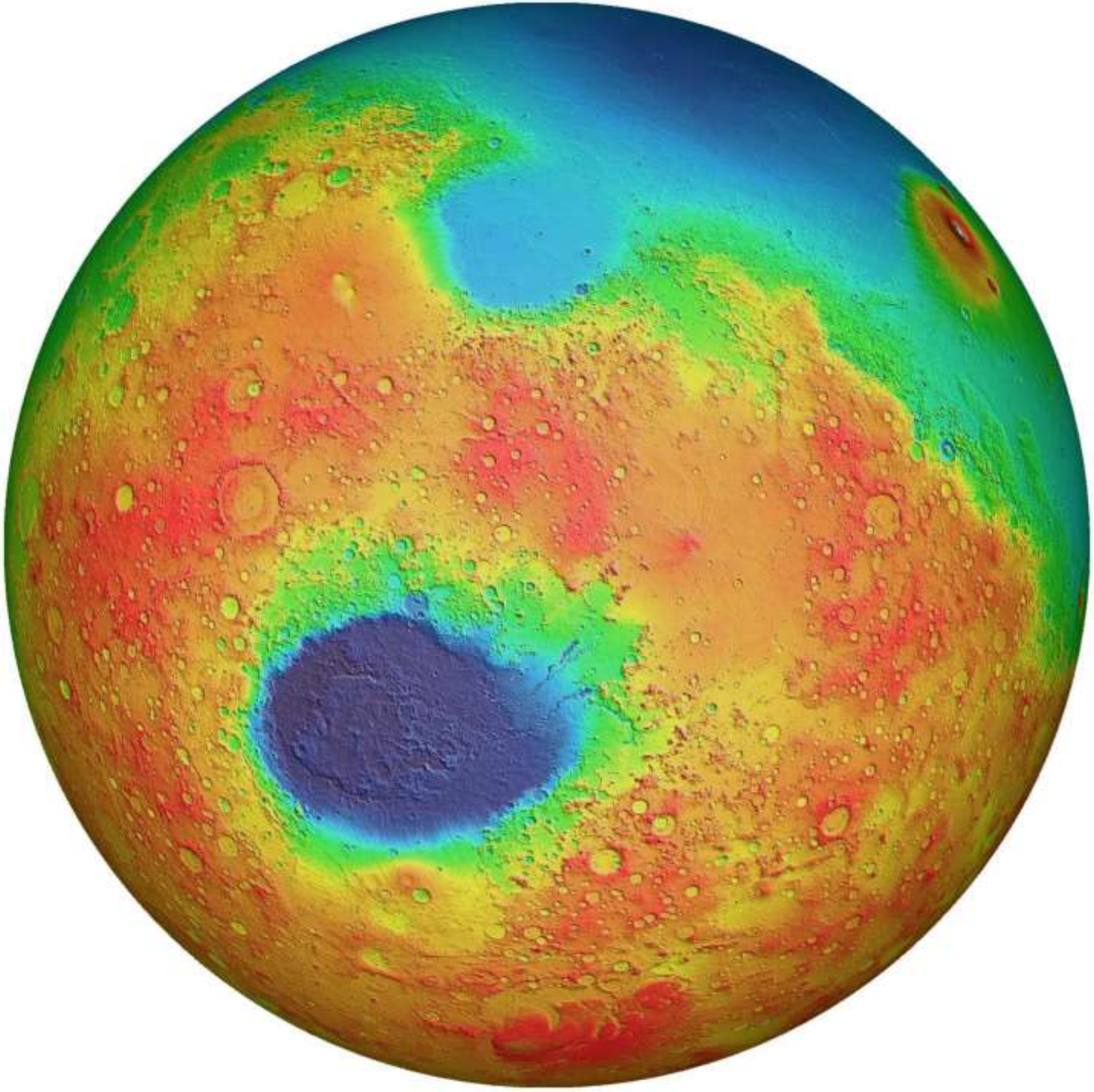
This false-colour map, produced by the Mars Orbiter Laser Altimeter (MOLA), depicts the topography of the Martian surface.

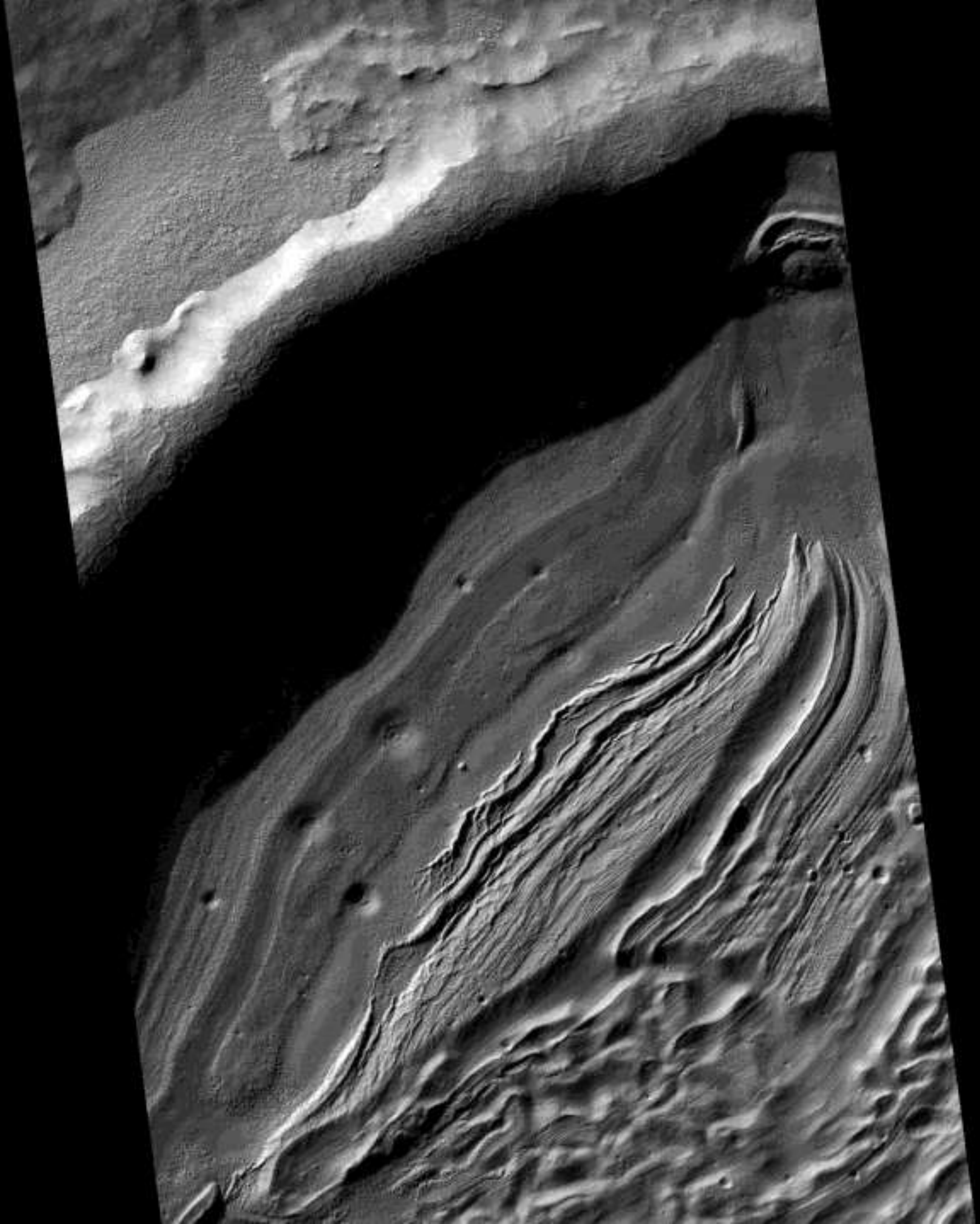
Hellas Basin, the large, dark blue region below the centre, has a diameter of 2300 km, and 8 km deep. Its floor, covered with partly eroded sediments, is the lowest place on Mars.

The basin was probably created by collision with an asteroid very early in Mars's history, about 4 billion years ago, not long after the planet formed.

It is one of the largest identified impact craters both on Mars and within the Solar System.

Source: European Space Agency





Hellas Planitia

This image from the High Resolution Imaging Science Experiment (HiRISE) camera on NASA's Mars Reconnaissance Orbiter covers a small portion of the northwest quadrant of Hellas Planitia on Mars. With a diameter of about 1,400 miles and a depth reaching the lowest elevations on Mars, Hellas is one of the largest impact craters in the solar system.

The area has a number of unusual features, which are thought to be quite old because of the high crater density. The crater inside Hellas has been filled with material, which may be related to volcanic activity on the basin's northwestern rim. It also might be related to the presence water and water ice. However, there is evidence elsewhere that the ground here is rich with ice.

Image Credit: NASA/JPL-Caltech/University of Arizona/International Research School of Planetary Sciences

Last Updated: Aug 7, 2017

Not So Fun Fact:
The Kinetic Energy of an Asteroid Impact on Earth

- The amount of kinetic energy will depend on speed, mass, density, and composition. An asteroid has to be big enough, dense enough and of a sufficiently heat resistant material to reach the ground
- The largest nuclear bomb ever detonated was the 50 Megatonne Tsar Bomb which was detonated in 1961 over the Russian arctic Severeny Island at an altitude of about 4,000 meters to maximize blast effect creating a blast radius of 35km
- If a 140 meter diameter iron/nickel asteroid with a density of 2.5metric tonnes/cubic meter travelling at the minimum possible speed of 11 km/s were to strike a city that was built on typical sedimentary rock, the impact would create a yield of pproximately 50 Megatonnes and
  - A crater about 300 meters in depth and 1,250 meters in diameter
  - 3rd degree burns to exposed skin within 100 km
  - Destruction of all buildings within 60 km
- A mile wide spherical asteroid would yield about 72,000 Megatonnes!

Mars as seen from Earth

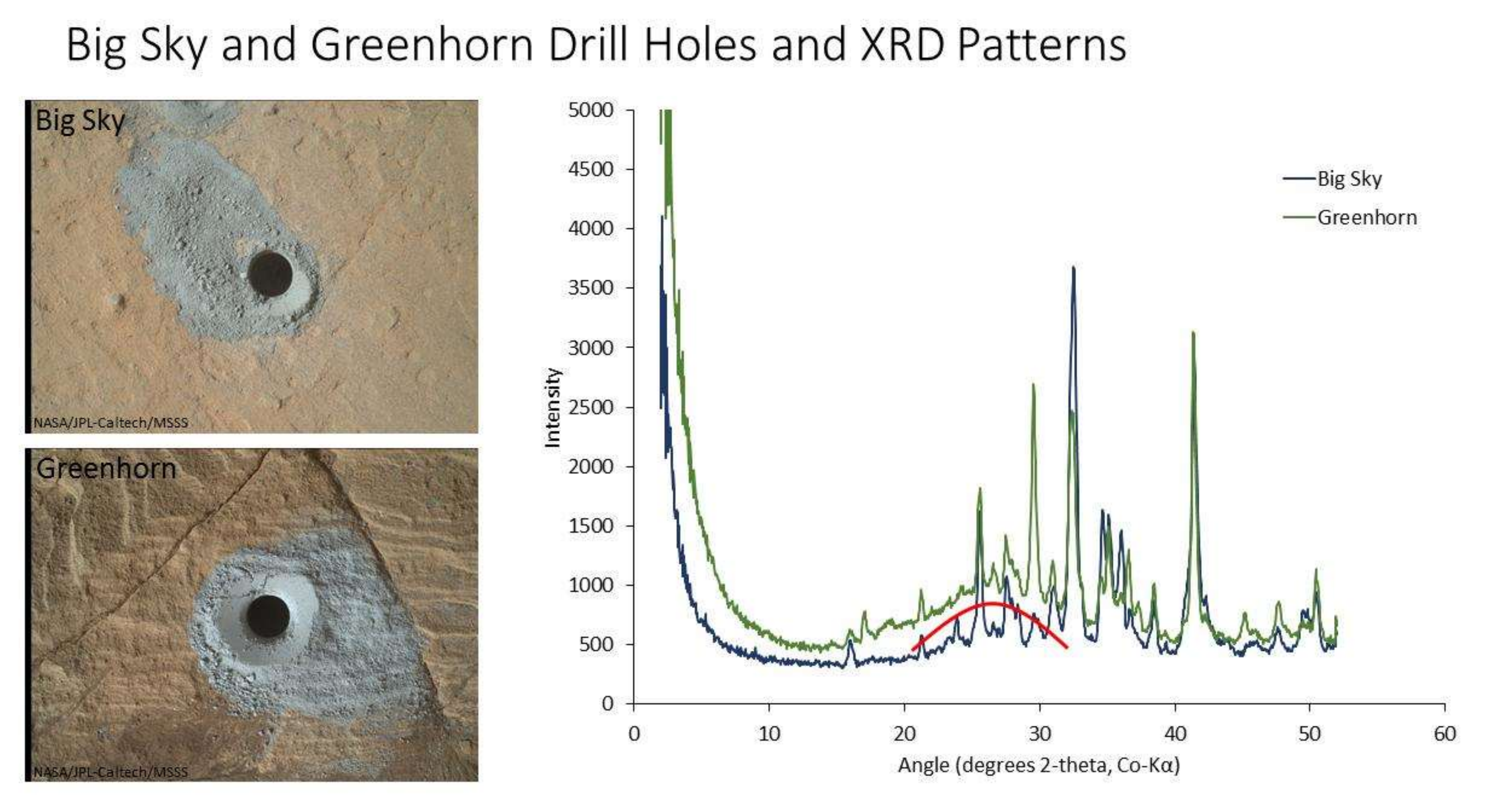
Source: Adam Kortrey 20th Feb 2015 Venus, Mars, and the Moon
Camera: Pentax Q10 Lens: Canon FD 135mm f/3.5
5.6x crop factor = 756mm equivalent

Structure and Composition of Mars

The graph at right presents information from the NASA Curiosity Mars rover's onboard analysis of rock powder drilled from the "Big Sky" and "Greenhorn" target locations, shown at left.

X-ray diffraction analysis of the Greenhorn sample inside the rover's Chemistry and Mineralogy (CheMin) instrument revealed an abundance of silica in the form of noncrystalline opal. The broad hump in the background of the X-ray diffraction pattern for Greenhorn, compared to Big Sky, is diagnostic of opal.

The image of Big Sky at upper left was taken by the rover's Mars Hand Lens Imager (MAHLI) camera the day the hole was drilled, Sept. 29, 2015, during the mission's 1,119th Martian day, or sol. The Greenhorn hole was drilled, and the MAHLI image at lower left was taken, on Oct. 18, 2015 (Sol 1137).

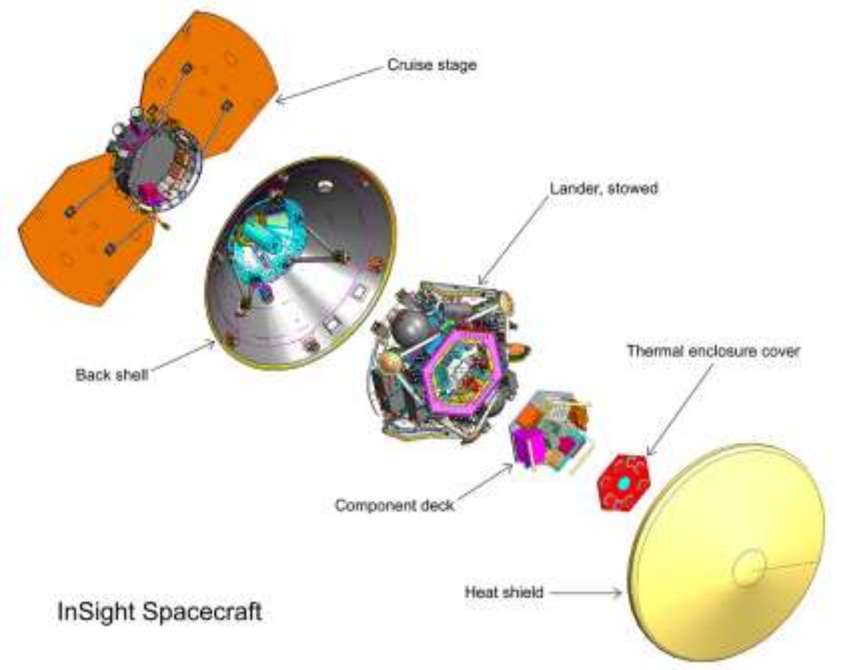


What is InSight?

NASA's InSight (Interior Exploration using Seismic Investigations, Geodesy and Heat Transport) is the first mission to study the deep interior of Mars.

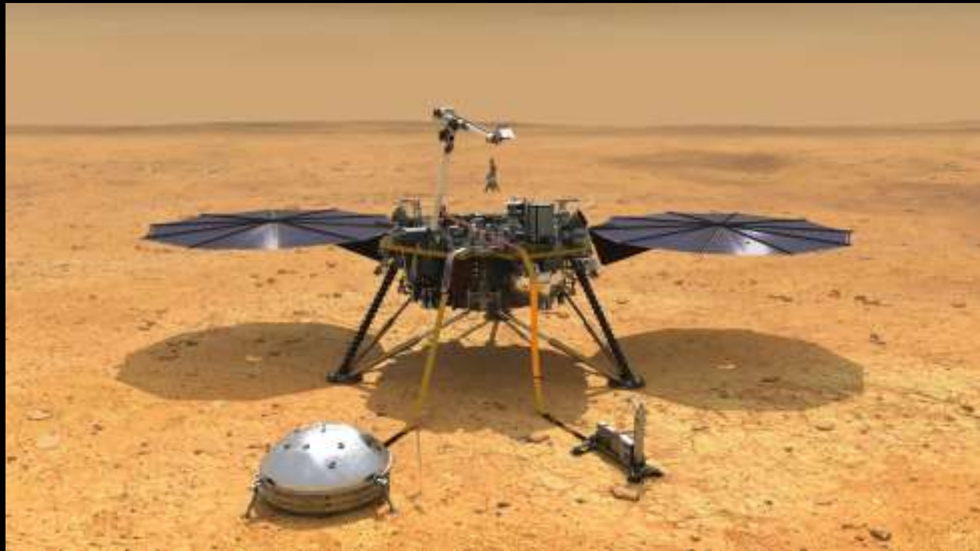
InSight is investigating Martian tectonic activity and meteorite impacts. The mission seeks to answer one of science's most fundamental questions: How did the terrestrial planets form?
Two suitcase-sized spacecraft called CubeSats separated from the main InSight spacecraft and followed it to Mars.

The lander is the core of the InSight spacecraft. Not only will it be the element carrying out all of the activity on Mars, its computer also controls functions of the three secondary elements of the flight system: the cruise stage, back shell and heat shield.



The InSight spacecraft is based on the design of NASA's 2007-2008 Phoenix Mars Lander, with updates to accommodate InSight's unique science payload and new mission requirements. Some key functions and features of the InSight spacecraft are power, communications, command and data handling, propulsion, guidance and thermal control.

Lockheed Martin Space, Denver, designed, built and tested the InSight spacecraft



THE CORE OF MARS

NASA's InSight spacecraft, sitting on the Martian surface with the aim of seeing deep inside the planet, has revealed the size of Mars's core by listening to seismic energy ringing through the planet's interior.

The measurement suggests that the radius of the Martian core is 1,810 to 1,860 kilometres, roughly half that of Earth's. That's larger than some previous estimates, meaning the core is less dense than had been predicted. The finding suggests the core must contain lighter elements, such as oxygen, in addition to the iron and sulfur that constitute much of its make-up. InSight scientists reported their measurements in several presentations this week at the virtual Lunar and Planetary Science Conference, based out of Houston, Texas.

Rocky planets such as Earth and Mars are divided into the fundamental layers of crust, mantle and core. Knowing the size of each of those layers is crucial to understanding how the planet formed and evolved. InSight's measurements will help scientists to determine how Mars's dense, metal-rich core separated from the overlying rocky mantle as the planet cooled. The core is probably still molten from Mars's fiery birth, some 4.5 billion years ago.

PLANETARY SCIENCE

Seismic detection of the martian core

Simon C. Stähler[1]*, Amir Khan[1,2], W. Bruce Banerdt[3], Philippe Lognonné[4], Domenico Giardini[1], Savas Ceylan[1], Mélanie Drilleau[5], A. Cecilia Duran[1], Raphaël F. Garcia[5], Quancheng Huang[6], Doyeon Kim[6], Vedran Lekic[6], Henri Samuel[4], Martin Schimmel[7], Nicholas Schmerr[6], David Sollberger[1], Éléonore Stutzmann[4], Zongbo Xu[4], Daniele Antonangeli[8], Constantinos Charalambous[9], Paul M. Davis[10], Jessica C. E. Irving[11], Taichi Kawamura[4], Martin Knapmeyer[12], Ross Maguire[6], Angela G. Marusiak[3], Mark P. Panning[3], Clément Perrin[13], Ana-Catalina Plesa[12], Attilio Rivoldini[14], Cédric Schmelzbach[1], Géraldine Zenhäusern[1], Éric Beucler[13], John Clinton[15], Nikolaj Dahmen[1], Martin van Driel[1], Tamara Gudkova[16], Anna Horleston[11], W. Thomas Pike[9], Matthieu Plasman[4], Suzanne E. Smrekar[3]

Clues to a planet's geologic history are contained in its interior structure, particularly its core. We detected reflections of seismic waves from the core-mantle boundary of Mars using InSight seismic data and inverted these together with geodetic data to constrain the radius of the liquid metal core to 1830 ± 40 kilometers. The large core implies a martian mantle mineralogically similar to the terrestrial upper mantle and transition zone but differing from Earth by not having a bridgmanite-dominated lower mantle. We inferred a mean core density of 5.7 to 6.3 grams per cubic centimeter, which requires a substantial complement of light elements dissolved in the iron-nickel core. The seismic core shadow as seen from InSight's location covers half the surface of Mars, including the majority of potentially active regions—e.g., Tharsis—possibly limiting the number of detectable marsquakes.

The core of a planet plays a prominent role because it governs many of the fundamental processes—from dynamo action and magnetic-field generation to mantle convection—that affect the surface through volcanic and tectonic activity and may influence the early climate through magnetic shielding of the atmosphere. The size of the martian core is of particular interest because of its notable impact on the planet's evolution, which differs from that of Earth primarily as a result of Mars' smaller size and, therefore, accelerated differentiation and core formation and cooling-off that resulted in a rigid-shell, one-plate planet (*1*, *2*).

would instead be enriched in light elements and exclude the presence of a phase transition equivalent to the 660-km discontinuity that marks the onset of Earth's lower mantle (*4*). It would exert a markedly different dynamic control over the martian mantle (*5*–*8*), with implications for an early martian dynamo (*1*) that could explain the observed highly magnetized crust in the southern highlands (*9*). Direct constraints on the core and deep interior of Mars, however, are scarce and limited to global geophysical measurements, including mass, moment of inertia, and tidal response (*10*, *11*), in addition to geochemical data based on achondritic

insights gained from studying the chemistry of the martian rocks, whose siderophile element depletion and isotopic signature point to a core-forming event early in Mars' history (*25*, *26*), but also to considerably improve our understanding of the deep interior of Mars.

After a full martian year, the Interior Exploration using Seismic Investigations, Geodesy, and Heat Transport (InSight) mission (*27*) and its seismometer SEIS (*28*) have recorded a multitude of seismic events, which have been located and classified by the Marsquake Service (*29*–*31*). Of these, the low-frequency events with main energy below 1 Hz and waves traveling through the mantle can be used to characterize the crustal and mantle structure of Mars (*32*, *33*).

To investigate the core of Mars, we analyzed seismic data from 11 low-frequency marsquakes. Six of them were found in a suitable distance range [27° to 38.5° (*30*)], with high enough signal-to-noise ratio (SNR) to identify potential core-reflected *S* waves (*ScS* waves) (Table 1). Because *S* waves cannot propagate in a fluid medium, the core-mantle boundary (CMB) acts as a polarization filter, reflecting horizontally polarized *S* waves (*SH* waves) back into the mantle, whereas vertically polarized *S* waves (*SV*) lose some energy as a result of *S*-to-*P* conversion. *S* waves reflected from the CMB are therefore expected to be predominantly horizontally polarized, with an azimuth orthogonal to the source-receiver direction. The events for which the direction could be determined from *P*- and *S*-wave polarization (S0173a and S0235b) appear to originate in the Cerberus Fossae graben system (*29*, *34*),

Stähler et al.,
Science
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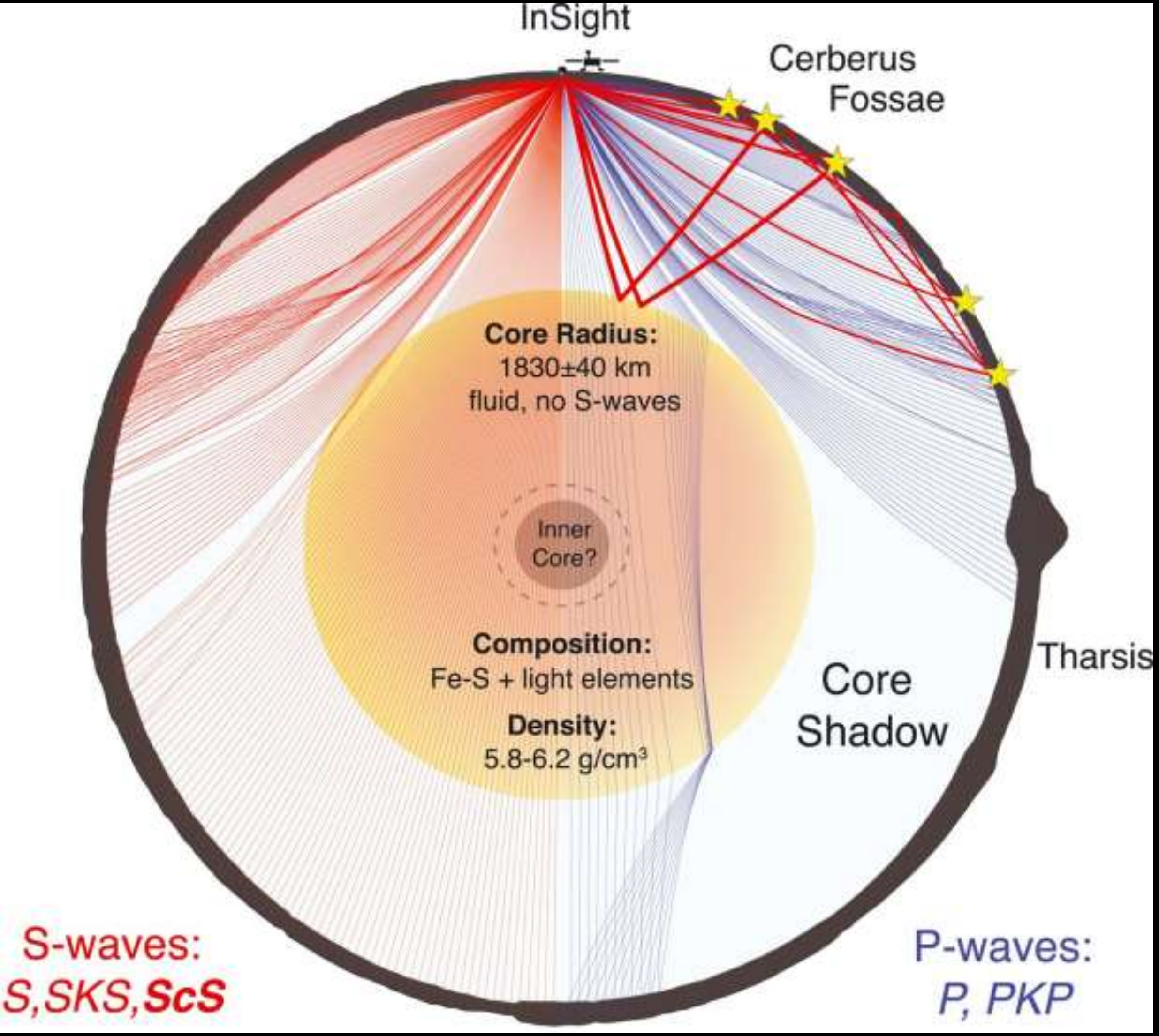


Schematic diagram of Mars' interior structure.The cross section depicts the core-induced shadow zone for seismic waves. The surface topography is a cut through the MOLA map on a great circle arc from InSight through Olympus Mons.
The S-wave shadow zone is minimal and probably filled by diffracted S waves (Sdiff), whereas the P-wave shadow zone is large and contains specifically the Tharsis region. The existence of an inner core cannot be determined by current data, and the seismic ray paths shown assume no inner core. Topography and InSight lander are exaggerated in scale.

Seismic detection of the martian core. SIMON C. STÄHLER et al
SCIENCE 23 Jul 2021 Vol 373, Issue 6553 pp. 443-448

Martian Volcanoes

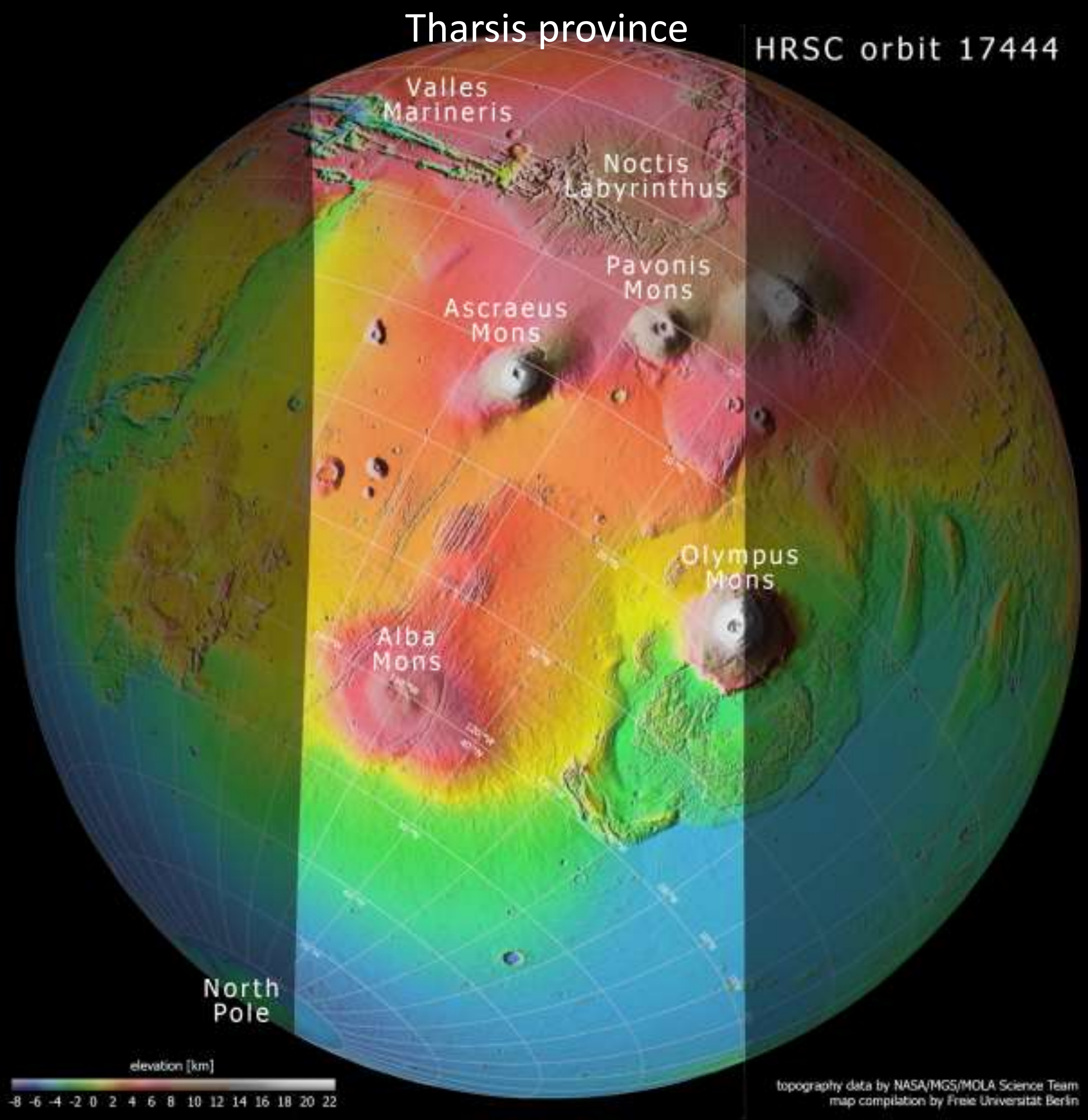
Martian Volcanoes

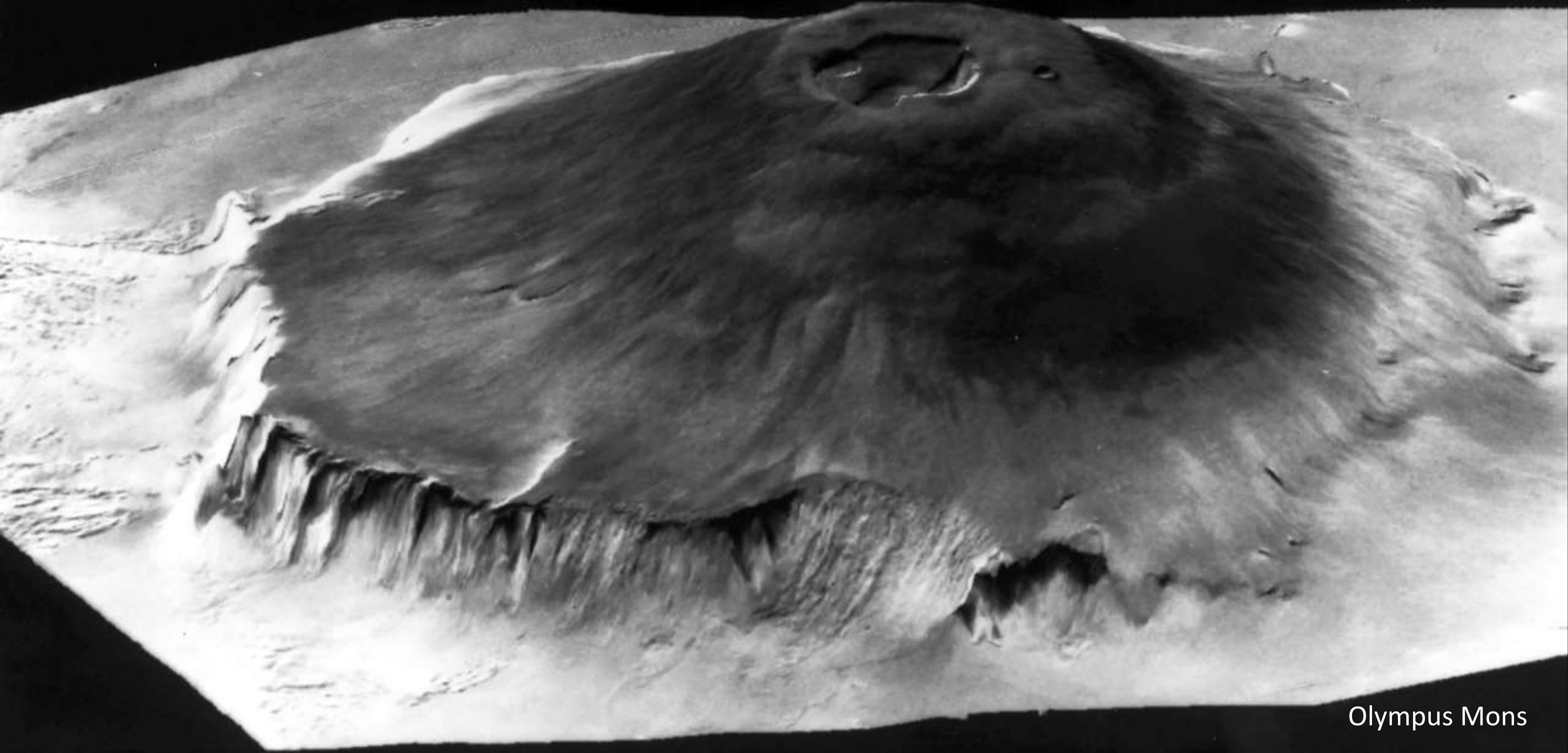
The most prominent regions of volcanic activity include Tharsis and Elysium. These large volcanic regions have been active throughout most of Mars' history

The context map (right) is based on data from the Mars Orbiter Laser Altimeter (MOLA) experiment onboard NASA's Mars Global Surveyor (MGS) mission. It shows the slice of Mars captured by the High Resolution Stereo Camera aboard ESA's Mars Express spacecraft to celebrate the mission's 15th anniversary: the intriguing and once-active Tharsis province.

Included in this labelled view is the extensive canyon system of Valles Marineris, the web-like system of fissures comprising Noctis Labyrinthus, two out of four volcanoes, the north pole, and the so-called Martian dichotomy: the difference in altitude between the northern and southern regions of Mars. Areas at higher altitudes are shown in red-orange tones, while those at lower ones are displayed in blue-greens (as indicated by the scale to the bottom left).

This map was created by the Planetary Sciences and Remote Sensing group at Freie Universität Berlin, Germany.





Olympus Mons

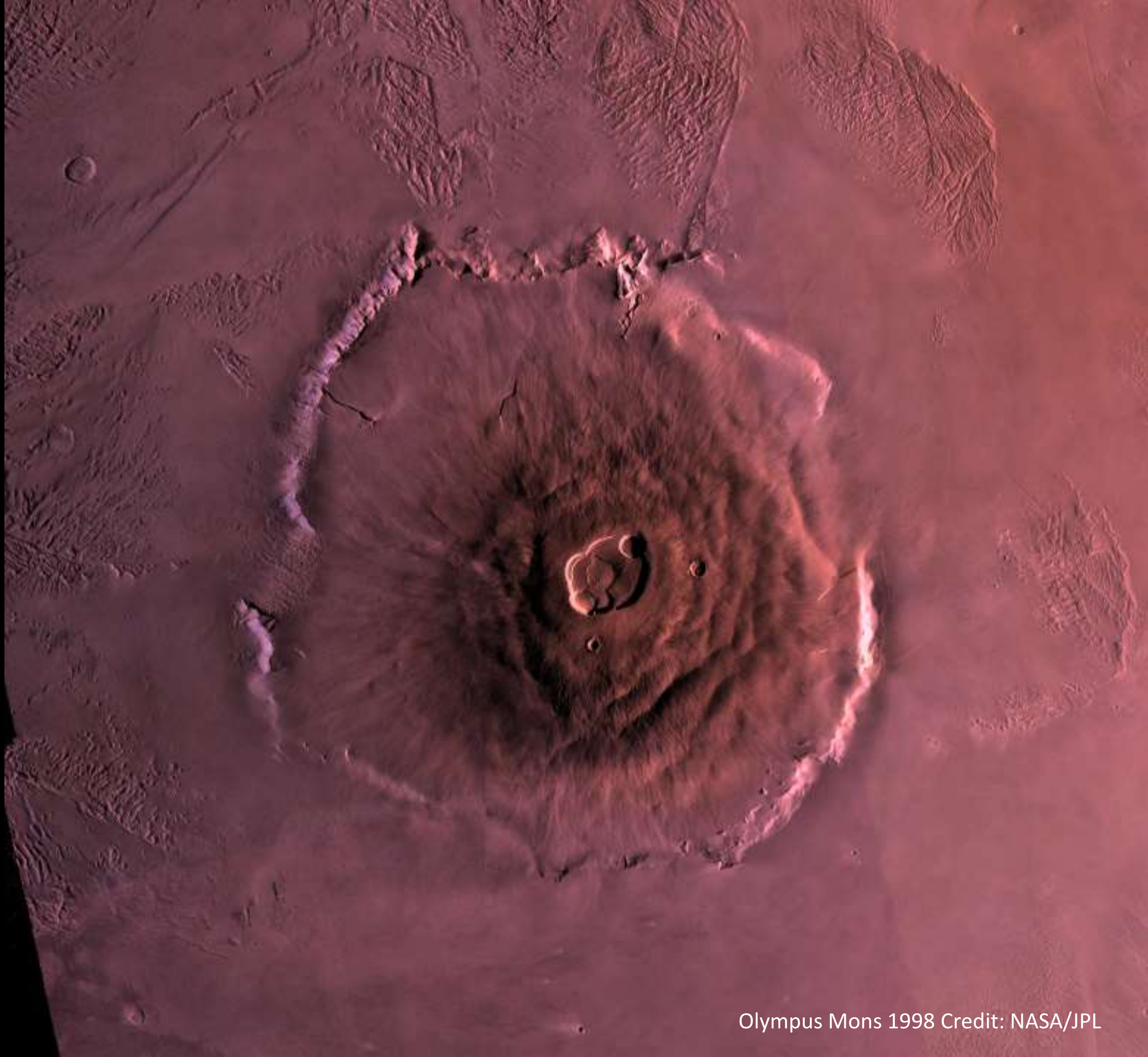
Olympus Mons

- It is the largest volcano in the solar system, measures some 624 kilometres across rises nearly 27 kilometres above the surrounding terrain and rimmed by a 6 km (4 mi) high scarp.
- It is a shield volcano that began some 3 billion years ago.
- Olympus Mons is part of a complex of volcanoes that lie along a volcanic plateau called the Tharsis Bulge. This entire region lies over a hotspot, a place in the planet's crust that allows magma from deep inside to flow out to the surface.
- Lava flows drape over the scarp in places. Much of the plains surrounding the volcano are covered by the ridged and grooved 'aureole' of Olympus Mons. The origin of the aureole is controversial, but may be related to gravity sliding larva off of the flanks of an ancestral volcano.
- The summit caldera (central depression) is almost 3 km deep and 25 km across. It probably formed from recurrent collapse following drainage of magma resulting from flank eruptions.
- To compare, the largest volcano on Earth is Mauna Kea. Mauna Kea is a shield volcano 10 km high (although it is only 4.2 km above sea level) and 120 km across. The volume of Olympus Mons is about 100 times larger than that of Mauna Kea.

Credit: https://www.nasa.gov/sites/default/files/atoms/files/how_big_is_it_022616.pdf?msclkid=4569c038ce9e11ecb789e1a1999abe7c

Why are Martian Volcanoes so large?

1. The lava flows on the Martian surface are observed to be much longer, probably a result of higher eruption rates and lower surface gravity.
2. On Earth, the hot spots remain stationary but crustal tetonic plates are moving above them. As plates move over hotspots, new volcanoes are formed and the existing ones become extinct. This distributes the total volume of lava among many volcanoes rather than one large volcano. On Mars, the crust remains stationary and the lava piles up in one, very large volcano.



Olympus Mons 1998 Credit: NASA/JPL

This image acquired on October 1, 2020 by NASAs Mars Reconnaissance Orbiter, shows several craters in Arabia Terra filled with layered rock. Credits: NASA/Molly Wasser

Martian Volcanoes

Most volcanism on Mars occurred between 3 billion and 4 billion years ago, leaving behind giant extinct volcanoes such as Olympus Mons, the tallest mountain in the solar system. At 16 miles (25 km) high, Olympus Mons is about three times as tall as Mount Everest, Earth's highest mountain.

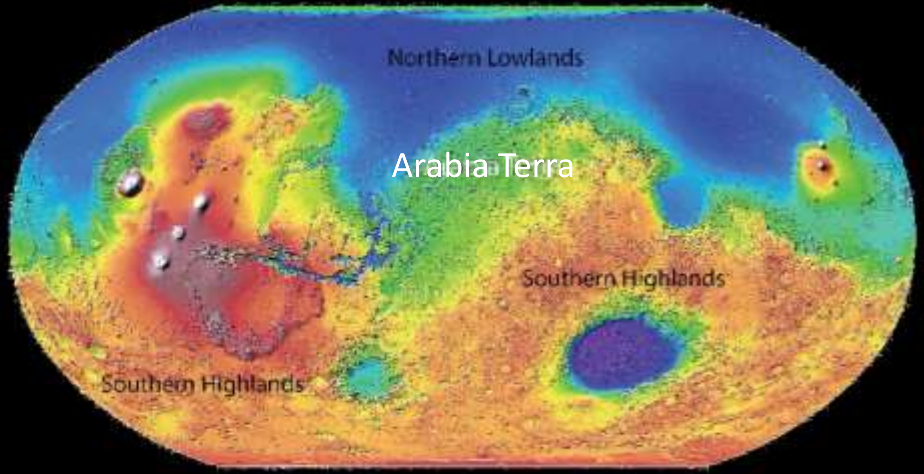
Previous research suggested the Red Planet may still have flared with smaller volcanic eruptions as recently as 2.5 million years ago. Now scientists have found evidence that Mars may still be volcanically active, with signs of an eruption within the past 50,000 years or so.

Author: Charles Q. Choi
Published May 12, 2021
https://www.space.com/mars-still-volcanically-active-elysium-planitia

A satellite image of a recent explosive volcanic deposit around a fissure of the Cerberus Fossae system on Mars.
Image credit: NASA/JPL/MSSS/The Murray Lab

NASA Confirms Thousands of Massive, Ancient Volcanic Eruptions on Mars

September 15, 2021



Scientists found evidence that a region of northern Mars called Arabia Terra experienced thousands of "super eruptions," the biggest volcanic eruptions known, over a 500-million-year period about 4 billion years ago
Each one of these eruptions would have had a significant climate impact — maybe the released gas made the atmosphere thicker or blocked the Sun and made the atmosphere colder," said Patrick Whelley, a geologist at NASA's Goddard Space Flight Center in Greenbelt, Maryland, who led the Arabia Terra analysis.

After blasting the equivalent of 400 million Olympic-size swimming pools of molten rock and gas through the surface and spreading a thick blanket of ash up to thousands of miles from the eruption site, a volcano of this magnitude collapses into a giant hole called a "caldera." Calderas, which also exist on Earth, can be dozens of miles wide. Seven calderas in Arabia Terra were the first giveaways that the region may once have hosted volcanoes capable of super eruptions, rather depressions left by asteroid impacts.

Scientists first proposed in a 2013 study that these basins were volcanic calderas. They noticed that they weren't perfectly round like craters, and they had some signs of collapse, such as very deep floors and benches of rock near the walls.
"We read that paper and were interested in following up, but instead of looking for volcanoes themselves, we looked for the ash, because you can't hide that evidence," Whelley said. By laying the mineral data over the topographic maps of the canyons and craters analyzed, the researchers could see in the mineral-rich deposits that the layers of ash were very well preserved — instead of getting jumbled by winds and water, the ash was layered in the same way it would have been when it was fresh.

Excerpt by Lonnie Shekhtman NASA's Goddard Space Flight Center, Greenbelt, Md.

AGU ADVANCING EARTH AND SPACE SCIENCE

Geophysical Research Letters

RESEARCH LETTER
10.1029/2021GL094109

Stratigraphic Evidence for Early Martian Explosive Volcanism in Arabia Terra

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Key Points:

- Layered deposits are found at seven locations in Arabia Terra involving minerals consistent with or diagnostic of altered volcanic ash
- Volcanic ash deposits documented here thin away from previously suggested sources, consistent with supereruption model predictions
- Between 1 and 2 thousand caldera-forming eruptions over 500 million years from western Arabia Terra are needed to produce the observed ash

Supporting Information:

Supporting Information may be found in the online version of this article.

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Citation:

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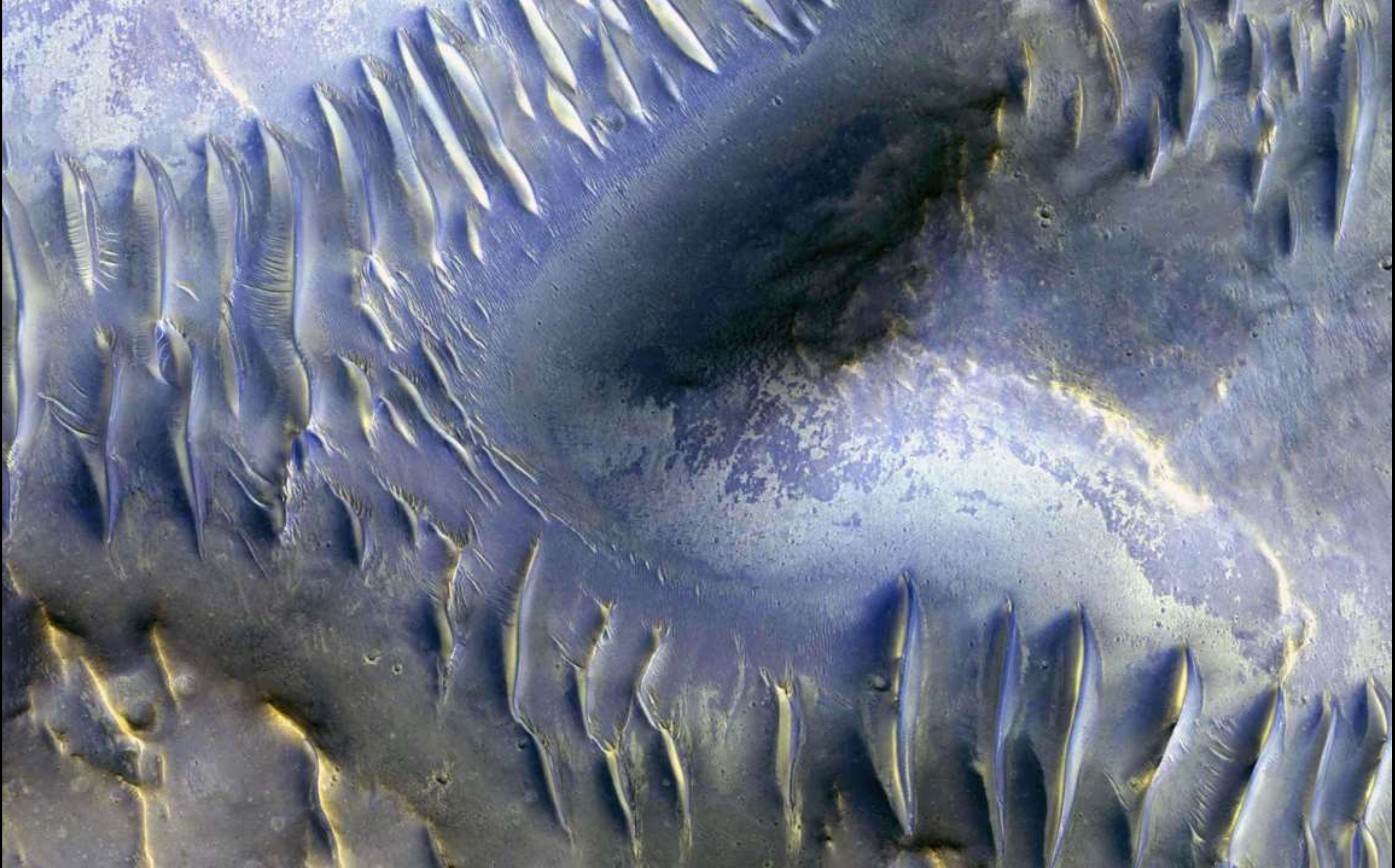
Abstract Several large paterae in Arabia Terra are suggested to be calderas that produced colossal explosive eruptions (i.e., supereruptions). If these features are indeed explosive calderas, dispersion modeling suggests extensive ash deposits should be common throughout the region. However, such deposits have not previously been linked with the suggested calderas. Here, we describe layered deposits containing minerals both consistent with and diagnostic of altered volcanic ash throughout Arabia Terra. These deposits include Al-dominant minerals such as montmorillonite, imogolite, and allophane among others. Altered ash deposits are found to thin (from 1-km to 100-m thickness) away from the suggested calderas. We estimate that the volcanic ash observed in Arabia Terra is the result of between 1,000 and 2,000 individual explosive eruptions over 500-million years. Our observations support the hypothesis that Arabia Terra hosted supereruptions in the late Noachian-early Hesperian that repeatedly blanketed the region with layers of ash.

Plain Language Summary Several large and deep craters in western Arabia Terra, Mars are thought to be explosive calderas, a type of volcano capable of producing supereruptions. If these craters are calderas, vast layers of volcanic ash should be common in Arabia Terra. While layered deposits have been observed previously in Arabia, until now, no deposits have been associated with the suggested calderas. We present mineral signatures of volcanic ash deposits that thin (from 1 km to 100 m thickness) away from the suggested calderas. Our observations support the idea that explosive calderas do exist in western Arabia Terra, and they produced thousands of super eruptions spread out over 500 million years of ancient Mars history.

Wind on Mars

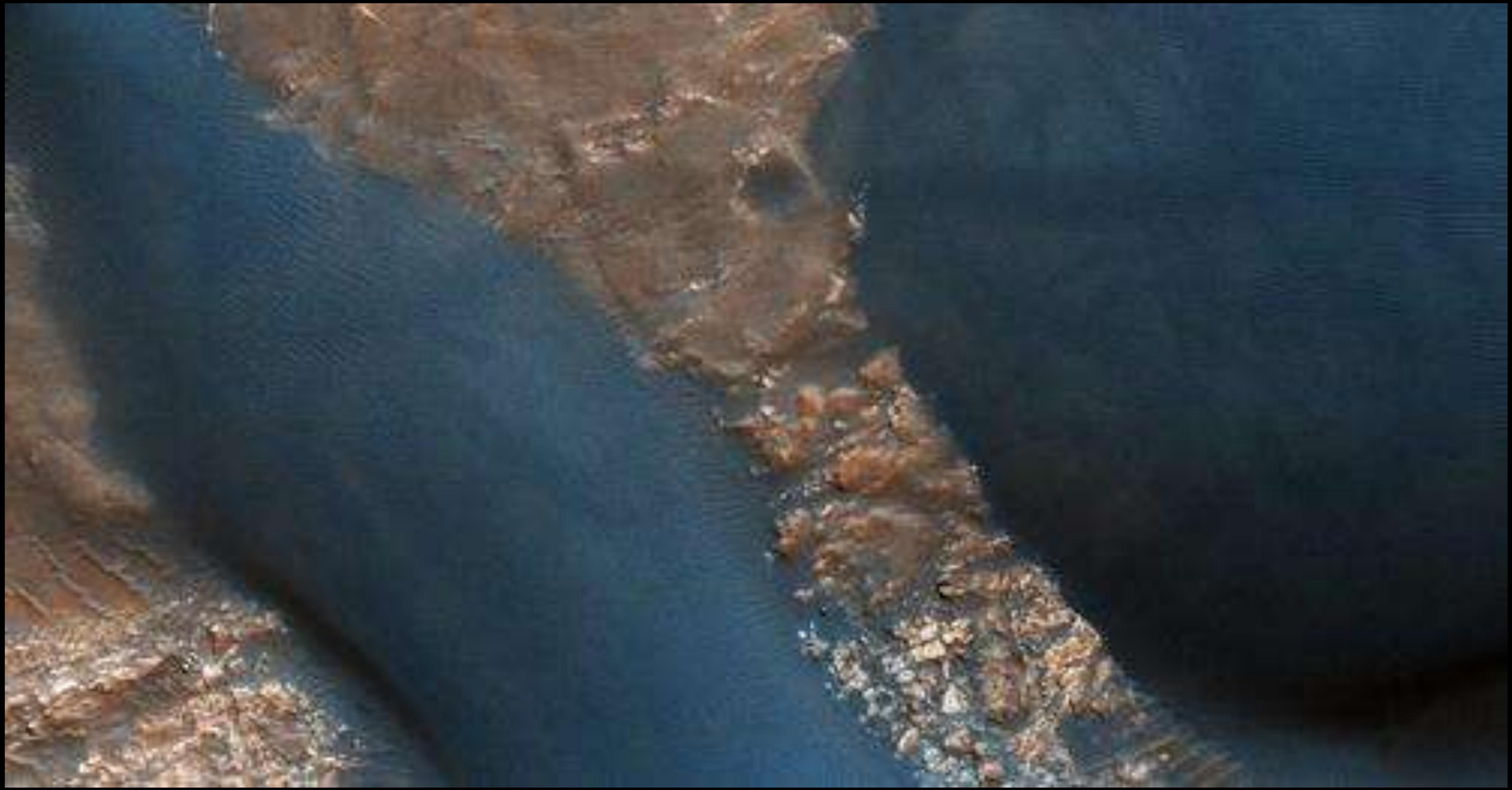
Sounds of Mars: NASA’s InSight Senses Martian Wind
Link: https://youtu.be/yT50Q_Zbf3s?t=82



The mound in the center of this image — which was captured by the HiRISE camera aboard NASA's Mars Reconnaissance Orbiter in April 2009 — appears to have blocked the path of sand dunes as they marched across the scene.
Image credit: NASA/JPL-Caltech/University of Arizona

The Dunes in Mars' Wirtz Crater

Image Credit: NASA/JPL-Caltech/University of Arizona



In Mars' Wirtz Crater, these dunes are likely active, with ripples on their upwind slopes and dark streaks on their downwind slopes forming and changing due to wind-driven sand motion. Colour has been enhanced to highlight the dunes.

This motion will also keep the dune brink (the edge between the two slopes) and bottom edges sharply defined. The dark lines and squiggles on the dune slope are formed by passing dust devils.

Last Updated: Nov 29, 2018 Editor: Yvette Smith NASA

Nili Patera, 2014
Located on top of a lava bed at the site of an ancient volcano, Nili Patera is one of the most active dune fields on the planet Mars.

Dust Storms on Mars

Mars is infamous for intense dust storms, which sometimes kick up enough dust to be seen by telescopes on Earth.

"Every year there are some moderately big dust storms that pop up on Mars and they cover continent-sized areas and last for weeks at a time," said Michael Smith, a planetary scientist at NASA's Goddard Space Flight Center in Greenbelt, Maryland.

Beyond Mars' large annual storms are massive storms that occur more rarely but are much larger and more intense.

"Once every three Mars years (about 5 ½ Earth years), on average, normal storms grow into planet-encircling dust storms, and we usually call those 'global dust storms' to distinguish them," Smith said.

It is unlikely that even these dust storms could strand an astronaut on Mars, however. Even the wind in the largest dust storms likely could not tip or rip apart major mechanical equipment. The winds in the strongest Martian storms top out at about 100 kilometers per hour, less than half the speed of some hurricane-force winds on Earth.

Focusing on wind speed may be a little misleading, as well. The atmosphere on Mars is about 1 percent as dense as Earth's atmosphere. That means to fly a kite on Mars, the wind would need to blow much faster than on Earth to get the kite in the air.

"The key difference between Earth and Mars is that Mars' atmospheric pressure is a lot less," said William Farrell, a plasma physicist who studies atmospheric breakdown in Mars dust storms at Goddard. "So things get blown, but it's not with the same intensity."

Dust Devils on Mars

NASA Jet Propulsion Laboratory Link
https://www.youtube.com/watch?v=k8lfJ0c7WQ8

Mars' Whirling Dust Devil
A Martian dust devil roughly 20 kilometers high was captured winding its way along the Amazonis Planitia region of Northern Mars on March 14, 2012 by the High Resolution Imaging Science Experiment (HiRISE) camera on NASA's Mars Reconnaissance Orbiter. Despite its height, the plume is little more than 70 meters wide.

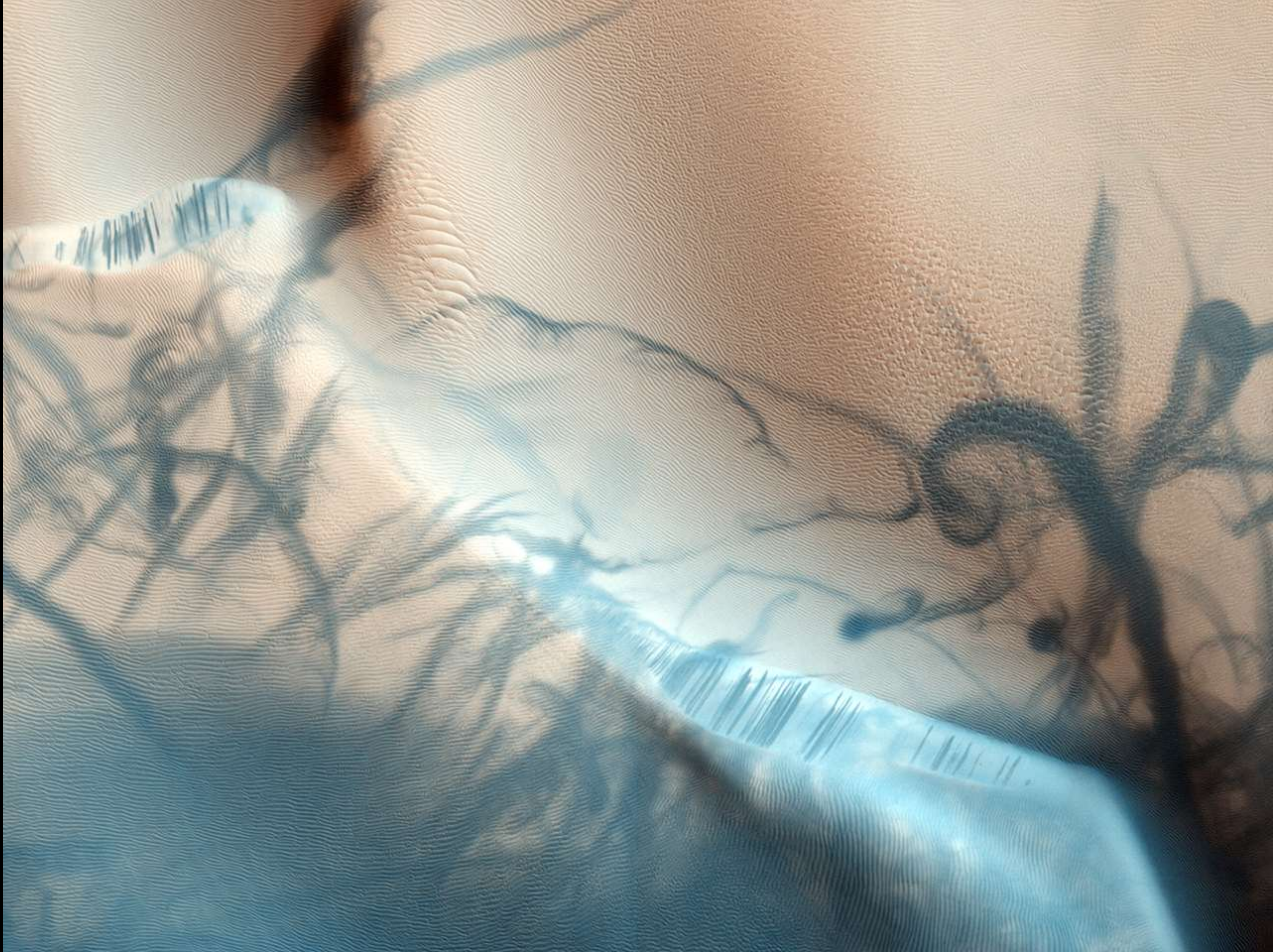
HiRISE is operated by the University of Arizona, Tucson. The instrument was built by Ball Aerospace & Technologies Corp.,

Image credit: NASA/JPL-Caltech/UA

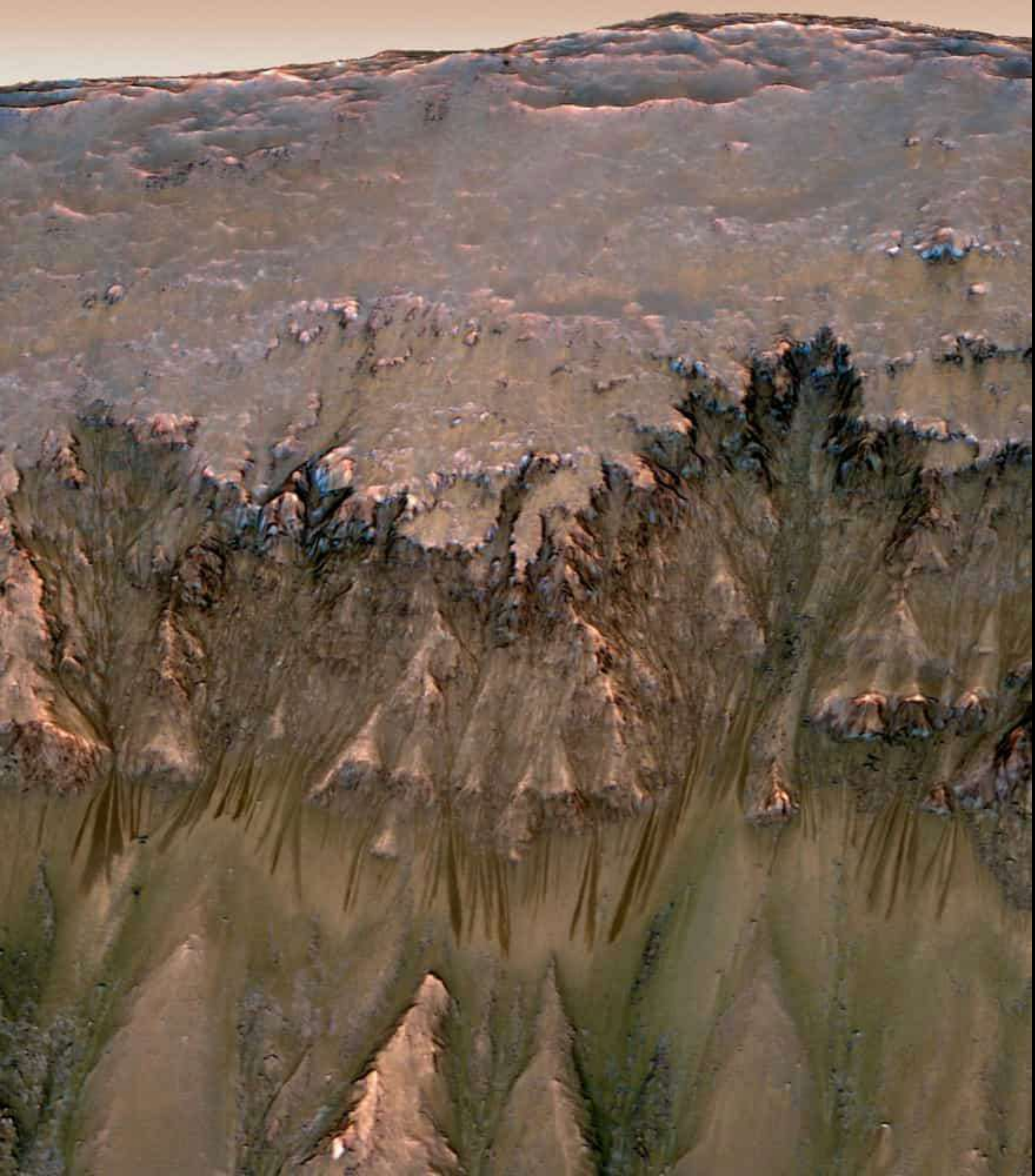
April 01, 2012

This beautiful observation shows a gorgeous pattern of dust devil tracks. Like on Earth, they often expose materials just underneath the surface, which in this case, makes for stunning patterns.

Credit
NASA/JPL-Caltech/University of Arizona



Water on Mars



Dark streaks on Mars

A leading hypothesis is flowing -- but quickly evaporating -- water. The streaks, visible in dark brown near the image center, appear in the Martian spring and summer but fade in the winter months, only to reappear again the next summer.

These are not the first markings on Mars that have been interpreted as showing the effects of running water, but they are the first to add the clue of a seasonal dependence.

The above picture, taken in May 2011, digitally combines several images from the the HiRISE instrument on the Mars Reconnaissance Orbiter (MRO).

The image is colour-enhanced and depicts a slope inside Newton crater in a mid-southern region of Mars.

The streaks bolster evidence that water exists just below the Martian surface in several locations.

Authors: Robert Nemiroff (MTU) & Jerry Bonnell (UMCP)

2011 August 8

Image Credit: HiRISE, MRO, LPL (U. Arizona), NASA

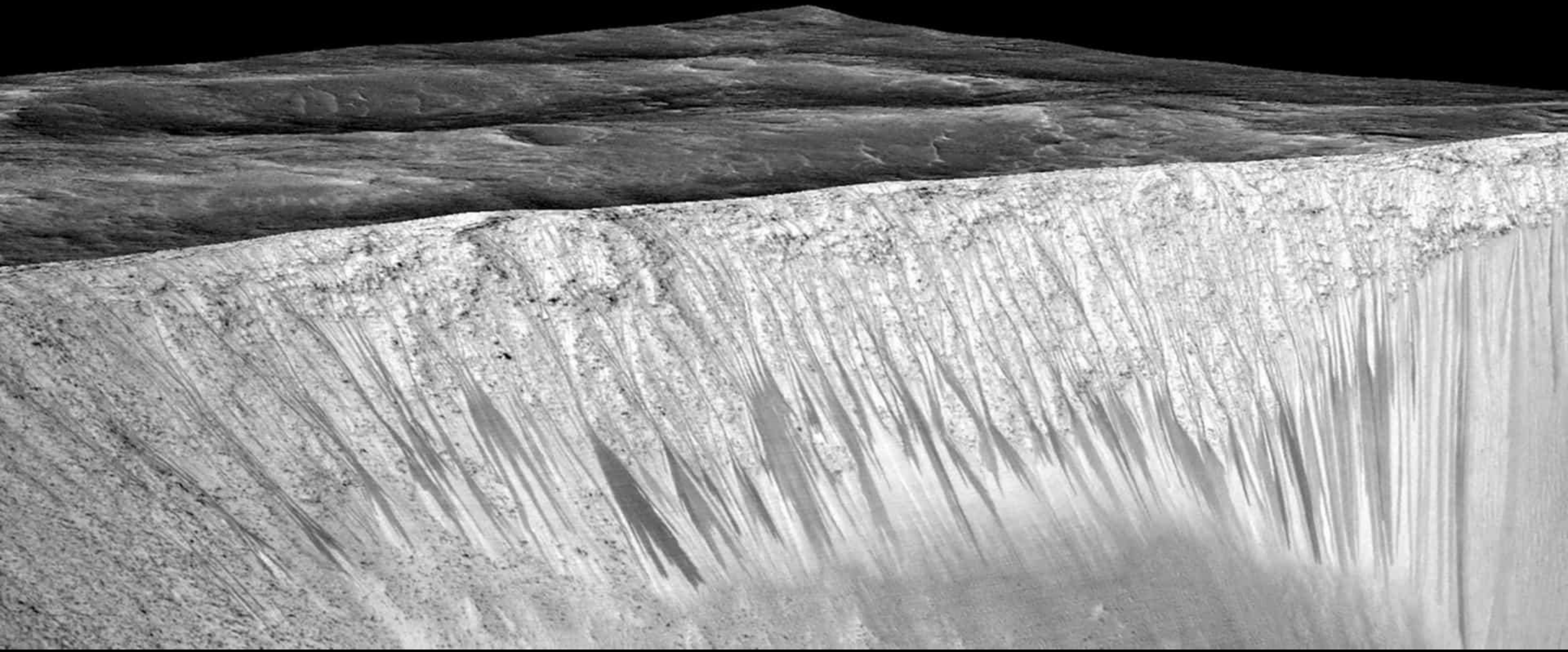
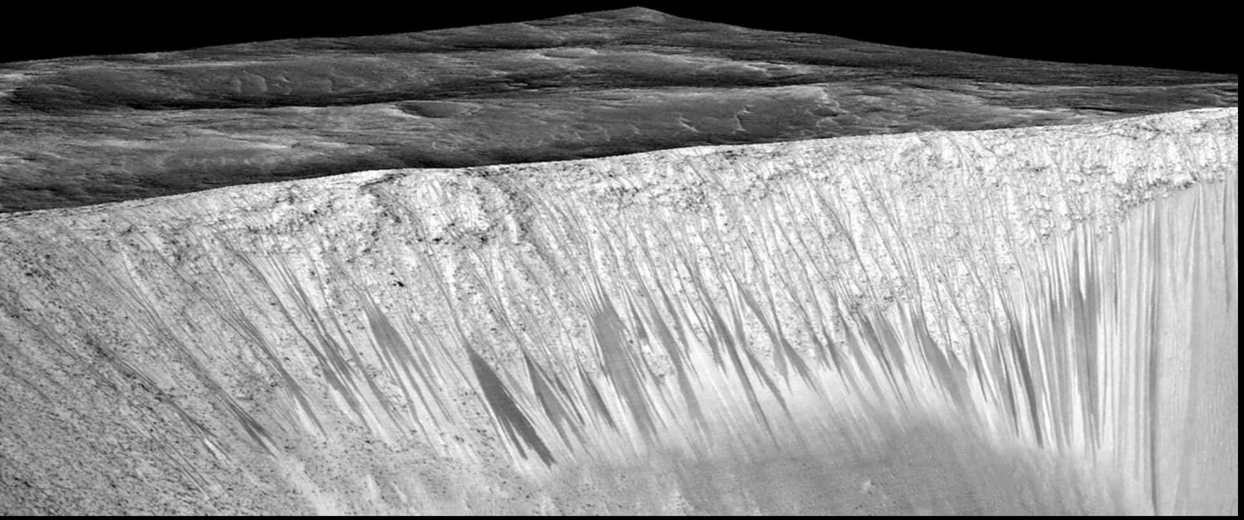


Image credit: NASA/JPL-Caltech/Univ. of Arizona



The cause of the dark streaks on some Martian slopes known as recurring slope lineae, imaged here by NASA’s Mars Reconnaissance Orbiter, is a topic of considerable debate. Some scientists think temporary surface flows of salty water are responsible, and others consider landslides a more likely explanation. Image credit: NASA/JPL-Caltech/Univ. of Arizona

Martian landslides might help explain mystery lines seen on the surface of the Red Planet, a new study finds.

For years, scientists analyzing the Martian surface have detected clusters of dark, narrow lines that seasonally appear on steep, sun-facing slopes in the warmer regions. Previous research has suggested that these enigmatic dark streaks, called recurring slope lineae (RSL), are signs that salty water regularly flows on the Red Planet during its warmest seasons.

Recent missions to Mars have revealed that the planet does possess huge underground pockets of ice. Prior work suggested that warmer temperatures during the Martian spring and summer could help generate salty brines capable, at least for a time, of staying liquid in the cold, thin air of the Red Planet.

Dark narrow streaks, called "recurring slope lineae," emanate from the walls of Garni Crater on Mars, in this view constructed from observations by the High Resolution Imaging Science Experiment (HiRISE) camera on NASA's Mars Reconnaissance Orbiter.

The dark streaks here are up to few hundred yards, or meters, long. They are hypothesized to be formed by flow of briny liquid water on Mars.

The image was produced by first creating a 3-D computer model (a digital terrain map) of the area based on stereo information from two HiRISE observations, and then draping an image over the land-shape model. The vertical dimension is exaggerated by a factor of 1.5 compared to horizontal dimensions. The draped image is a red waveband (monochrome) product from HiRISE observation ESP_031059_1685, taken on March 12, 2013 at 11.5 degrees south latitude, 290.3 degrees east longitude. Other image products from this observation are at http://hirise.lpl.arizona.edu/ESP_031059_1685.

The University of Arizona, Tucson, operates HiRISE, which was built by Ball Aerospace & Technologies Corp., Boulder, Colorado. NASA's Jet Propulsion Laboratory, a division of the California Institute of Technology in Pasadena, manages the Mars Reconnaissance Orbiter Project and Mars Science Laboratory Project for NASA's Science Mission Directorate, Washington.

Image Credit: NASA/JPL-Caltech/Univ. of Arizona

Last Updated: Aug 7, 2017
Editor: Tony Greicius

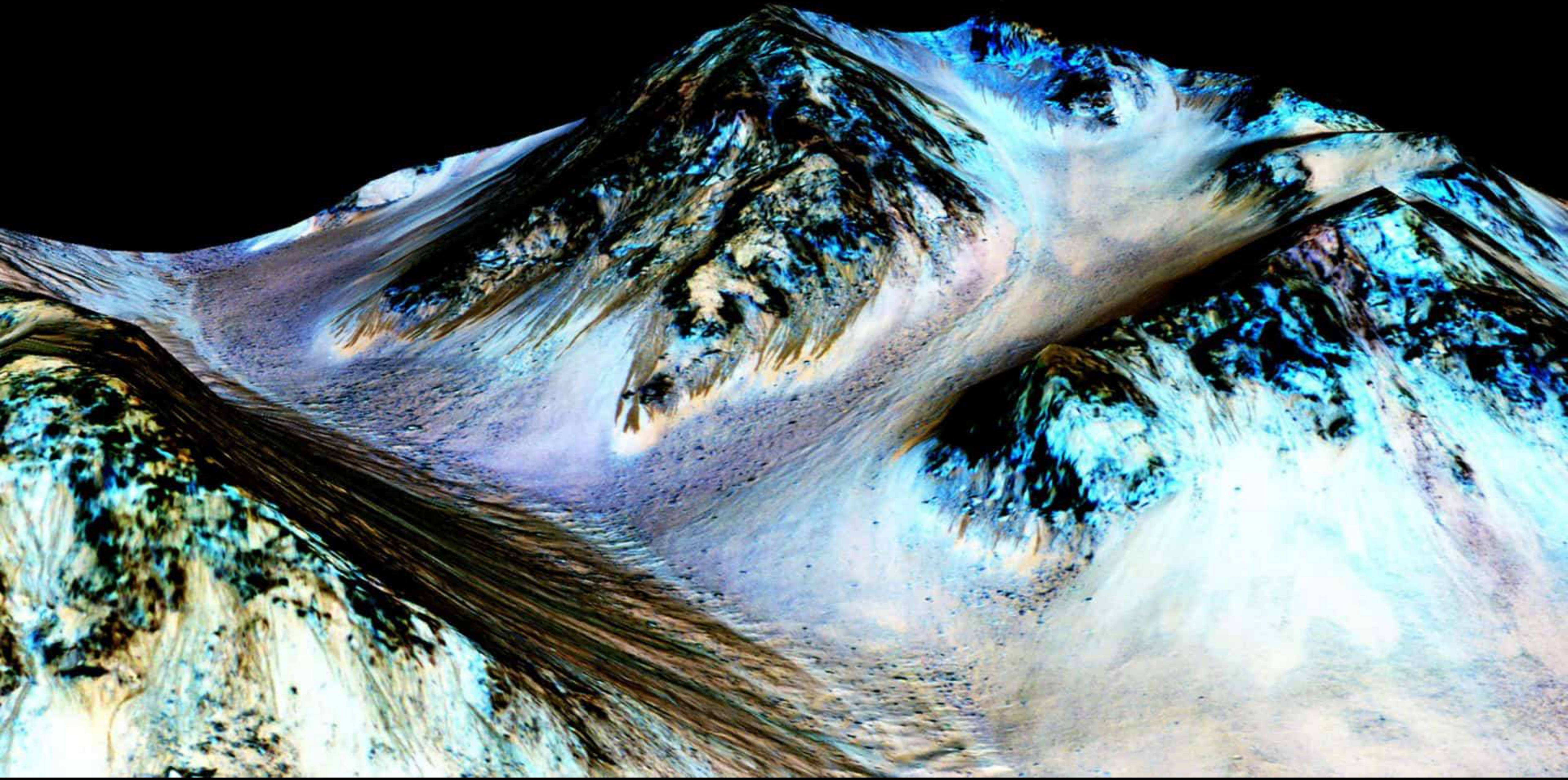
NASA's Curiosity Rover Finds Patches of Rock Record Erased, Revealing Clues July 8, 2021

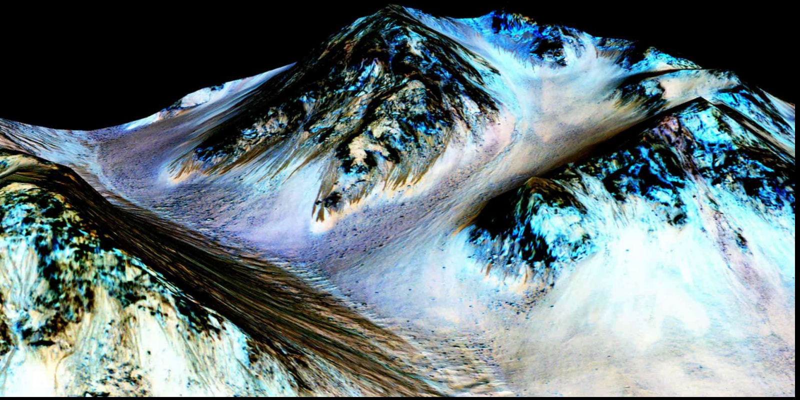
A new paper enriches scientists' understanding of where the rock record preserved or destroyed evidence of Mars' past and possible signs of ancient life.

Today, Mars is a planet of extremes – it's bitterly cold, has high radiation, and is bone-dry. But billions of years ago, Mars was home to lake systems that could have sustained microbial life. As the planet's climate changed, one such lake – in Mars' Gale Crater – slowly dried out. Scientists have new evidence that supersalty water, or brines, seeped deep through the cracks, between grains of soil in the parched lake bottom and altered the clay mineral-rich layers beneath.

"We used to think that once these layers of clay minerals formed at the bottom of the lake in Gale Crater, they stayed that way, preserving the moment in time they formed for billions of years," said Tom Bristow, CheMin principal investigator and lead author of the paper at NASA's Ames Research Center in California's Silicon Valley. "But later brines broke down these clay minerals in some places – essentially resetting the rock record."

Gullies, 2017
These viscous, lobate flow features found in the mid-latitudes of Mars resemble terrestrial moraines, suggesting that these deposits are ice-rich, or may have been ice-rich in the past.





Recurring 'Lineae' on Slopes at Hale Crater, Mars

Dark, narrow streaks on Martian slopes such as these at Hale Crater are inferred to be formed by seasonal flow of water on contemporary Mars. The streaks are roughly the length of a football field.

The imaging and topographical information in this processed, false-color view come from the High Resolution Imaging Science Experiment (HiRISE) camera on NASA's Mars Reconnaissance Orbiter.

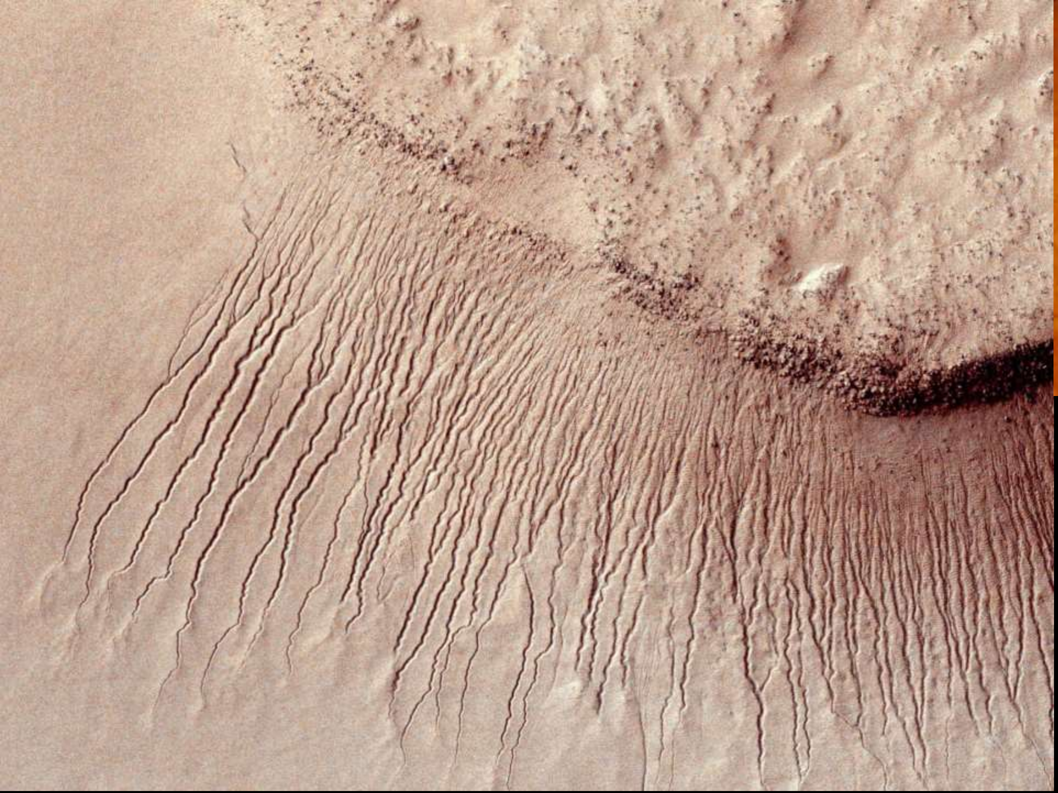
These dark features on the slopes are called "recurring slope lineae" or RSL. Planetary scientists using observations with the Compact Reconnaissance Imaging Spectrometer on the same orbiter detected hydrated salts on these slopes at Hale Crater, corroborating the hypothesis that the streaks are formed by briny liquid water.

The image was produced by first creating a 3-D computer model (a digital terrain map) of the area based on stereo information from two HiRISE observations, and then draping a false-color image over the land-shape model. The vertical dimension is exaggerated by a factor of 1.5 compared to horizontal dimensions. The camera records brightness in three wavelength bands: infrared, red and blue-green. The draped image is one product from HiRISE observation ESP_03070_1440.

The University of Arizona, Tucson, operates HiRISE, which was built by Ball Aerospace & Technologies Corp., Boulder, Colorado. NASA's Jet Propulsion Laboratory, a division of the California Institute of Technology in Pasadena, manages the Mars Reconnaissance Orbiter Project and Mars Science Laboratory Project for NASA's Science Mission Directorate, Washington.
Image Credit: NASA/JPL-Caltech/Univ. of Arizona

Hellas Planitia, 2011

The channels on the Hellas Planitia basin range from 1m to 10 m in width.



Hellas Planitia is a plain located within the huge, roughly circular impact basin Hellas located in the southern hemisphere Mars. Hellas is the largest impact structure on Mars & the third- or fourth-largest known impact crater in the Solar System.

The basin floor is about 7,152 m deep, which is 3,000 m deeper than the Moon's South Pole-Aitken basin, and has a diameter of about 2,300 km east to west. It is centred at 42.4°S 70.5°E
Hellas Planitia is thought to have been formed during the Late Heavy Bombardment period of the Solar System, approximately 4.1 to 3.8 billion years ago, when a protoplanet or large asteroid hit the surface.

The altitude difference between the rim and the bottom is over 9,000 m. The crater's depth of 7,152 m below the topographic datum of Mars explains the atmospheric pressure at the bottom: 12.4 mbar (1240 Pa or 0.18 psi) during winter, when the air is coldest and reaches its highest density. This is 103% higher than the pressure at the topographical datum (610 Pa, or 6.1 mbar, or 0.09 psi) and above the triple point of water, suggesting that the liquid phase could be present under certain conditions of temperature, pressure, and dissolved salt content. It has been theorized that a combination of glacial action and explosive boiling may be responsible for gully features in the crater.

Some of the low elevation outflow channels extend into Hellas from the volcanic Hadriacus Mons complex to the northeast, two of which Mars Orbiter Camera images show contain gullies: Dao Vallis and Reull Vallis. These gullies are also low enough for liquid water to be transient around Martian noon, if the temperature were to rise above 0 Celsius.

Frost on Mars
Image from High Resolution Imaging Science experiment HiRISE camera Mars Reconnaissance Orbiter taken 11th April 2008
Source: NASA/JPL/University of Arizona

Water Ice on Mars

- Water ice will be a key consideration for any potential landing site for astronauts
- Liquid water can't last in the thin air of Mars; with so little air pressure, it evaporates from a solid to a gas when exposed to the atmosphere
- Martian water ice is locked away underground throughout the planet's mid-latitudes.
- These regions near the poles have been studied by NASA's Phoenix lander, which scraped up ice, and MRO, which has taken many images from space of meteor impacts that have excavated this ice.
- To find ice that astronauts could easily dig up, the study's authors relied on two heat-sensitive instruments: MRO's Mars Climate Sounder and the Thermal Emission Imaging System (THEMIS) camera on Mars Odyssey.
- The northern and southern mid-latitudes have more plentiful sunlight and warmer temperatures than the poles. But there's a heavy preference for landing in the northern hemisphere, which is generally lower in elevation and provides more atmosphere to slow a landing spacecraft.
- A large portion of a region called Arcadia Planitia is the most tempting target in the northern hemisphere. This region, has water ice less than 30 centimeters to 60 centimeters below the surface.

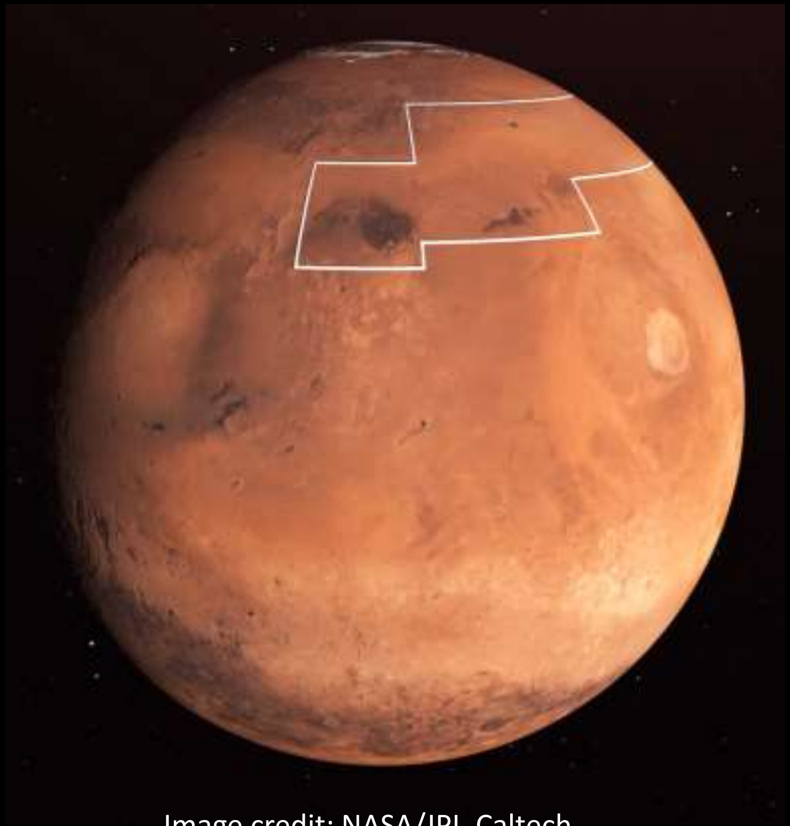


Image credit: NASA/JPL-Caltech

The area marked above holds near-surface water ice that would be easily accessible for astronauts to dig up. The water ice was identified as part of a map using data from NASA orbiters.

Perspective view of a mountain in the eastern Hellas region of Mars surrounded by a deposit that scientists think are debris-covered glaciers. Image is 20 miles (31 km) across. (Image credit: ESA/DLR/FU Berlin)

Mars has vast glaciers hidden under aprons of rocky debris near mid-latitude mountains, pointing to a new and large potential reservoir of life-supporting water on the planet.

These mounds of ice exist at much lower latitudes than any ice previously found on the red planet.

"Altogether, these glaciers almost certainly represent the largest reservoir of water ice on Mars that's not in the polar caps," said John Holt of the University of Texas at Austin and the main author of the study. "Just one of the features we examined is three times larger than the city of Los Angeles and up to one-half-mile thick, and there are many more.“

Credit: Space.com By Andrea Thompson published November 21, 2008
Buried Glaciers Found on Mars

This handout image, released November 20, 2008, shows a perspective view of a mountain in the eastern Hellas region of Mars surrounded by a lobate deposit with flow textures on the surface.
A ground-penetrating radar instrument aboard the U.S. space agency's Mars Reconnaissance Orbiter collected the data that confirmed the presence of the buried glaciers that extend for dozens of km from the edges of mountains or cliffs.
These closely resemble glaciers in Antarctica that similarly are covered by rocky debris.
They may be the vestiges of ice sheets that blanketed parts of Mars in a past ice age.

Credit: REUTERS/Ernst Hauber/ESA/DLR/Handout

nature astronomy

ARTICLES

https://doi.org/10.1038/s41550-020-1200-6

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Multiple subglacial water bodies below the south pole of Mars unveiled by new MARSIS data

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The detection of liquid water by the Mars Advanced Radar for Subsurface and Ionosphere Sounding (MARSIS) at the base of the south polar layered deposits in Ultimi Scopuli has reinvigorated the debate about the origin and stability of liquid water under present-day Martian conditions. To establish the extent of subglacial water in this region, we acquired new data, achieving extended radar coverage over the study area. Here, we present and discuss the results obtained by a new method of analysis of the complete MARSIS dataset, based on signal processing procedures usually applied to terrestrial polar ice sheets. Our results strengthen the claim of the detection of a liquid water body at Ultimi Scopuli and indicate the presence of other wet areas nearby. We suggest that the waters are hypersaline perchlorate brines, known to form at Martian polar regions and thought to survive for an extended period of time on a geological scale at below-eutectic temperatures.

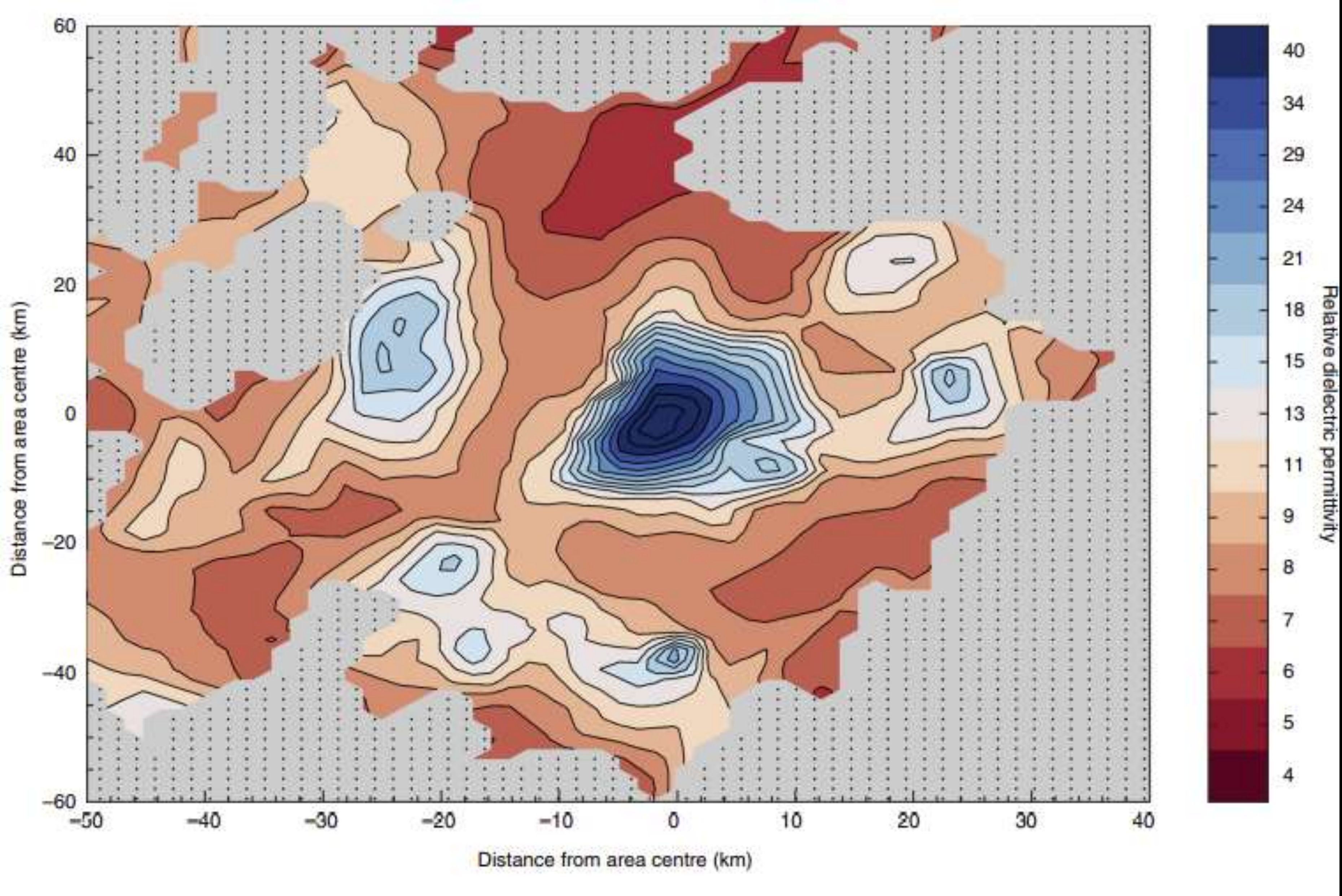


Fig. 5 | Relative dielectric permittivity map computed by inverting the radar data considering all regions where the number of samples is larger than 100. The map only shows the permittivity values retrieved from radar data having acuity values larger than 0.5 (Methods). This procedure has reduced the dimension of the study area to 90 × 120 km2 Values larger than 15 suggest the presence of liquid water.

Source: "Multiple subglacial water bodies below the south pole of Mars unveiled by new MARSIS data" Lauro et al Nature Astronomy, 2021-01-01, Vol.5 (1), p.63-70

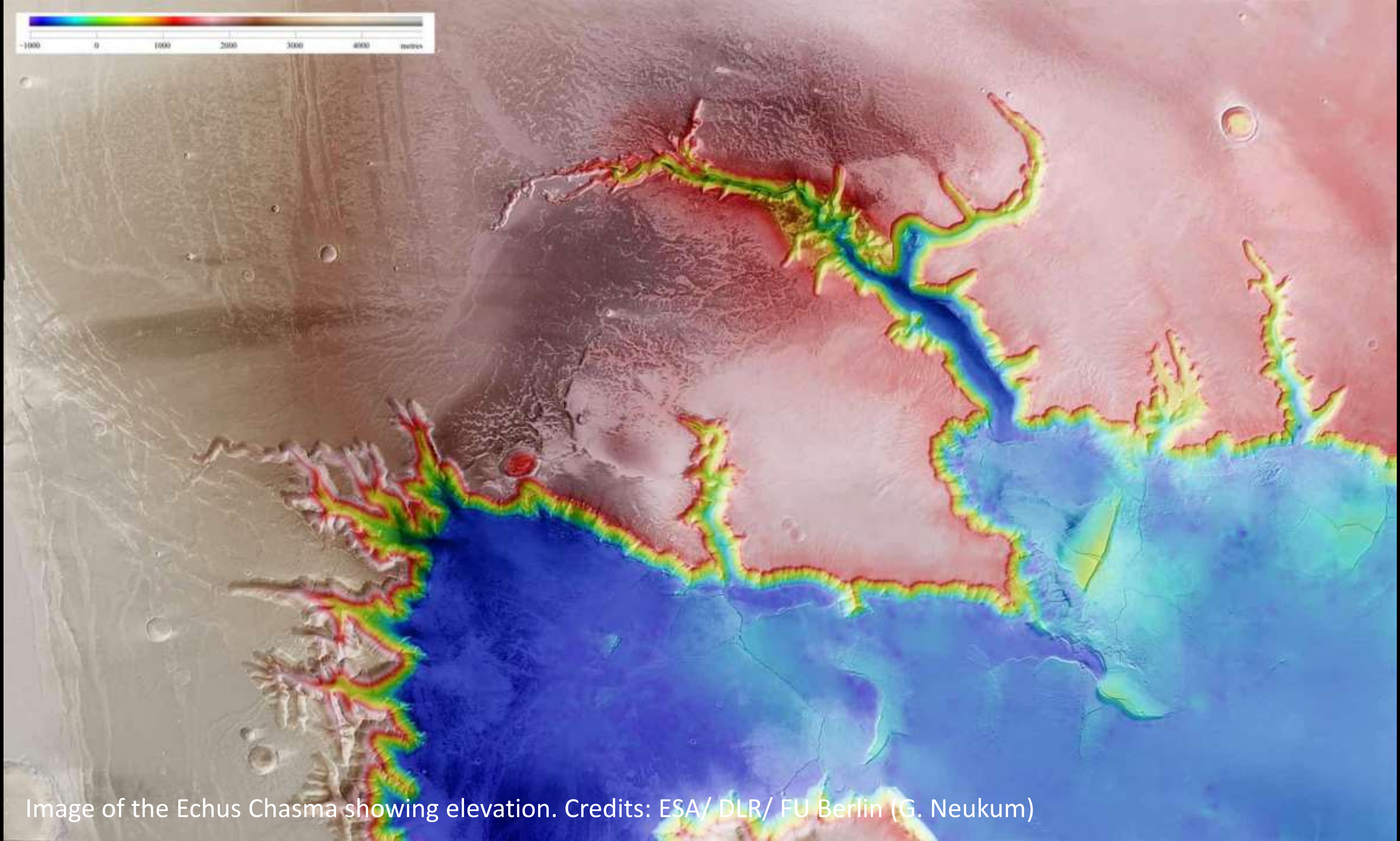
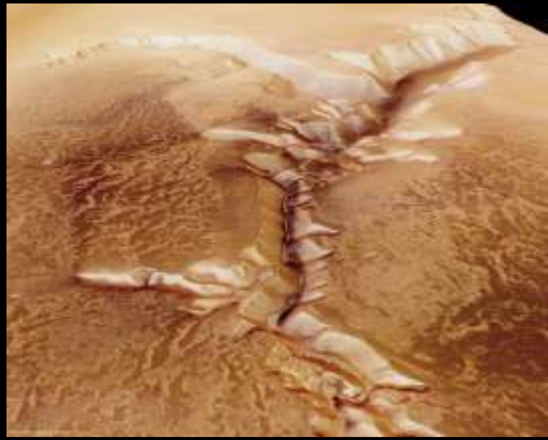


Image of the Echus Chasma showing elevation. Credits: ESA/ DLR/ FU Berlin (G. Neukum)

The majority of planetary geologists seem to favour the idea of water flowing on Mars surface in the past. The images shown here of Echus Chasma are from the European Space Agency's Mar's Express, and its High-Resolution Stereo Camera (HRSC). Echus Chasma is believed to be one of the largest water source regions on the Red Planet. The valleys, cut into the landscape look similar to drainage networks found on Earth.

Echus Chasma is approximately 100 km long and 10 km wide. Echus Chasma is believed to be the water source region that formed Kasei Valles, a large valley which extends thousands of kilometers to the north. It's located in the Lunae Planum high plateau, north of Valles Marineris " the Grand Canyon of Mars". This image indicates elevation data, also obtained by the HRSC.

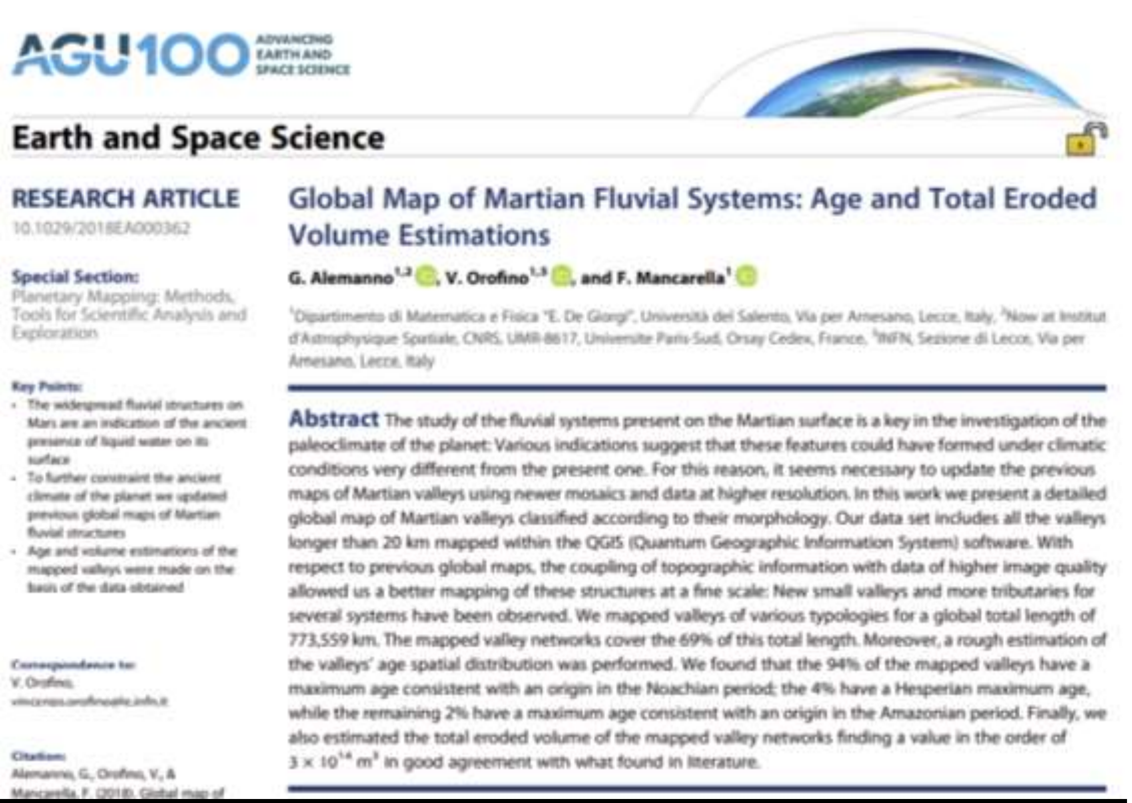
An impressive cliff, up to 4000 m high, is located in the eastern part of Echus Chasma. Possibly, gigantic water falls may once have plunged over these cliffs on to the valley floor. The remarkably smooth valley floor was later flooded by basaltic lava.



Overhead view of the Echus Chasma.
Credits: ESA/ DLR/ FU Berlin (G. Neukum)

Image of the Echus Chasma showing elevation.
Credits: ESA/ DLR/ FU Berlin (G. Neukum)

Echus Chasma mosaic.
Credits: ESA/DLR/ FU Berlin (G. Neukum)



AGU100 ADVANCING EARTH AND SPACE SCIENCE

Earth and Space Science

RESEARCH ARTICLE
10.1029/2018EA000362

Special Section:
Planetary Mapping: Methods, Tools for Scientific Analysis and Exploration

Key Points:
- The widespread fluvial structures on Mars are an indication of the ancient presence of liquid water on its surface
- To further constraint the ancient climate of the planet we updated previous global maps of Martian fluvial structures
- Age and volume estimations of the mapped valleys were made on the basis of the data obtained

Correspondence to:
V. Orofino,

Citation:
Alemanno, G., Orofino, V., & Mancarella, F. (2018). Global map of

Global Map of Martian Fluvial Systems: Age and Total Eroded Volume Estimations

G. Alemanno[1,2], V. Orofino[1,3], and F. Mancarella[1]

[1]Dipartimento di Matematica e Fisica "E. De Giorgi", Università del Salento, Via per Arnesano, Lecce, Italy, [2]Now at Institut d'Astrophysique Spatiale, CNRS, UMR-8617, Universite Paris-Sud, Orsay Cedex, France, [3]INFN, Sezione di Lecce, Via per Arnesano, Lecce, Italy

Abstract The study of the fluvial systems present on the Martian surface is a key in the investigation of the paleoclimate of the planet: Various indications suggest that these features could have formed under climatic conditions very different from the present one. For this reason, it seems necessary to update the previous maps of Martian valleys using newer mosaics and data at higher resolution. In this work we present a detailed global map of Martian valleys classified according to their morphology. Our data set includes all the valleys longer than 20 km mapped within the QGIS (Quantum Geographic Information System) software. With respect to previous global maps, the coupling of topographic information with data of higher image quality allowed us a better mapping of these structures at a fine scale: New small valleys and more tributaries for several systems have been observed. We mapped valleys of various typologies for a global total length of 773,559 km. The mapped valley networks cover the 69% of this total length. Moreover, a rough estimation of the valleys' age spatial distribution was performed. We found that the 94% of the mapped valleys have a maximum age consistent with an origin in the Noachian period; the 4% have a Hesperian maximum age, while the remaining 2% have a maximum age consistent with an origin in the Amazonian period. Finally, we also estimated the total eroded volume of the mapped valley networks finding a value in the order of 3×10^{14} m^3 in good agreement with what found in literature.

Reference

Alemanno et al. (2018). Global Map of Martian Fluvial Systems: Age and Total Eroded Volume Estimations.
Earth and Space Science. 5. 10.1029/2018EA000362.

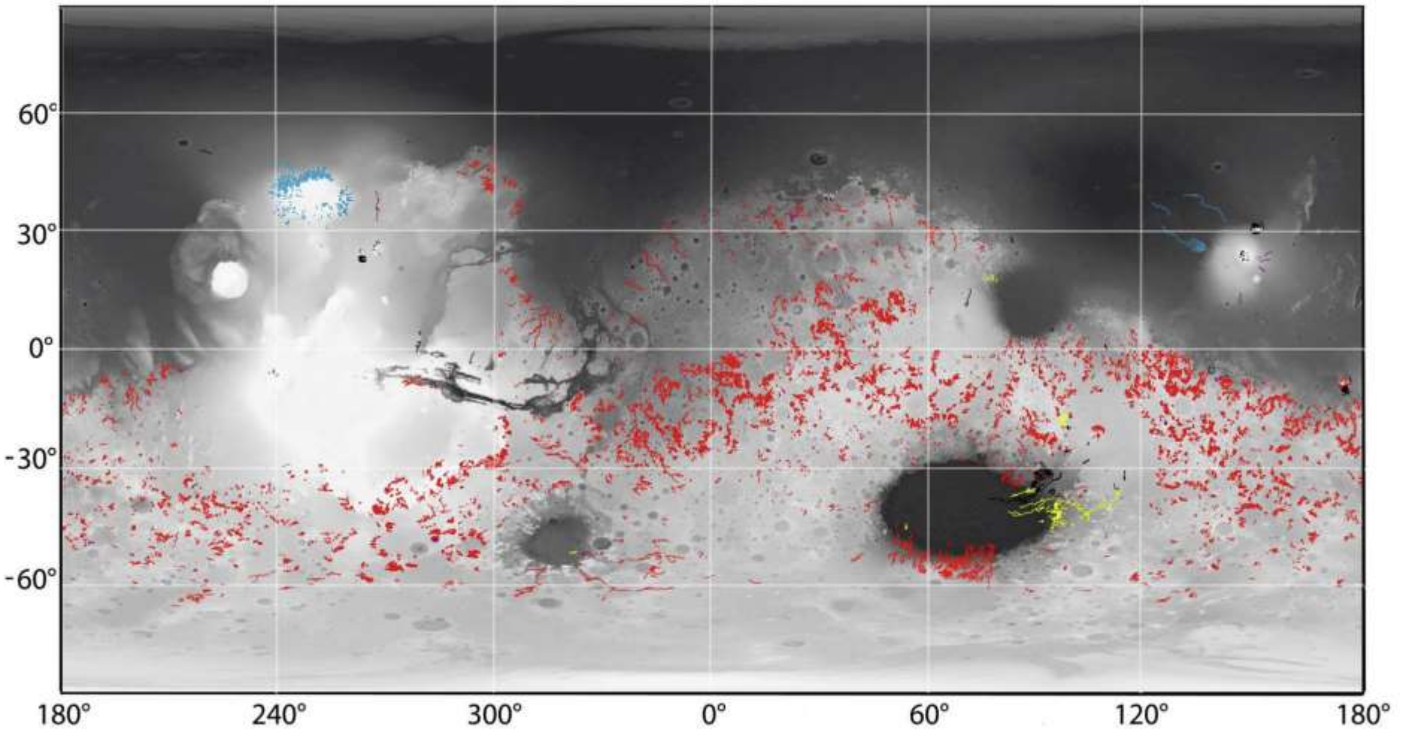


Figure 6. Mapped Martian fluvial systems in different colors according to various age classes: Noachian (red), Noachian-Hesperian (yellow), Hesperian (black), Hesperian-Amazonian (pink), and Amazonian (blue). The background map is a grayscale MOLA topographic mosaic from high (white) to low (gray). The map projection is equidistant cylindrical at low latitudes and sinusoidal and polar stereographic at middle to high latitudes.

A fluvial system is a drainage basin, the spatial geomorphic area occupied by a river system.

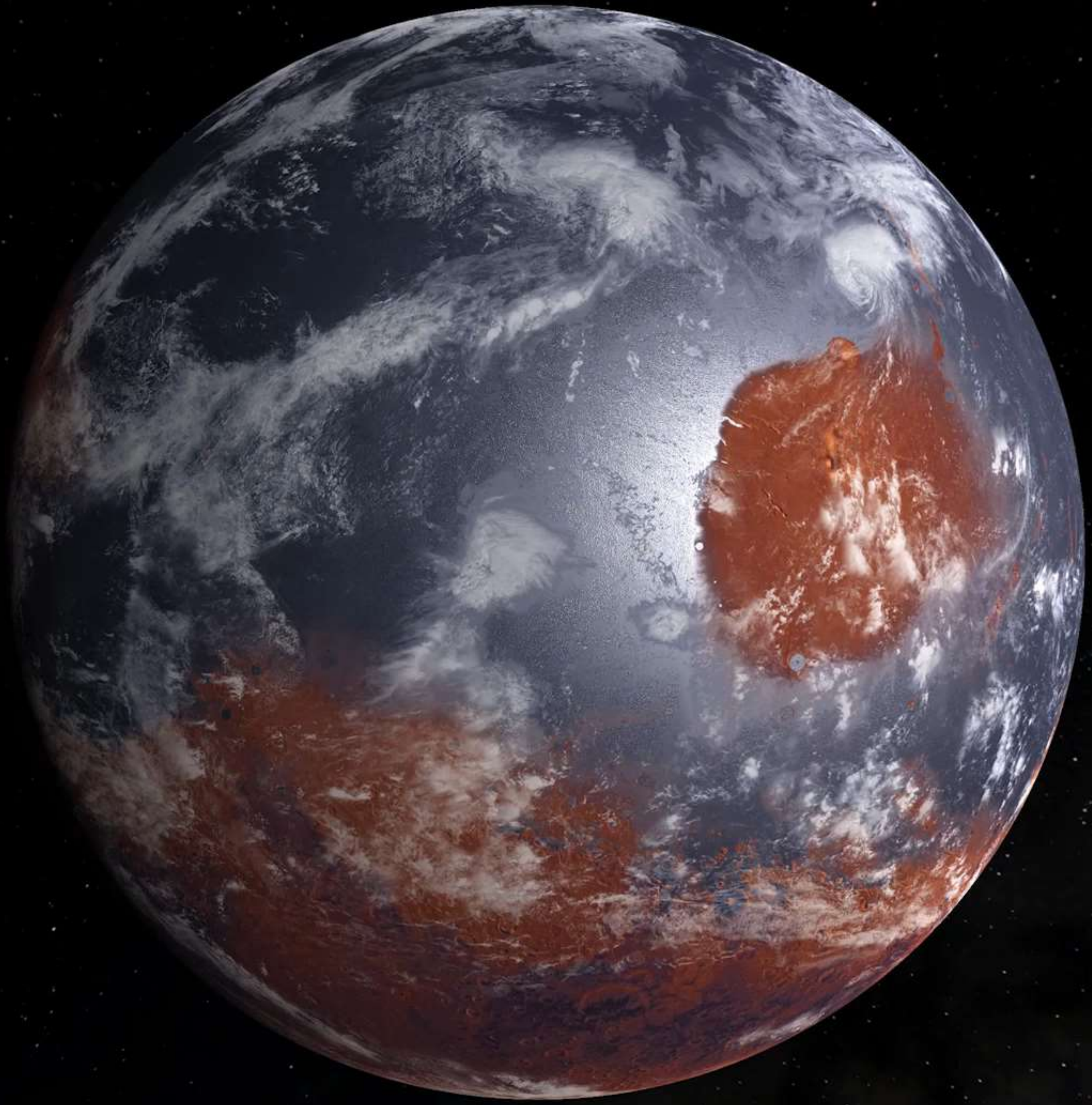
Mars has extensive fluvial systems

This illustration shows Jezero Crater — the landing site of the Mars 2020 Perseverance rover — as it may have looked billions of years go on Mars, when it was a lake. An inlet and outlet are also visible on either side of the lake
Image Credit: NASA/JPL-Caltech

Source: NASA/MAVEN/Lunar and Planetary Institute
Published: August 6, 2018
What might a wet Mars have looked like? This artist's concept attempts to fill in the blanks.

This artist's model of shows a theoretical view of Mars — billions of years ago — with liquid water on the surface and a thicker atmosphere.

The globe was created by filling Mars' lower altitudes with water and adding cloud cover. The locations for the ancient ocean are based on current altitudes and do not reflect the actual ancient topography.



Martian Magnetic Fields

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Earth and Space Science

RESEARCH ARTICLE
10.1029/2021EA001860

A Spherical Harmonic Martian Crustal Magnetic Field Model Combining Data Sets of MAVEN and MGS

J. W. Gao[1,2,3], Z. J. Rong[1,2,3], Lucy Klinger[4], X. Z. Li[1,2,3], D. Liu[1,2,3], and Y. Wei[1,2,3]

[1]Key Laboratory of Earth and Planetary Physics, Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing, China, [2]College of Earth and Planetary Sciences, University of Chinese Academy of Sciences, Beijing, China, [3]Mohe Observatory of Geophysics, Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing, China, [4]Beijing International Center for Mathematical Research, Peking University, Beijing, China

Key Points:

- A spherical harmonic Martian crustal field model is presented that combines both MAVEN and MGS data
- The global power spectrum of the Martian crustal field, up to spherical-harmonic degree 90, is robustly determined
- Our new model demonstrates that small-scale crustal fields on Mars may have been largely underestimated by most previous models

Supporting Information:

Supporting Information may be found in the online version of this article.

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Citation:

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Abstract

This study presents a new spherical harmonic (SH) model of the crustal magnetic field of Mars, based on the magnetic field data set measured by the Mars Global Surveyor (MGS) and the Mars Atmosphere and Volatile EvolutioN (MAVEN) spacecraft. To minimize the influence of external fields due to solar wind interaction with Mars, we rejected data that were observed dayside and above an altitude of 500 km. The data points of MAVEN were reduced by using a proxy of solar wind activity that identified and rejected any data measured during magnetically disturbed intervals. We used a conventional least squares technique to estimate the Gauss coefficients fitted to the reduced data set and made a compromise between model misfit and model roughness by truncating the SH model at degree 110. This model is capable of representing crustal fields with a spatial resolution approaching ~200 km at 120 km altitude and ~260 km at the Martian surface. Since our model fits MAVEN's observational data better than previous models, especially the data obtained during MAVEN's low altitude periapsis passes, we conclude that it may more accurately approximate the low-altitude crustal field. We calculate the crustal field power spectrum of various models and find that small-scale fields at low altitudes were underestimated by most previous models. This new model could benefit future studies associated with the Martian crustal field and its interaction with the solar wind.

Plain Language Summary

In contrast to Earth, Mars does not have a global dipole magnetic field. An earlier Mars Global Surveyor (MGS) mission discovered that Mars possesses localized magnetic field anomalies, which most likely originate in the Martian crust. The localized crustal magnetic fields on Mars are much stronger than the crustal fields usually observed on Earth. The strong Martian crustal field can significantly affect the interaction between solar wind and Mars. An accurate crustal field model is thus necessary and important for studying, among others, the Martian space environment and the geometry and origin of the crustal field. Here, we present a new crustal magnetic field model that combines the spacecraft data of Mars Atmosphere and Volatile EvolutioN and MGS. For low altitudes, the new model fits the data much better than previous models, giving a more accurate representation of the Martian crustal field. This new model could thus greatly improve our knowledge of the Martian crustal field, including its field morphology, its field map at low altitudes, and its field strength at different wavelengths.

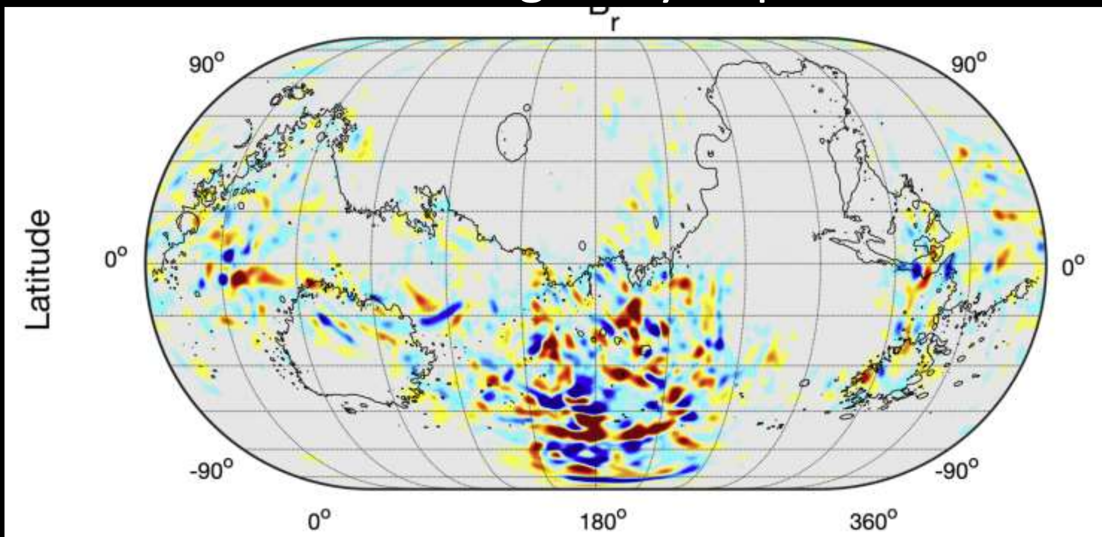
1. Introduction

From 1997 to 2006, the Mars Global Surveyor (MGS) spacecraft provided magnetic field measurements while orbiting Mars, extensively sampling the magnetic field at an altitude of about 400 km (Acuña et al., 1998) after periapsis was raised upon completion of the aerobraking phase. The MGS mission discovered that Mars possesses many localized remanent magnetic fields, which most likely originate in the Martian lithosphere (Acuña et al., 1999). Remanent magnetic fields, otherwise known as crustal fields or lithospheric magnetic fields, are widely believed to be induced by an ancient core dynamo. Mars currently does not have a global dipole magnetic field as in the case of Earth and Mercury (Langlais et al., 2010). The most intense crustal fields of Mars are located in the Southern Hemisphere. These fields are 1 to 2 orders of magnitude stronger than the crustal fields on Earth (Kother et al., 2015; Voorhies et al., 2002), 3 to 4 orders of magnitude stronger than the crustal fields on Moon (Purucker & Nicholas, 2010) and Mercury (Johnson et al., 2015).

Citation:
Gao, J. W., Rong, Z. J., Klinger, L., Li, X. Z., Liu, D., & Wei, Y. (2021). A spherical harmonic Martian crustal magnetic field model combining data sets of MAVEN and MGS.
Earth and Space Science, 8, e2021EA001860.
https://doi.org/10.1029/2021EA001860

Martian Magnetic Fields

- Mars does not presently have a global magnetic field but had one early in its life, similar to that of Earth
- An earlier Mars Global Surveyor (MGS) mission discovered that Mars possesses localized magnetic field anomalies, which most likely originate in the Martian crust and represent remanent magnetism in ancient rocks formed from the molten core during the early period of volcanism on Mars.
- Some localized crustal magnetic fields are more than 30 times stronger than those of Earth.
- The strong Martian crustal field can significantly affect the interaction between solar wind and Mars.
- Gao et al 2021 present a new crustal magnetic field model that combines the spacecraft data of Mars Atmosphere and Volatile EvolutioN and MGS.
- For low altitudes, the new model fits the data much better than previous models, giving a more accurate representation of the Martian crustal field. This new model could thus greatly improve our knowledge of the Martian crustal field, including
  - its field morphology,
  - its field map at low altitudes,
  - and its field strength at different wavelengths.

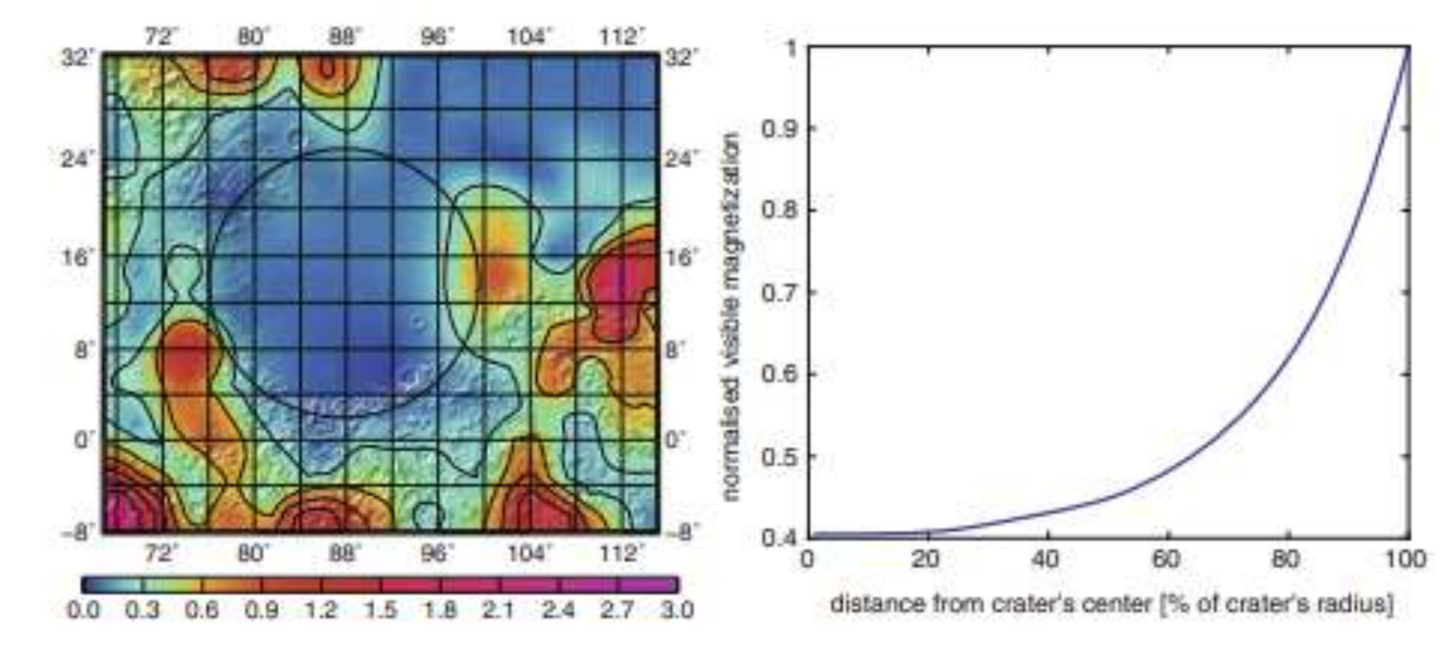


Gao, et al (2021). A spherical harmonic Martian crustal magnetic field model combining data sets of MAVEN and MGS.

Martian Magnetic Fields

The interpretation of the magnetic signature both of volcanoes and impact craters allows for a Martian core dynamo shutdown in the late Noachian, at around 4.1 billion years ago

Effect of Meteorite Impacts on Crust magnetization



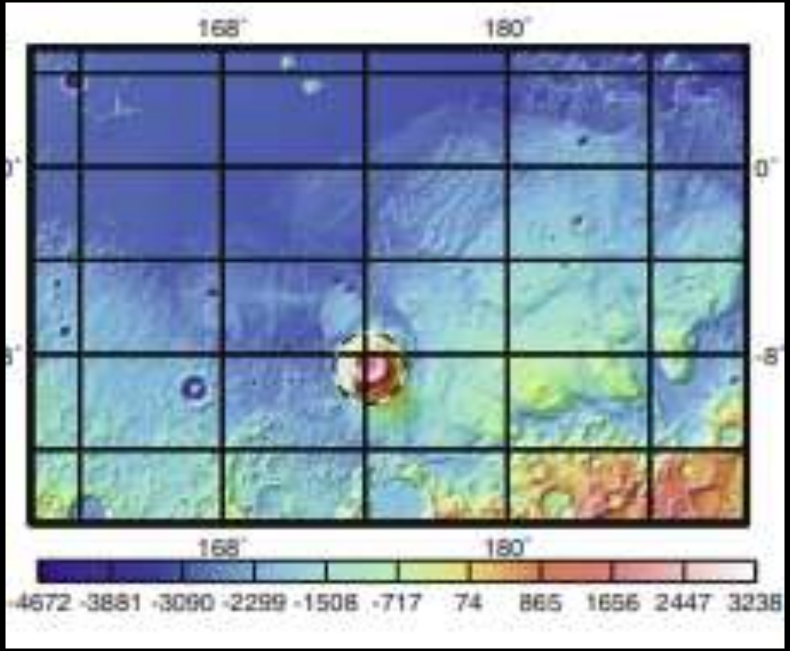
The visible magnetization, I , (in A/m), over the region around the Isidis impact basin. Projection is Mercator.
The left panel of this figure shows a map of the magnetization intensity.
The right panel shows the normalized circumferential average of the magnetization intensity in dependence of the distance to the crater's centre. This figure shows that the magnetization near the crater's centre is demagnetized to 40% of the mean magnetization at the crater's edge

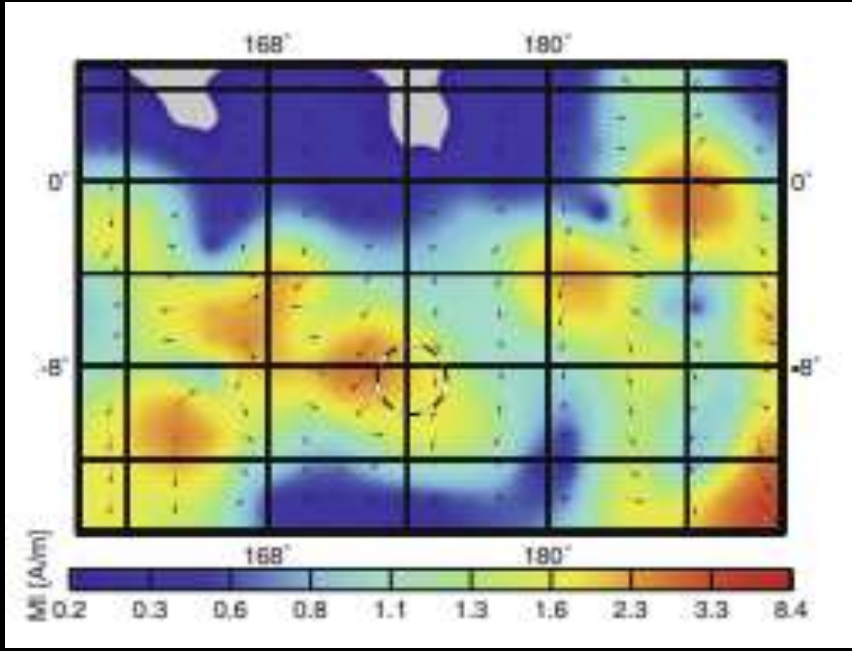
Source: Morschhauser, et al. (2018). Mars' Crustal Magnetic Field. In: Lühr, H., Wicht, J., Gilder, S.A., Holschneider, M. (eds) Magnetic Fields in the Solar System. Astrophysics and Space Science Library, vol 448. Chapter 12 pp 331-356 Springer, Cham. https://doi.org/10.1007/978-3-319-64292-5_12

Effect of Volcanic eruptions on Crust magnetization

Martian Magnetic Fields

Left: Topographic map of the region surrounding Apollinaris Patera.
Apollinaris is located in the centre of the figure and indicated by the black-white circle.
Lower right: Visible magnetization over the same region for a 40 km thick magnetized layer



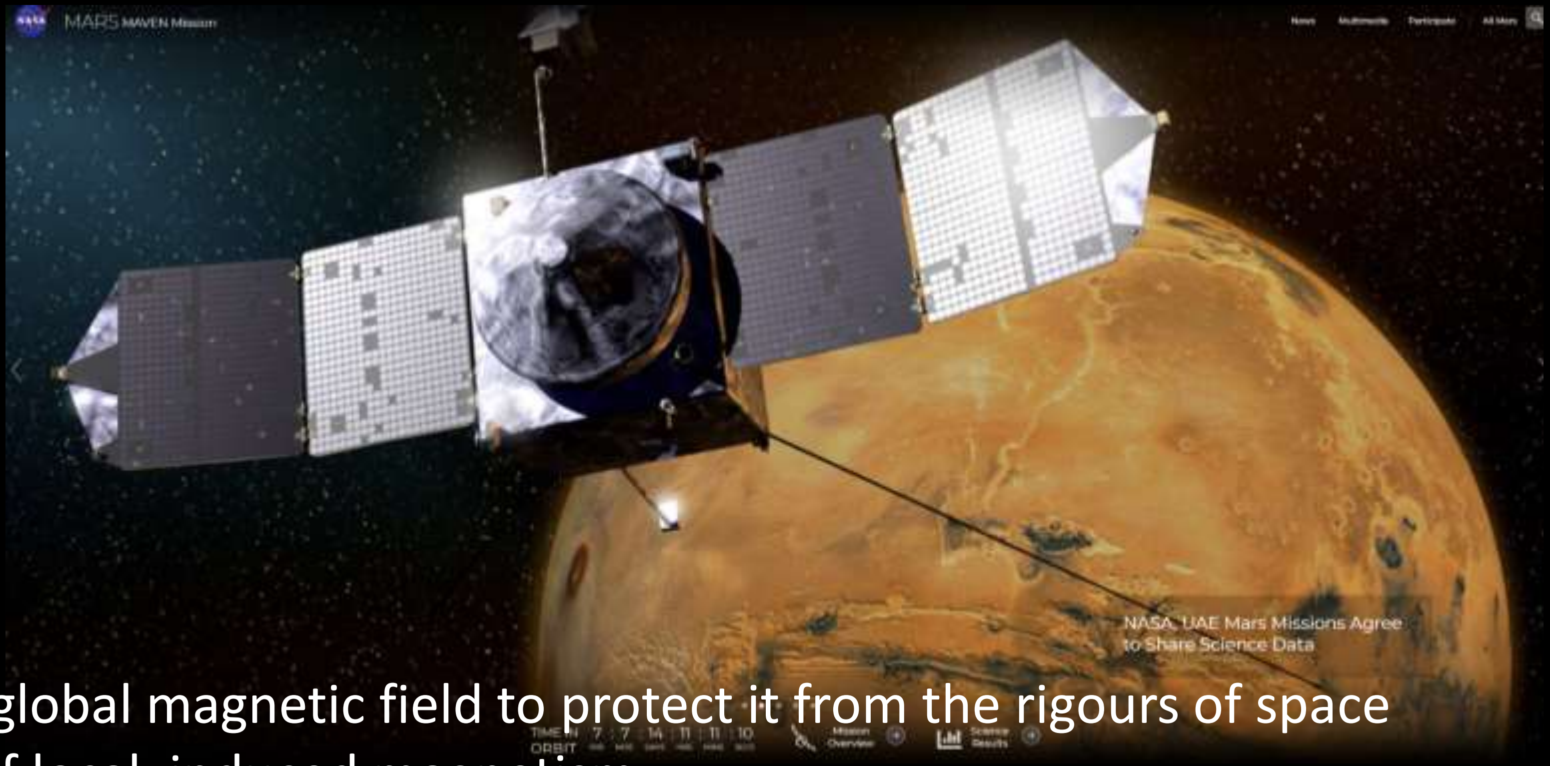


The volcanic caldera (marked by the black and white circle clearly appears to be less magnetized than the region to its west. This region is older than the volcano, and corresponds to a Hesperian Noachian transition unit (Tanaka et al. 2014). Therefore, we argue that Apollinaris Patera may have partially demagnetized a previously emplaced larger region of elevated magnetic field intensity. In consequence, the magnetic signature of Apollinaris does not necessarily contradict the implications on the timing of the Martian core dynamo which were made from studying the magnetic signature of impact craters.

Source: Morschhauser, et al. (2018). Mars' Crustal Magnetic Field. In: Lühr, H., Wicht, J., Gilder, S.A., Holschneider, M. (eds) Magnetic Fields in the Solar System. Astrophysics and Space Science Library, vol 448. Chapter 12 pp 331-356 Springer, Cham. https://doi.org/10.1007/978-3-319-64292-5_12

MAVEN: Mars Atmosphere and Volatile Evolution (MAVEN) spacecraft

Mission Status: Currently Operating
Mars Orbit Insertion 21st Sept 2014
Launched: 18th November 2013

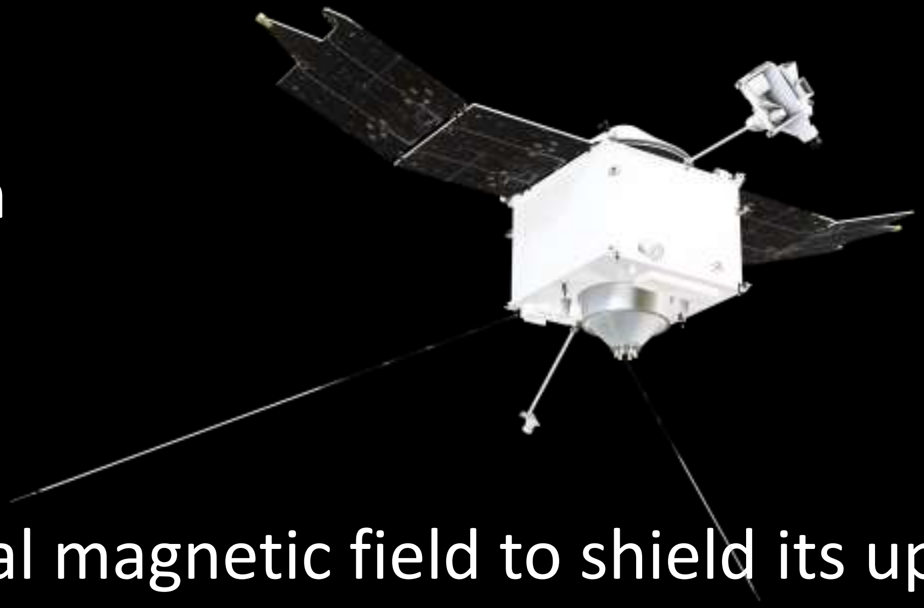


Unlike Earth, Mars doesn't have a global magnetic field to protect it from the rigours of space weather – but it does have spots of local, induced magnetism.

Now, researchers have been able to create an incredible, detailed map of the electric currents that are responsible for shaping these magnetic fields.

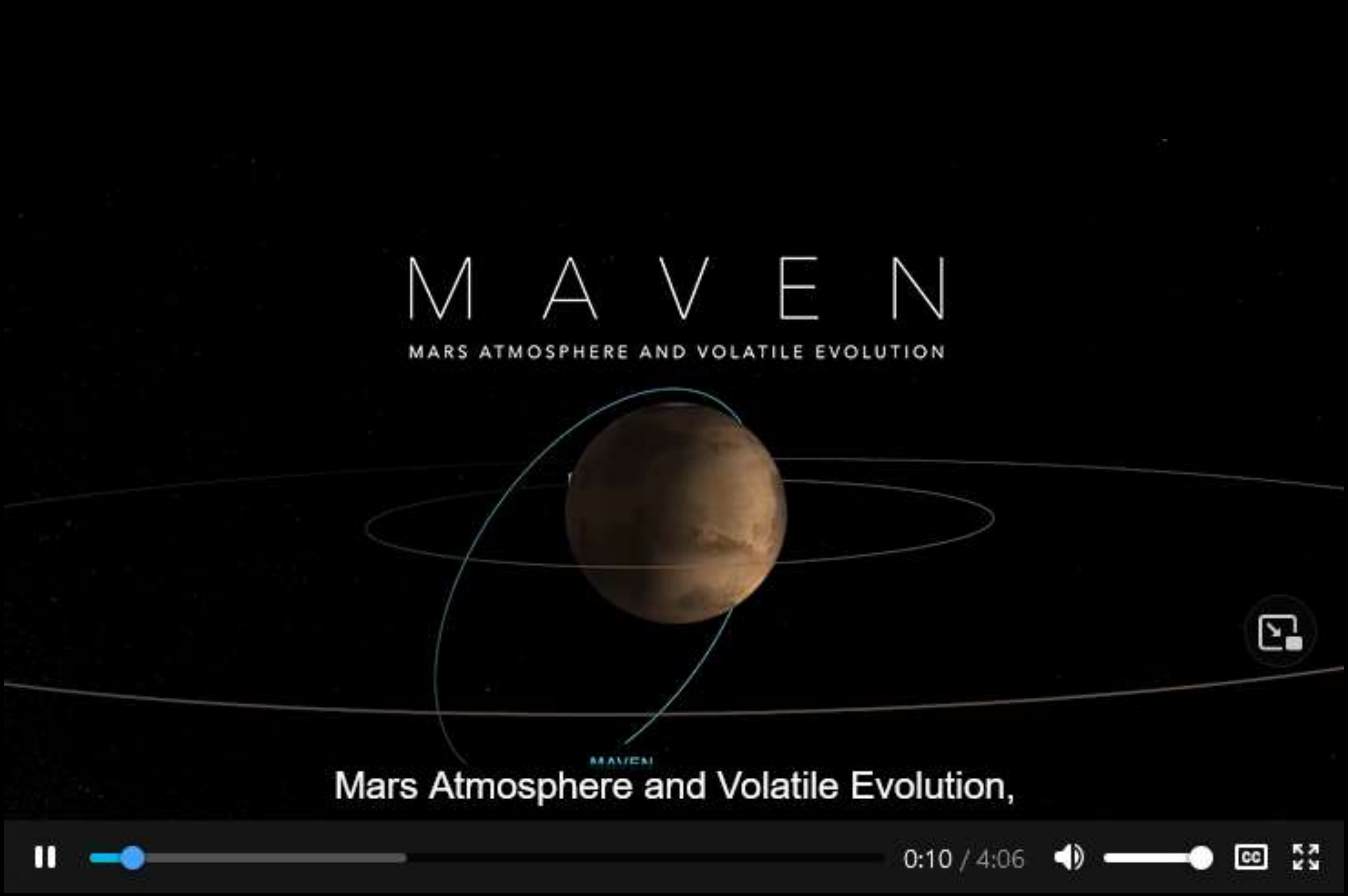
It gives scientists a much greater understanding of how Mars might have lost much of its atmosphere over the course of billions of years, as well as how interactions between the solar winds and Mars' magnetosphere are playing out today.

https://mars.nasa.gov/files/resources/MAVEN_PressKit_Final.pdf



- Five years after NASA’s MAVEN spacecraft entered into orbit around Mars, data from the mission has led to the creation of a map of electric current systems in the Martian atmosphere.
- Unlike Earth, Mars lacks a protective global magnetic field to shield its upper atmosphere from the solar wind.
- Instead, the solar wind crashes into the upper atmosphere and its magnetic field lines drape around the planet.
- This creates an induced magnetosphere that tugs on charged particles in the Mars upper atmosphere, generating electric currents.
- Now, MAVEN’s detailed measurements of the magnetic environment surrounding Mars have revealed the shape of these electric currents for the first time.

NASA – Goddard 26th May 2020 https://svs.gsfc.nasa.gov/13625



NASA – Goddard 26th May 2020 VIDEO LINK: https://svs.gsfc.nasa.gov/13625

When did Mars lose its Magnetic core?

- The Martian core had a magnetic dynamo that persisted from 4.5 to 3.7 billion years ago, and there is evidence that this magnetization processes affected the Martian surface, including depositional and crystallization remanences.
- NASA scientists also noted that 4.5 to 3.7 billion years ago, shortly after the birth of the sun, it was far more active than the middle-age star we live with now.
- Mars lost its global magnetic field during the time of this heightened activity. After 500 million years, the Martian atmosphere was substantially destroyed, all due to the disappearance of Mars global magnetic field.

GEOPHYSICS

Timing of the martian dynamo: New constraints for a core field 4.5 and 3.7 Ga ago

A. Mittelholz[1]*, C. L. Johnson[1,2], J. M. Feinberg[3], B. Langlais[4], R. J. Phillips[5]

The absence of crustal magnetic fields above the martian basins Hellas, Argyre, and Isidis is often interpreted as proof of an early, before 4.1 billion years (Ga) ago, or late, after 3.9 Ga ago, dynamo. We revisit these interpretations using new MAVEN magnetic field data. Weak fields are present over the 4.5-Ga old Borealis basin, with the transition to strong fields correlated with the basin edge. Magnetic fields, confined to a near-surface layer, are also detected above the 3.7-Ga old Lucus Planum. We conclude that a dynamo was present both before and after the formation of the basins Hellas, Utopia, Argyre, and Isidis. A long-lived, Earth-like dynamo is consistent with the absence of magnetization within large basins if the impacts excavated large portions of strongly magnetic crust and exposed deeper material with lower concentrations of magnetic minerals.

INTRODUCTION

Global magnetic fields are intimately tied to a planet's interior, surface, and atmospheric evolution. For terrestrial planets, magnetization acquired by rocks in an ancient field can be preserved over billions of years and thus provide a window into a planet's earliest history. Mars has no current global magnetic field; however, magnetic field measurements made by the Mars Global Surveyor (MGS) spacecraft (*1*) in orbit around the planet unequivocally demonstrated the presence of rocks magnetized in a past dynamo field. The first billion years of Mars' history [from ~4.5 to 3.6 billion years (Ga) ago] included massive volcanism forming most of the volume of the Tharsis province by ~3.9 Ga ago (*2*), the formation of major impact basins such as Hellas, Argyre, Isidis, and Utopia, and atmospheric and climatic conditions very different from those today as evidenced via surface morphological signatures such as valley networks (*3*) and erosional features (*4*).

Establishing the timing and duration of the martian magnetic field, relative to these major events in martian history, is critical to, e.g., understanding whether large impacts played a role in initiating (*5*) or inhibiting (*6*) a dynamo, or whether the change in surface climatic conditions after ~3.7 Ga ago (*3*) was linked to the cessation of a core dynamo. Most hypotheses regarding timing of the martian dynamo are based on the presence of magnetic fields over the heavily cratered southern hemisphere and their absence over the interiors of the large basins: Hellas, Argyre, and Isidis (*1*, *7*–*9*). An "early" dynamo [e.g., (*1*, *7*, *8*)] that had ceased by the time of basin excavation around 3.9 Ga ago (Fig. 1) remains the most accepted scenario. In this interpretation, the unmagnetized basin interiors and magnetized exteriors result from demagnetization within the basin during its formation in the absence of a global field. Furthermore, in this scenario, although a dynamo is inferred to have been present at the timing of formation of ~4.2- to 4.3-Ga old basins (*7*), the earliest history of the dynamo field was unknown. A "late" dynamo that started (*9*) after basin formation has also been proposed (Fig. 1) based on magnetic signals observed over younger volcanoes and lava flows (*10*–*13*), active or emplaced after 3.9 Ga ago. Although such spatial correlations are suggestive, a critical limitation is that it has not been possible to identify whether buried units of unknown age (likely predating 3.9 Ga ago) or datable surficial units give rise to the magnetic field signatures (*10*).

Here, we present new constraints on the timing and strength of the martian dynamo from Mars Atmosphere and Volatile EvolutioN (MAVEN) magnetic field data (*14*) acquired globally at altitudes as low as ~130 km at night [(*15*); table S1]. These data reveal a high-fidelity, high-spatial resolution (*15*, *16*) picture of the martian crustal magnetic field (table S1 caption and fig. S1) that allows detection of signals too weak or wavelengths too short to have been observed by MGS. We use nighttime MAVEN data collected below 200 km altitude to demonstrate that a dynamo likely operated at the time of formation of the northern hemisphere lowlands and the dichotomy boundary, providing new information on the earliest existence of a global magnetic field. Furthermore, we provide the first identification of a datable surface unit as the source of martian magnetization that postdated major basin formation. We suggest scenarios for the martian dynamo that can reconcile these observations with the strong magnetizations in the southern hemisphere and the absence of magnetic fields over the major basins.

RESULTS

Northern hemisphere, an early dynamo

The earliest known feature on Mars is the dichotomy boundary, at which strong magnetic signatures present in the southern hemisphere end abruptly (Fig. 2) (*1*). MGS results showed hints of weak signals over the northern hemisphere, but these were near the noise level of MGS-based models (*17*, *18*). MAVEN data clearly reveal short-wavelength, low-intensity magnetic fields over the northern hemisphere (Fig. 2 and fig. S1). These can also be seen in a new MAVEN-based model (*16*) but have not been previously discussed. Some, located around

Reference:
Timing of the Martian dynamo: New constraints for a core field 4.5 and 3.7 Ga ago
A. MITTELHOLZ C. L. JOHNSON J. M. FEINBERG B. LANGLAIS and R. J. PHILLIPS
SCIENCE ADVANCES 1st May 2020
Vol 6, Issue 18
DOI: 10.1126/sciadv.aba0513

Why Did Mars lose its Magnetic Field?

nature COMMUNICATIONS

ARTICLE

https://doi.org/10.1038/s41467-022-28274-z OPEN

Stratification in planetary cores by liquid immiscibility in Fe-S-H

Shunpei Yokoo [1✉], Kei Hirose [1,2], Shoh Tagawa [1,2], Guillaume Morard[3] & Yasuo Ohishi[4]

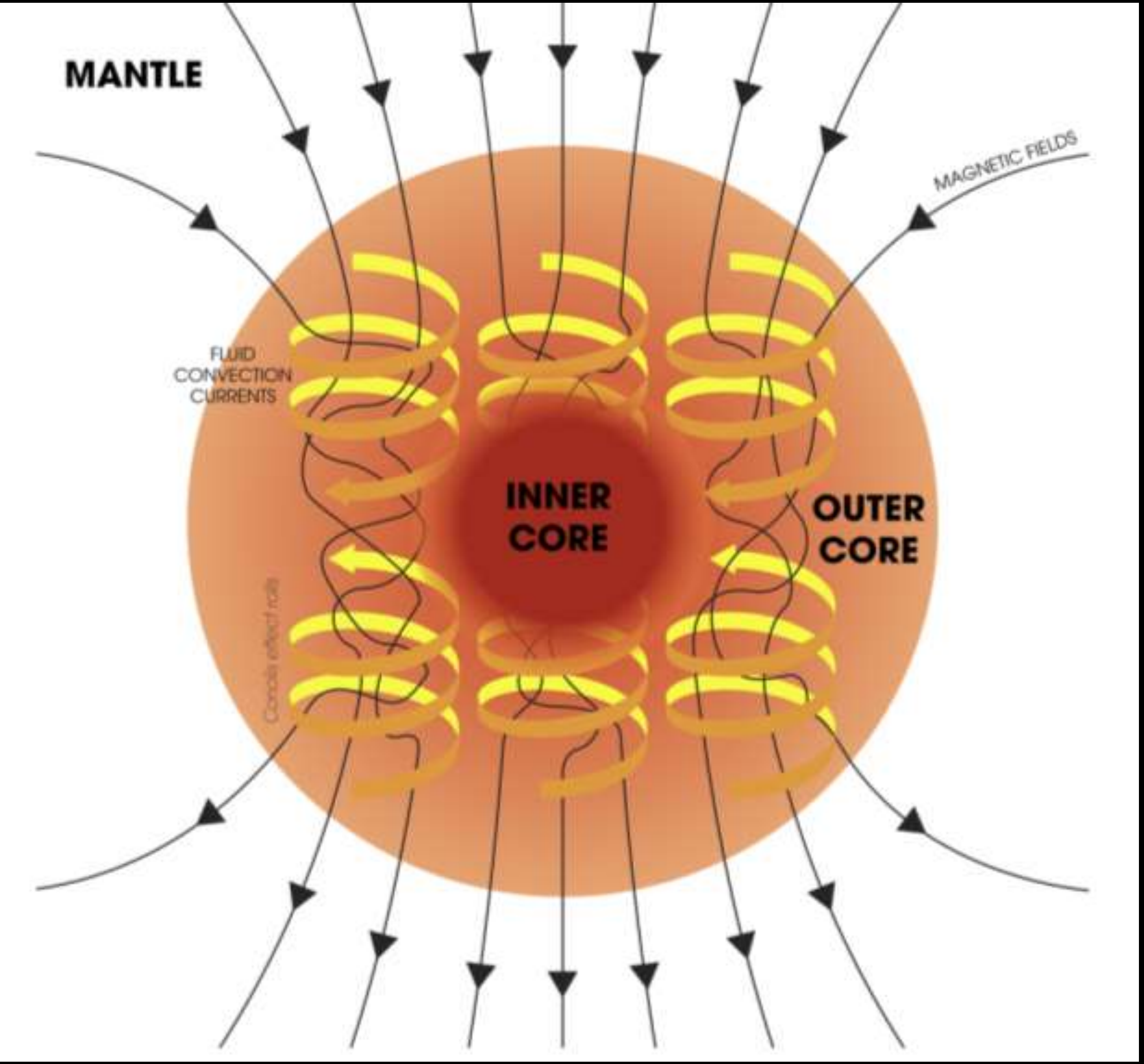
Liquid-liquid immiscibility has been widely observed in iron alloy systems at ambient pressure and is important for the structure and dynamics in iron cores of rocky planets. While such previously known liquid immiscibility has been demonstrated to disappear at relatively low pressures, here we report immiscible S(±Si,O)-rich liquid and H(±C)-rich liquid above ~20 GPa, corresponding to conditions of the Martian core. Mars' cosmochemically estimated core composition is likely in the miscibility gap, and the separation of two immiscible liquids could have driven core convection and stable stratification, which explains the formation and termination of the Martian planetary magnetic field. In addition, we observed liquid immiscibility in Fe-S-H(±Si,O,C) at least to 118 GPa, suggesting that it can occur in the Earth's topmost outer core and form a low-velocity layer below the core-mantle boundary.

Earth's core creates a magneto effect that generates our planet's magnetic fields.

There's a solid inner core and an outer liquid core. Heat flows from the inner core to the outer core, generating convective currents in the outer liquid core.

The convective currents flow in patterns generated by the planet's rotation, the inner core, and the Coriolis effect.

This creates the planet's magnetosphere.



https://commons.wikimedia.org/w/index.php?curid=98901558

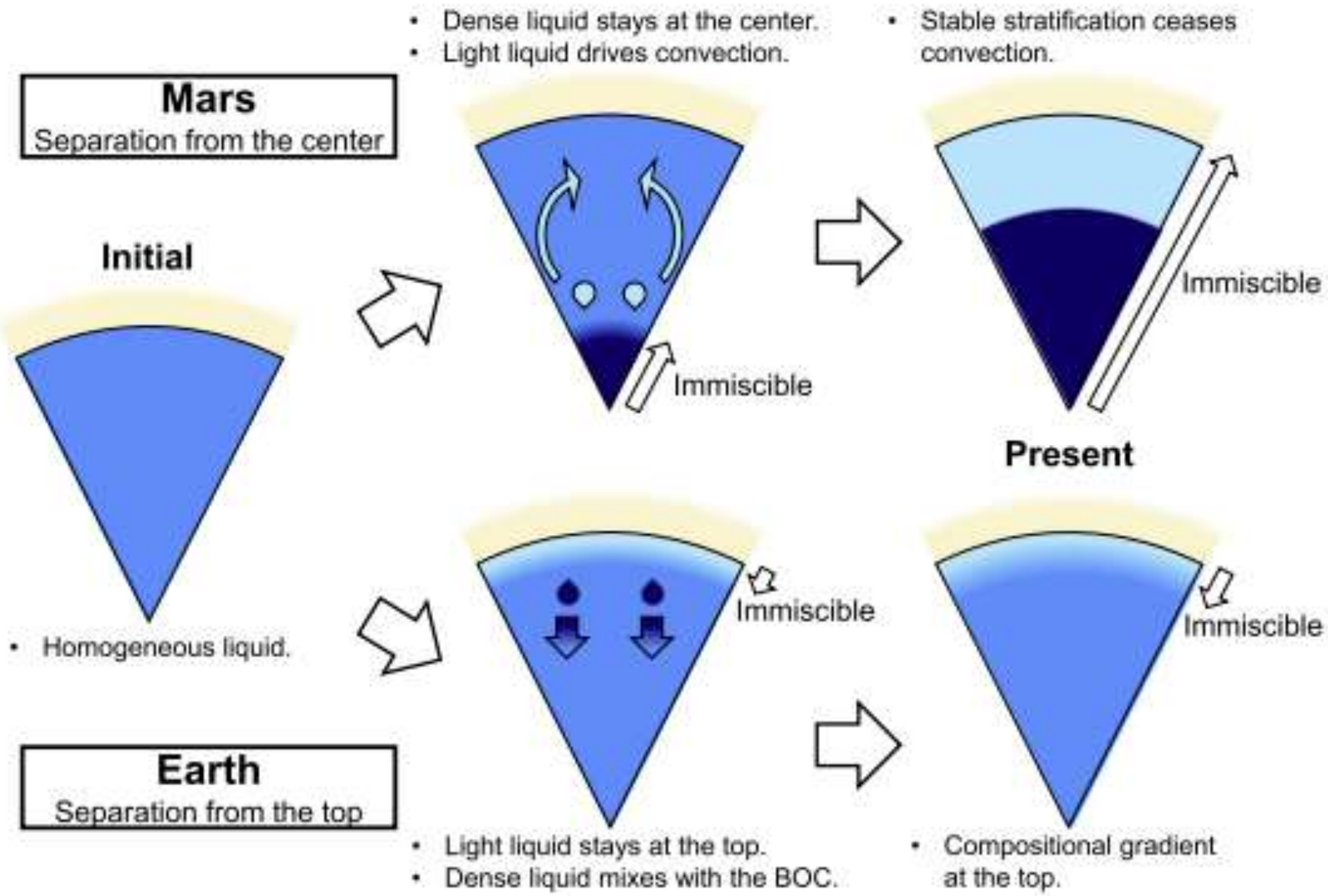
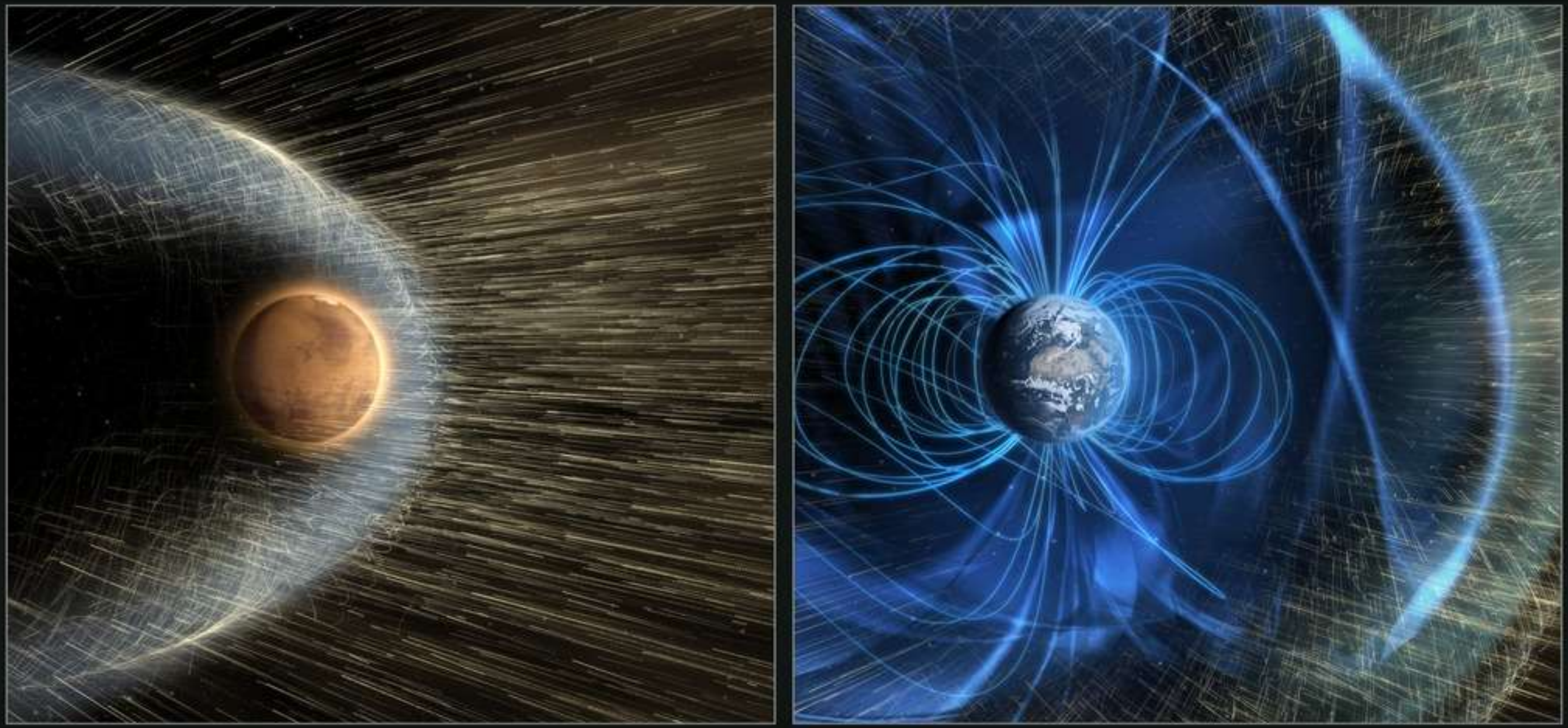


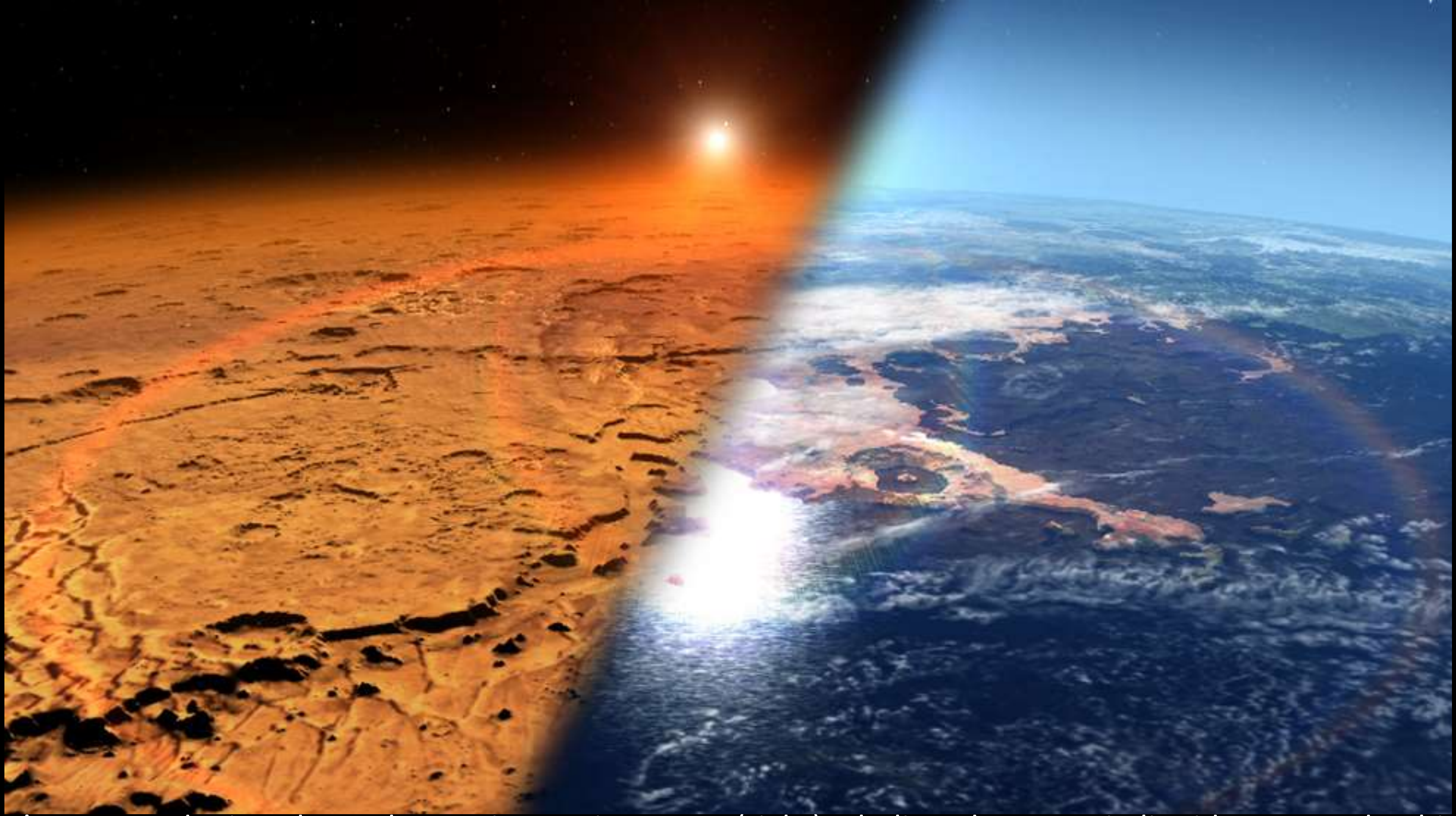
Fig. 3 Stratification in Mars' and Earth's cores caused by liquid immiscibility. Light- and dark-blue represent buoyant and dense liquids, respectively. In the Martian core, liquid immiscibility that started from the center had driven convection and dynamo but eventually formed entire core stratification which ended Mars' planetary magnetic field. In the case of the Earth, on the other hand, the core liquid immiscibility commenced from the top, leading to stratification at the uppermost core which is now observed as E′ layer. These illustrations are not to scale.

Why did Mars lose its Atmosphere?

Because it lost is global magnetic field
and is no longer able to deflect the effects of the incoming solar wind.



The solar wind interacts with the Mars upper atmosphere, but is deflected past Earth by a global magnetic field (artist's concept).
Credit: NASA/GSFC



This artist's concept depicts the early Martian environment (right) – believed to contain liquid water and a thicker atmosphere – versus the cold, dry environment seen at Mars today (left). NASA's Mars Atmosphere and Volatile Evolution is in orbit of the Red Planet to study its upper atmosphere, ionosphere and interactions with the sun and solar wind.
Credits: NASA's Goddard Space Flight Center

Solar Wind Strips the Martian Atmosphere

NASA's Mars Atmosphere and Volatile Evolution (MAVEN) mission has identified the process that appears to have played a key role in the transition of the Martian climate from an early, warm and wet environment that might have supported surface life to the cold, arid planet Mars is today.

MAVEN data have enabled researchers to determine the rate at which the Martian atmosphere currently is losing gas to space via stripping by the solar wind. The findings reveal that the erosion of Mars' atmosphere increases significantly during solar storms. The scientific results from the mission appear in the Nov. 5 issues of the journals Science and Geophysical Research Letters.

"Mars appears to have had a thick atmosphere warm enough to support liquid water which is a key ingredient and medium for life as we currently know it," said John Grunsfeld, astronaut and associate administrator for the NASA Science Mission Directorate in Washington. "Understanding what happened to the Mars atmosphere will inform our knowledge of the dynamics and evolution of any planetary atmosphere. Learning what can cause changes to a planet's environment from one that could host microbes at the surface to one that doesn't is important to know, and is a key question that is being addressed in NASA's journey to Mars."

MAVEN measurements indicate that the solar wind strips away gas at a rate of about 100 grams (equivalent to roughly 1/4 pound) every second. "Like the theft of a few coins from a cash register every day, the loss becomes significant over time," said Bruce Jakosky, MAVEN principal investigator at the University of Colorado, Boulder. "We've seen that the atmospheric erosion increases significantly during solar storms, so we think the loss rate was much higher billions of years ago when the sun was young and more active."

Credits: NASA-GSFC/CU Boulder LASP/University of Iowa
https://www.nasa.gov/press-release/nasa-mission-reveals-speed-of-solar-wind-stripping-martian-atmosphere

Solar Wind Strips the Martian Atmosphere (continued)

In addition, a series of dramatic solar storms hit Mars' atmosphere in March 2015, and MAVEN found that the loss was accelerated. The combination of greater loss rates and increased solar storms in the past suggests that loss of atmosphere to space was likely a major process in changing the Martian climate.

The solar wind is a stream of particles, mainly protons and electrons, flowing from the sun's atmosphere at a speed of about one million miles per hour. The magnetic field carried by the solar wind as it flows past Mars can generate an electric field, much as a turbine on Earth can be used to generate electricity. This electric field accelerates electrically charged gas atoms, called ions, in Mars' upper atmosphere and shoots them into space.

MAVEN has been examining how solar wind and ultraviolet light strip gas from of the top of the planet's atmosphere. New results indicate that the loss is experienced in three different regions of the Red Planet: down the "tail," where the solar wind flows behind Mars, above the Martian poles in a "polar plume," and from an extended cloud of gas surrounding Mars. The science team determined that almost 75 percent of the escaping ions come from the tail region, and nearly 25 percent are from the plume region, with just a minor contribution from the extended cloud. Ancient regions on Mars bear signs of abundant water – such as features resembling valleys carved by rivers and mineral deposits that only form in the presence of liquid water. These features have led scientists to think that billions of years ago, the atmosphere of Mars was much denser and warm enough to form rivers, lakes and perhaps even oceans of liquid water

Credits: NASA-GSFC/CU Boulder LASP/University of Iowa
https://www.nasa.gov/press-release/nasa-mission-reveals-speed-of-solar-wind-stripping-martian-atmosphere

Solar Wind Strips the Martian Atmosphere (continued)

Recently, researchers using NASA's Mars Reconnaissance Orbiter observed the seasonal appearance of hydrated salts indicating briny liquid water on Mars. However, the current Martian atmosphere is far too cold and thin to support long-lived or extensive amounts of liquid water on the planet's surface.

"Solar-wind erosion is an important mechanism for atmospheric loss, and was important enough to account for significant change in the Martian climate," said Joe Grebowsky, MAVEN project scientist from NASA's Goddard Space Flight Center in Greenbelt, Maryland. "MAVEN also is studying other loss processes -- such as loss due to impact of ions or escape of hydrogen atoms -- and these will only increase the importance of atmospheric escape."

The goal of NASA's MAVEN mission, launched to Mars in November 2013, is to determine how much of the planet's atmosphere and water have been lost to space. It is the first such mission devoted to understanding how the sun might have influenced atmospheric changes on the Red Planet. MAVEN has been operating at Mars for just over a year and will complete its primary science mission on Nov. 16.

Credits: NASA-GSFC/CU Boulder LASP/University of Iowa
https://www.nasa.gov/press-release/nasa-mission-reveals-speed-of-solar-wind-stripping-martian-atmosphere


MEASURING MARS' ATMOSPHERE LOSS
Mars began as a warm, wet planet that gradually dried out as it lost its atmosphere. To investigate Mars' climate history, scientists measured the ratio of argon isotopes in the upper atmosphere using NASA's MAVEN mission. This ratio reveals how much argon and other gases have been lost to space through a process called sputtering.
argon atoms
ion
SPUTTERING
Ions can get "picked up" by the solar wind and slammed into the top of the atmosphere, knocking other atoms into space. Over time, this leads to significant atmospheric erosion.
Argon-36 depletion in Mars' atmosphere over time
ARGON
This noble gas is removed from the atmosphere only through sputtering. Because the argon-36 isotope is lighter than argon-38, it is removed more efficiently. By measuring the ratio of light to heavy argon at various altitudes, scientists can determine how much of the gas has been lost to space.
65%
ARGON LOST TO SPACE
New measurements show that Mars has lost the majority of its argon through sputtering. Based on this finding, models of corresponding CO_2 and H_2O loss suggest that early Mars had an atmosphere as thick as that of Earth today.
4 billion years ago
present

AGU PUBLICATIONS

JGR

Journal of Geophysical Research: Planets

REVIEW ARTICLE

10.1002/2016JE005162

Special Section:
JGR-Planets 25th Anniversary

Atmospheric escape from unmagnetized bodies

D. A. Brain[1], F. Bagenal[1], Y.-J. Ma[2], H. Nilsson[3], and G. Stenberg Wieser[3]

[1]Laboratory for Atmospheric and Space Physics, University of Colorado Boulder, Boulder, Colorado, USA, [2]Institute of Geophysics and Planetary Physics, University of California, Los Angeles, California, USA, [3]Swedish Institute of Space Physics, Kiruna, https

heric Escape from Unmagnetized Bodies/download

Key Points:
- The atmospheres of unmagnetized solar system bodies interact more directly with the solar wind than those of magnetized objects
- Plasma interactions at unmagnetized bodies lead to some atmospheric escape processes that do not operate effectively at magnetized objects
- Comets, Pluto, Titan, Mars, and Venus span a variety of characteristics that lead to differences in their interaction with their environment

Abstract The upper atmospheres of unmagnetized solar system bodies interact more directly with their local plasma environment than their counterparts on magnetized bodies such as Earth. One consequence of this interaction is that atmospheric particles can gain energy from the flowing plasma, as well as solar photons, and escape to space. Escape proceeds through a number of different mechanisms that can remove neutral particles (Jeans escape, photochemical escape, and sputtering) and mechanisms that can remove ions (ion pickup, magnetic shear and tension-related escape, and pressure gradients). Here we discuss the plasma interactions and escape processes and rates from five solar system objects spanning 3 orders of magnitude in size: comets, Pluto, Titan, Mars, and Venus. We describe similarities and differences in escape for the different objects and provide four open questions that should be addressed in the coming years.

Reference: Brain, D. A., Bagenal, F., Ma, Y.-J., Nilsson, H., and Stenberg Wieser, G. (2016), Atmospheric escape from unmagnetized bodies, J. Geophys. Res. Planets, 121, 2364– 2385, doi:10.1002/2016JE005162.
Download article from https://agupubs.onlinelibrary.wiley.com/doi/epdf/10.1002/2016JE005162

Oxygen Atom Escape from the Martian Atmosphere during Proton Auroral Events

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Abstract—We present the model calculation results of the atomic oxygen loss rate from the Martian atmosphere induced by precipitation of high-energy protons and hydrogen atoms (H/H^+) from the solar wind plasma. Penetration of energetic protons and hydrogen atoms from the solar wind plasma to the upper atmosphere of Mars at altitudes of 100−250 km is accompanied by the momentum and energy transfer in collisions with the main component, atomic oxygen. This process is considered as atmospheric gas sputtering during proton auroral events, which is accompanied by formation of the suprathermal hydrogen and oxygen atom fluxes escaping from the atmosphere. When calculating the formation rate of suprathermal atoms, the modified Monto Carlo kinetic model was used. This model was earlier developed to analyze the data of the Analyzer of Space Plasma and Energetic Atoms (ASPERA-3) and the Solar Wind Ion Analyzer (SWIA) onboard the Mars Express (MEX) and the Mars Atmosphere and Volatile Evolution (MAVEN) spacecraft, respectively. We study the processes of kinetics and transport of hot oxygen atoms in the transition zone (from the thermosphere to the exosphere) of Mars' upper atmosphere. The kinetic energy distribution functions for suprathermal oxygen atoms were calculated. It has been shown that, during proton auroral events on Mars, the exosphere is populated with a significant number of suprathermal oxygen atoms, the kinetic energy of which reaches the escape energy, 2 eV. In addition to photochemical sources, a hot fraction is formed in the oxygen corona; and a nonthermal flux of atomic oxygen escaping from the Martian atmosphere is produced during proton aurora events. Proton aurorae are sporadic auroral events. Consequently, according to the estimates obtained from the recent MAVEN observations the magnitude of the precipitation-induced escaping flux of hot oxygen atoms may become prevailing over the photochemical sources under conditions of the extreme solar events such as solar flares and coronal mass ejections.

DOI: 10.1134/S1063772920080089

Reference: Shematovich, V.I., Kalinicheva, E.S. Oxygen Atom Escape from the Martian Atmosphere during Proton Auroral Events. Astron. Rep. 64, 628–635 (2020). https://doi-org.ezproxy.library.sydney.edu.au/10.1134/S1063772920080089
Download Abstract: https://link.springer.com/article/10.1134/S1063772920080089

The Geological History of Mars

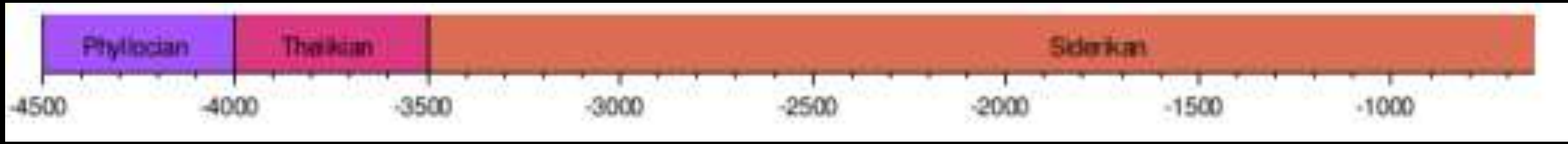
Mineral alteration timescale

In 2006, researchers using data from the OMEGA Visible and Infrared Mineralogical Mapping Spectrometer on board the Mars Express orbiter proposed an alternative Martian timescale based on the predominant type of mineral alteration that occurred on Mars due to different styles of chemical weathering in the planet's past. They proposed dividing the history of the Mars into three eras: the Phyllocian, Theiikian and Siderikan.

Phyllocian (named after phyllosilicate or clay minerals that characterize the era) lasted from the formation of the planet until around the Early Noachian (about 4.0 Gya). OMEGA identified outcropping of phyllosilicates at numerous locations on Mars, all in rocks that were exclusively Pre-Noachian or Noachian in age (most notably in rock exposures in Nili Fossae and Mawrth Vallis). Phyllosillicates require a water-rich, alkaline environment to form. The Phyllocian era correlates with the age of valley network formation on Mars, suggesting an early climate that was conducive to the presence of abundant surface water. It is thought that deposits from this era are the best candidates in which to search for evidence of past life on the planet.

Theiikian (named after sulphurous in Greek, for the sulphate minerals that were formed) lasted until about 3.5 Gya. It was an era of extensive volcanism, which released large amounts of sulphur dioxide (SO2) into the atmosphere. The SO2 combined with water to create a sulphuric acid-rich environment that allowed the formation of hydrated sulphates (notably kieserite and gypsum).

Siderikan (named for iron in Greek, for the iron oxides that formed) lasted from 3.5 Gya until the present. With the decline of volcanism and available water, the most notable surface weathering process has been the slow oxidation of the iron-rich rocks by atmospheric peroxides producing the red iron oxides that give the planet its familiar colour.



Source: Wikipedia

Crater density timescale

Studies of impact crater densities on the Martian surface have delineated four broad periods in the planet's geologic history. The periods were named after places on Mars that have large-scale surface features, such as large craters or widespread lava flows, that date back to these time periods. The absolute ages given here are only approximate. From oldest to youngest, the time periods are:

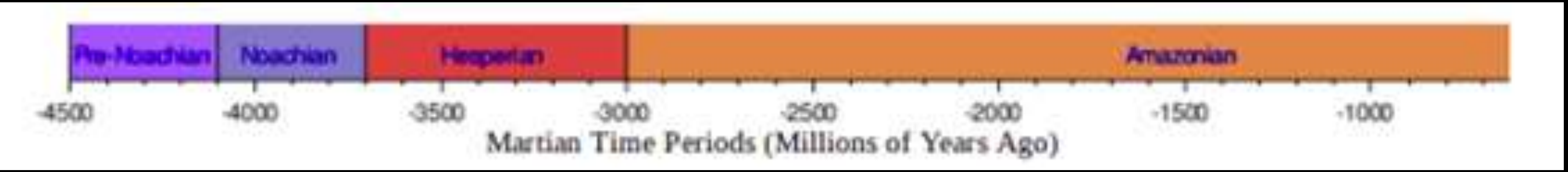
Pre-Noachian Represents the interval from the accretion and differentiation of the planet about 4.5 billion years ago (Gya) to the formation of the Hellas impact basin, between 4.1 and 3.8 Gya. Most of the geologic record of this interval has been erased by subsequent erosion and high impact rates. The crustal dichotomy is thought to have formed during this time, along with the Argyre and Isidis basins.

Noachian Period (named after Noachis Terra): Formation of the oldest extant surfaces of Mars between 4.1 and about 3.7 billion years ago (Gya). Noachian-aged surfaces are scarred by many large impact craters. The Tharsis bulge is thought to have formed during the Noachian, along with extensive erosion by liquid water producing river valley networks. Large lakes or oceans may have been present.

Hesperian Period (named after Hesperia Planum): 3.7 to approximately 3.0 Gya. Marked by the formation of extensive lava plains. The formation of Olympus Mons probably began during this period. Catastrophic releases of water carved extensive outflow channels around Chryse Planitia and elsewhere. Ephemeral lakes or seas may have formed in the northern lowlands.

Amazonian Period (named after Amazonis Planitia): 3.0 Gya to present. Amazonian regions have few meteorite impact craters but are otherwise quite varied. Lava flows, glacial/periglacial activity, and minor releases of liquid water continued during this period.

Martian Time Periods (Millions of Years Ago)



The date of the Hesperian/Amazonian boundary is particularly uncertain and could range anywhere from 3.0 to 1.5 Gya. Basically, the Hesperian is thought of as a transitional period between the end of heavy bombardment and the cold, dry Mars seen today.

Source: Wikipedia

This image from the High Resolution Imaging Science Experiment (HiRISE) camera on NASA's Mars Reconnaissance Orbiter around 4th December 2008, shows sedimentary-rock layering in which a series of layers are all approximately the same thickness.

Three-dimensional analysis using stereo pairs of HiRISE images has confirmed the periodic nature of the layering. Individual layers in the area average about 10 meters (33 feet) in thickness.

This image, taken on Feb. 25, 2007, is a portion of the HiRISE image catalogued as PSP_002733_1880. The location of the imaged area is at 8 degrees north latitude, 353 degrees east longitude, within the Arabia Terra region.

The view covers an area about 2 kilometers (1.2 miles) across, within an unnamed crater in the Arabia Terra region of Mars. An oblique view created from three-dimensional modelling shows the repetitive thickness of some of the same layers visible in this image.

Credit
NASA/JPL-Caltech/University of Arizona

Link, 2012

This rock outcrop, called Link, show rounded gravel fragments, or clasts, that are up to a couple of centimeters in size.

Nili Fossae is a group of large, concentric grabens on Mars, in the Syrtis Major quadrangle. They have been eroded and partly filled in by sediments and clay-rich ejecta from a nearby giant impact crater, the Isidis basin.
It is at approximately 22°N, 75°E, and has an elevation of −0.6 km

A large exposure of olivine is in Nili Fossae. In December 2008, NASA's Mars Reconnaissance Orbiter found that rocks at Nili Fossae contain carbonate minerals, the largest known carbonate deposit on Mars. NASA scientists discovered that Nili Fossae is the source of plumes of methane

Nili Fossae magnified

This image from the Mast Camera (Mastcam) on NASA's Mars rover Curiosity shows inclined layering known as cross-bedding in an outcrop called "Shaler" on a scale of a few tenths of meters. Decimeter-scale cross-bedding in the Shaler Unit is indicative of sediment transport in stream flows. Currents mould the sediments into small underwater dunes that migrate downstream. When exposed in cross-section, evidence of this migration is preserved as strata that are steeply inclined relative to the horizontal -- thus the term "cross-bedding”.

Humans on Mars

ROTATION PERIOD (DAY)	23.9 HOURS	24.6 HOURS
REVOLUTION PERIOD (YEAR)	365.2 DAYS	686.9 DAYS
AVERAGE TEMPERATURE	59°F (15°C)	-81°F (-63°C)
ATMOSPHERIC PRESSURE	1,013 MILLIBAR S	6 MILLIBAR S
AVG. DISTANCE FROM SUN	93 MILION MILES	142 MILION MILES
TILT OF AXIS	23.5°	25°
GRAVITY	1 G	0.4 G

1 **THE THOUSAND-YEAR PROJECT** might begin with a series of 18-month survey missions. Each crew making the six-month journey from Earth to Mars would add a small habitation module to the base.

2 **AN ATMOSPHERE** could be made by releasing carbon dioxide now frozen in dirt and polar ice caps. Factories spewing potent greenhouse gases, and maybe space mirrors focusing sunlight on ice, could start the thaw.

3 **RAIN** would fall and water would flow once enough CO_2 had been released to raise the atmospheric pressure and warm the planet above freezing. Microbes, algae, and lichens could start taming the desert rock.

4 **FLOWERING PLANTS** could be introduced after the microbes had created organic soil and added some oxygen to the atmosphere. Boreal and perhaps even temperate forests might ultimately take root.

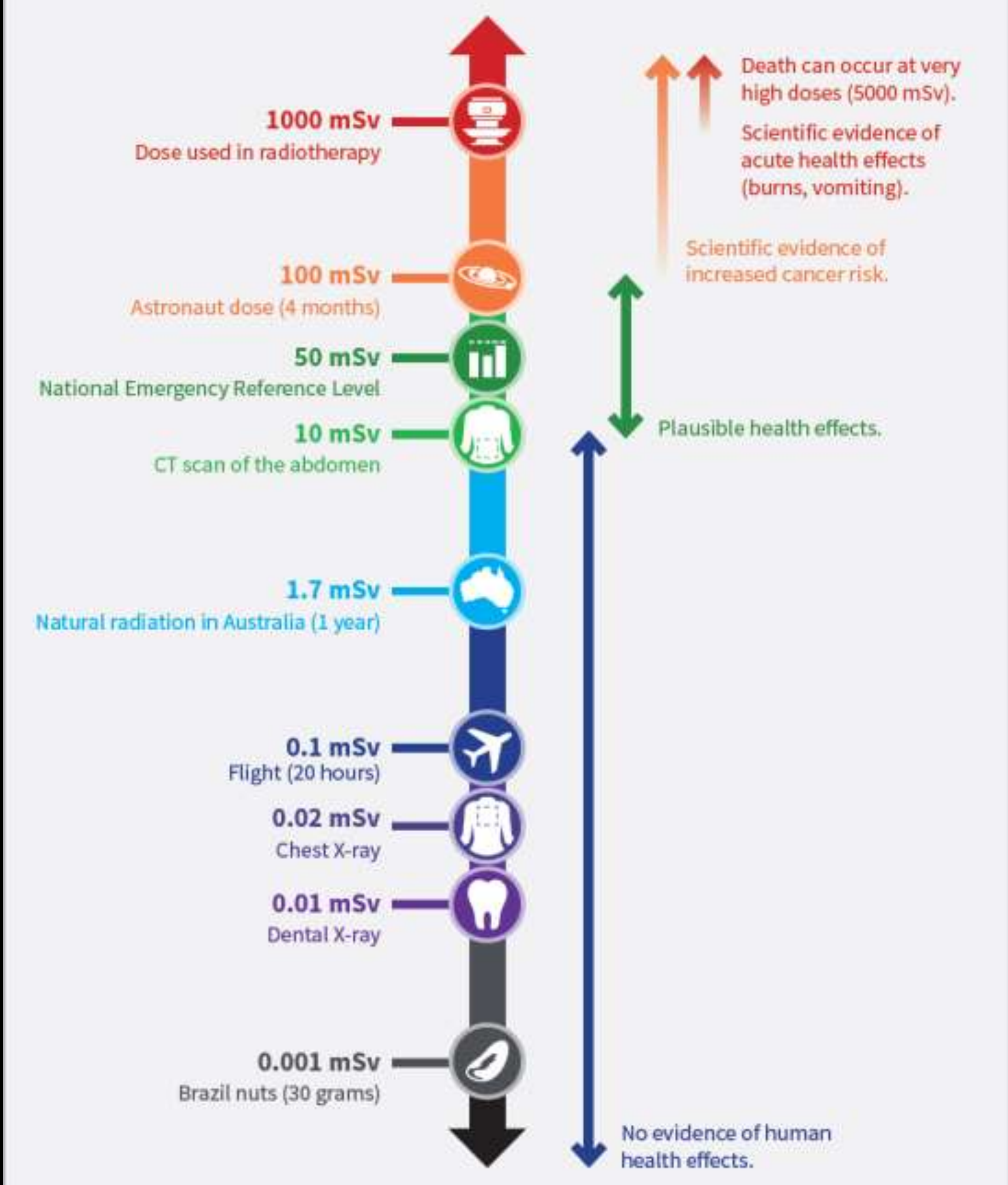
Credit: NASA

Several key physical challenges exist for human missions to Mars

- Health threat from cosmic rays and other ionizing radiation. (Cancer, DNA damage, mutations)
- Adverse health effects of prolonged weightlessness, including bone mineral density loss and eyesight impairment. (Depends on mission and spacecraft design).
- 33% of astronauts will be at risk for osteoporosis during a human mission to Mars which increase the risk of fractured bones.
- In November 2019, researchers reported that astronauts experienced serious blood flow and clot problems while on board the International Space Station, based on a six-month study of 11 healthy astronauts. The results may influence long-term spaceflight, including a mission to the planet Mars, according to the researchers.
- Psychological effects of isolation from Earth and, by extension, the lack of community due to lack of a real-time connection with Earth (Compare Hermit)
- Social effects of several humans living under cramped conditions for more than one Earth year, and possibly two or three years, depending on spacecraft and mission design
- Lack of medical facilities
- Potential failure of propulsion or life-support equipment

Natural background radiation on Earth:

- Natural background radiation is the ionising radiation in the environment that all living species are exposed to every day.
- The largest source of radiation exposure comes from natural radioactivity in rocks and soil, and the inhalation of radon gas that seeps from the Earth's crust into the air.
- There are also contributions from cosmic radiation, which comes from outer space, and
- Naturally occurring radioactivity in food and the human body.



Source:
Australian Radiation Protection and Nuclear Safety Agency (ARPANSA)

The millisievert (mSv) is a measure of the radiation dose received either from a radioactive source or from other sources like X-rays in medicine.
This is generally a whole body effective dose, but it may also be an equivalent dose received by a particular tissue or organ.
Exposure to 100 mSv a year is the lowest level at which any increase in cancer risk is clearly evident

Humans on Mars: radiation

Lethal dose (single short exposure)

- 5,000 mSv – Dose that kills a human with a 50% risk within 30 days (LD50/30), if the dose is received over a very short duration. Cause of death will be loss of bone marrow function.
- 8,000 mSv – Dose that kills a human with a 99% risk (LD99), if the dose is received over a very short duration.
- At around 10,000 mSv acute inflammation of the lungs can occur and lead to death quickly.

Normal exposures:

- Dose in full-body CT scan 10 mSv
- Airline crew flying New York to Tokyo polar route, annual exposure 9mSv
- Natural radiation we're all exposed to, per year 2mSv (some areas up to 20mSv)
- Spine x-ray 1.5mSv

Mars

- Little atmosphere and no global magnetic field to protect life from radiation
- The trip to Mars and back = 660 mSv
- Average Daily dose (Perseverance): approximately 0.7 milliSieverts per day of radiation.
- This dose can increase temporarily by a factor of 50 through the occurrence of highly energetic solar flares!

The End

With permission Annabelle Sandes