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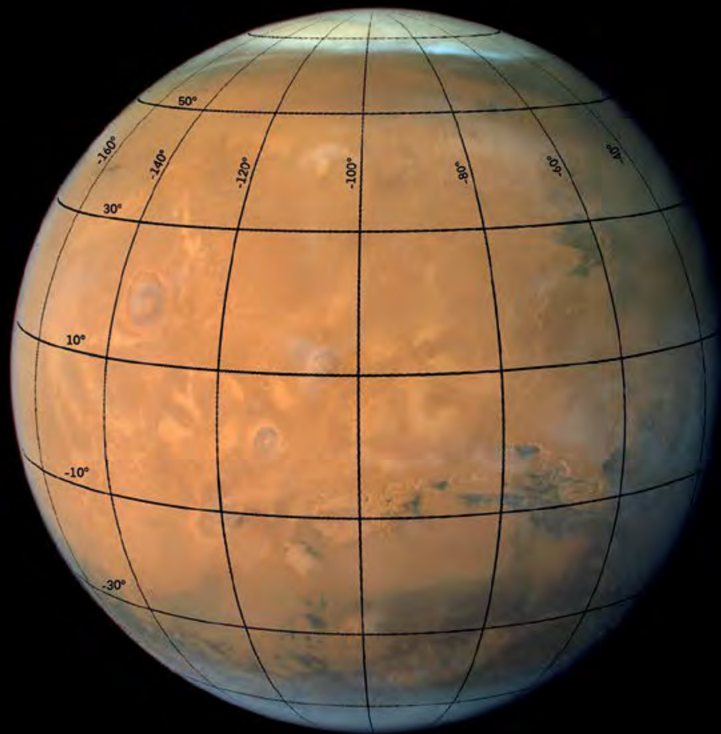
THE ATLAS OF MARS

A PHOTOGRAPHIC ATLAS, PREPARED WITH OBSERVATIONS FROM THE EMIRATES MARS MISSION, OR "HOPE" (AL-AMAL)



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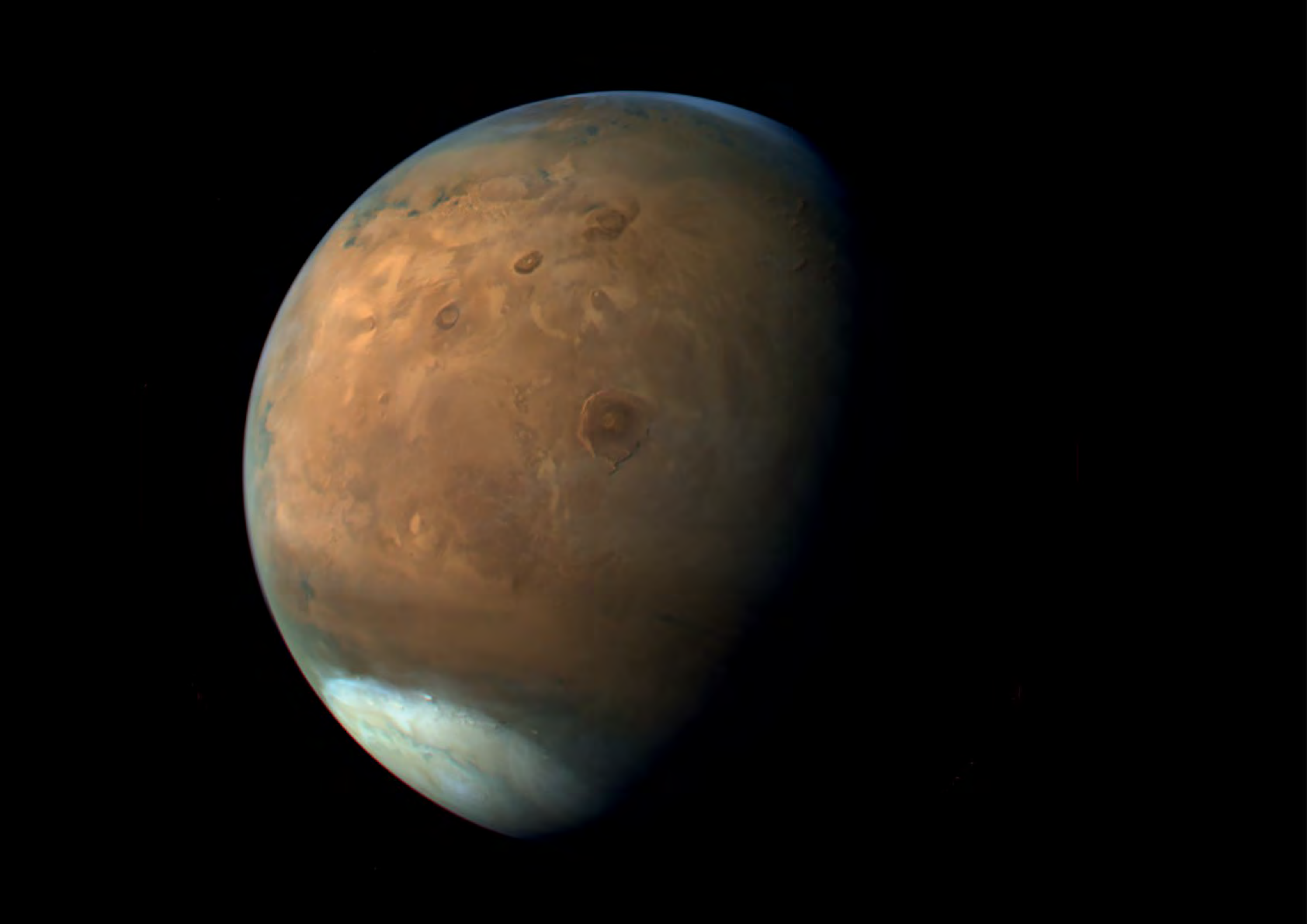

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PREFACE

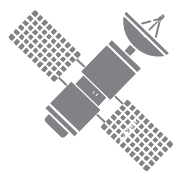
Once holding large bodies of water, ancient Mars would have looked a lot more like the Earth we know today than the barren red planet that marks the next frontier of space exploration. Around 4 billion years ago, life originated on the Earth.

But the big question: was there ever life on Mars? Perhaps even more pertinent to humanity as it faces climate change is the question of why and how did Mars get transformed from a warm hospitable place, to the cold, dry desert world that we see today? Finding answers to these questions about our sibling planet is one of the biggest challenges in planetary science today. It is also for this reason that exploring Mars is a top priority of space agencies around the globe. Over the past 50 years, numerous orbiters, landers and rovers have and still are providing us with valuable data, enabling us to investigate the planet and stitch together its rich history. And now, the UAE is playing its part in uncovering the mysteries of Mars.

The Emirates Mars Mission "Hope," with its unique orbit and set of instruments, is providing us with a holistic view of the planet. The mission was commissioned by the UAE's leadership in 2014, and in an impressively short timeframe, the spacecraft was launched from Japan on July 20,2020. After a 7-month journey, the Hope probe entered the Martian orbit on February 9,2021 and is scheduled to operate for one Martian year, or approximately two earth years.

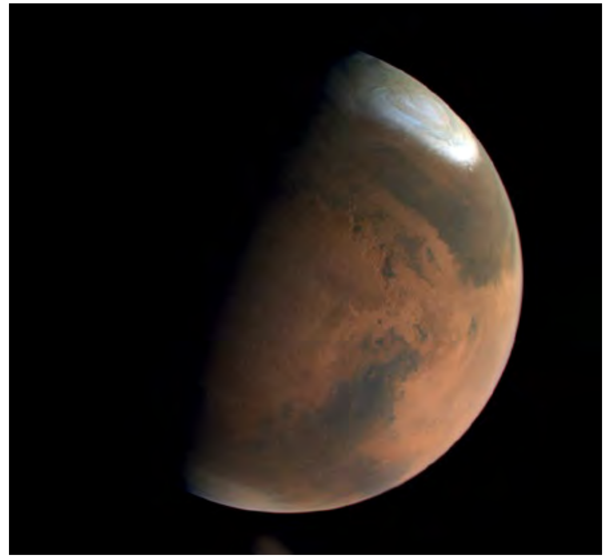
This atlas is created with data exclusively from the Hope probe to provide readers with a holistic view of Mars and stunning images of the planet that once looked like ours. Our plan is to update this atlas periodically as more data for the probe becomes available. Our aim is to capture and show how Mars changes during the day and across seasons through the entirety of the mission. We're also hoping you'll share our passion for the red planet through images in this document that have never been seen before.

The mission was commissioned by the UAE's leadership in 2014, and in an impressively short timeframe,



the spacecraft was launched from Japan on July 20,2020.

SELECTED MARS IMAGES
JUNE - AUGUST 2021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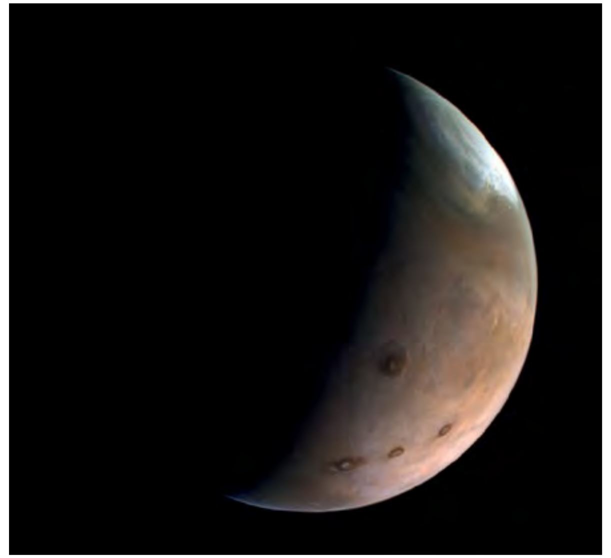
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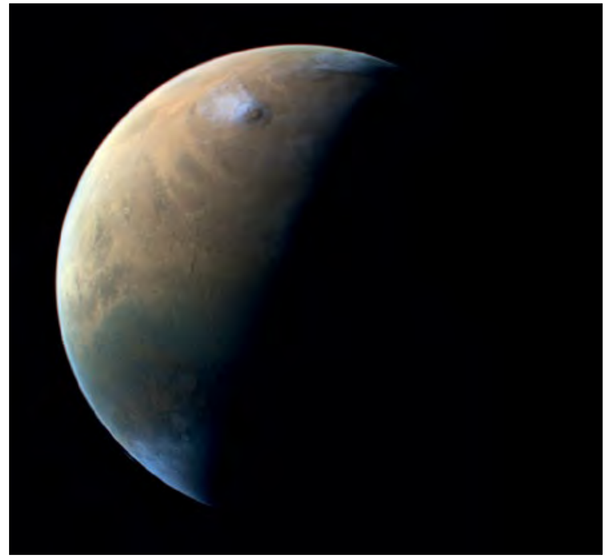
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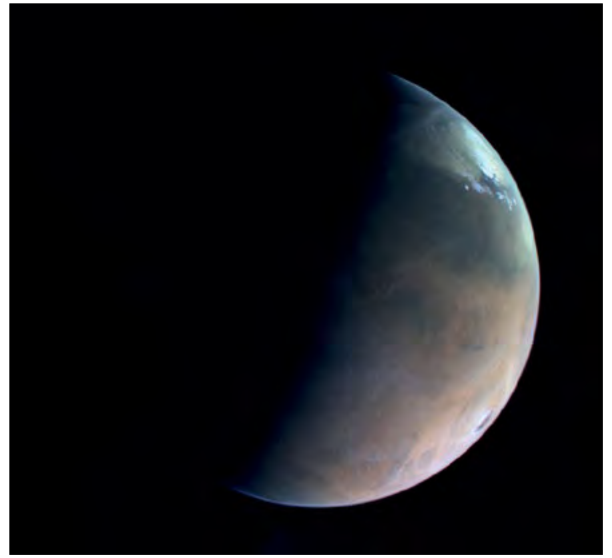
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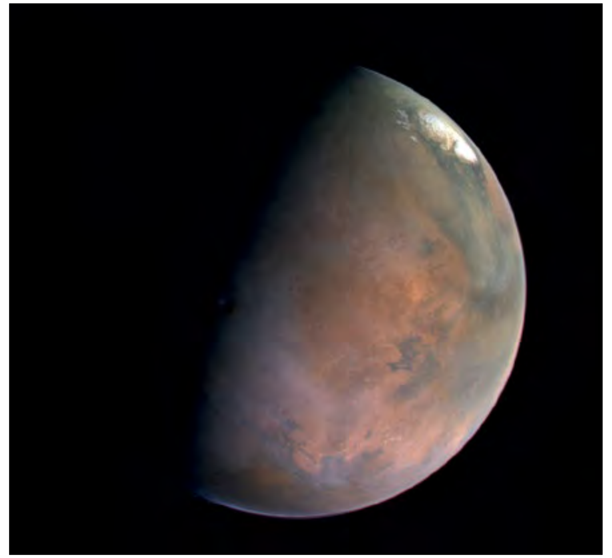

AUGUST 30, 2021

02

THE EMIRATES MARS MISSION

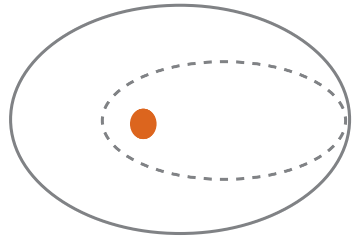
EMM: THE EMIRATES MARS MISSION

The Emirates Mars Mission (EMM) Hope probe was launched on July 20, 2020 at 01:58:14 GST from the Tanegashima Space Center in Japan aboard a H-IIA launch vehicle. EMM is the UAE's first mission to Mars and the Arab World's first journey to another planet.

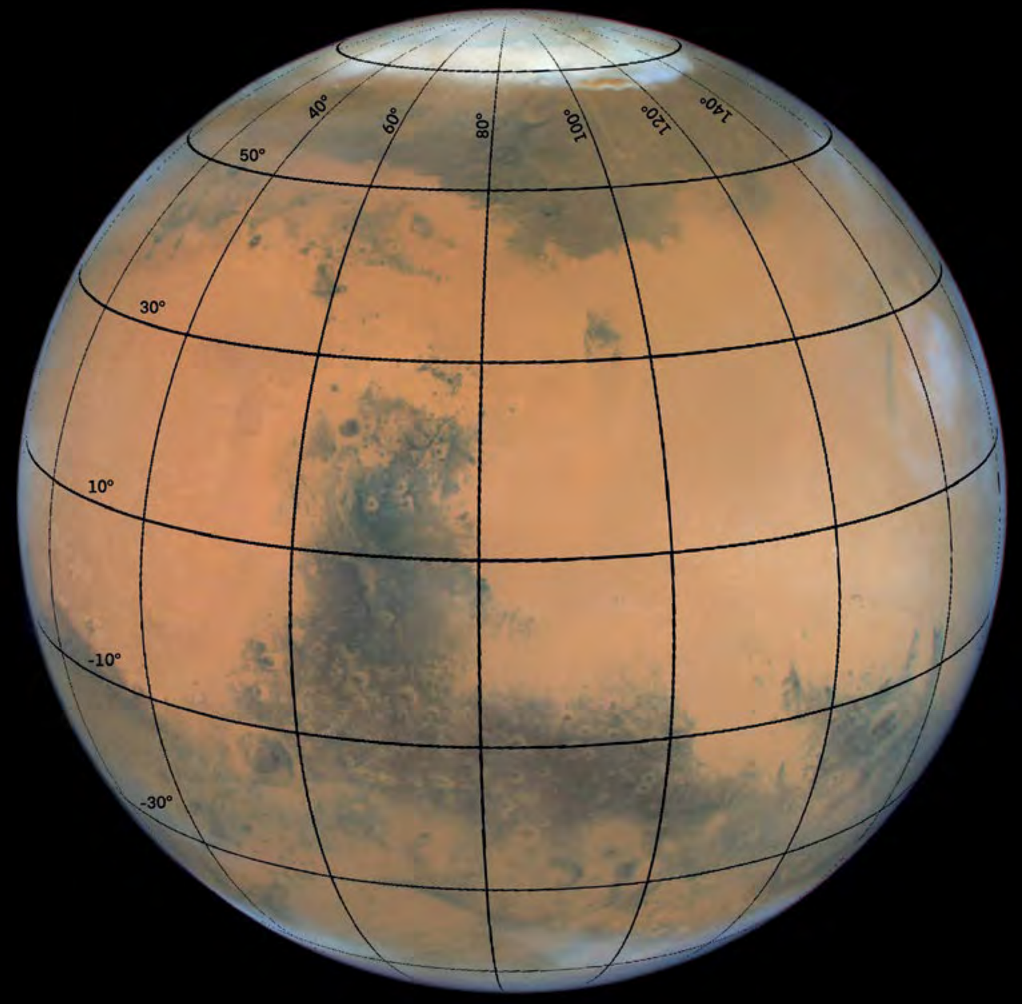
EMM entered Mars capture orbit on February 9, 2021. The low-altitude orbit held EMM at 1,072 km periapse, 42,450 km apoapse, 19.5° inclination, and circles the planet every 34 hours. While in the capture orbit, the EMM scientific instruments operations were tested and validated.

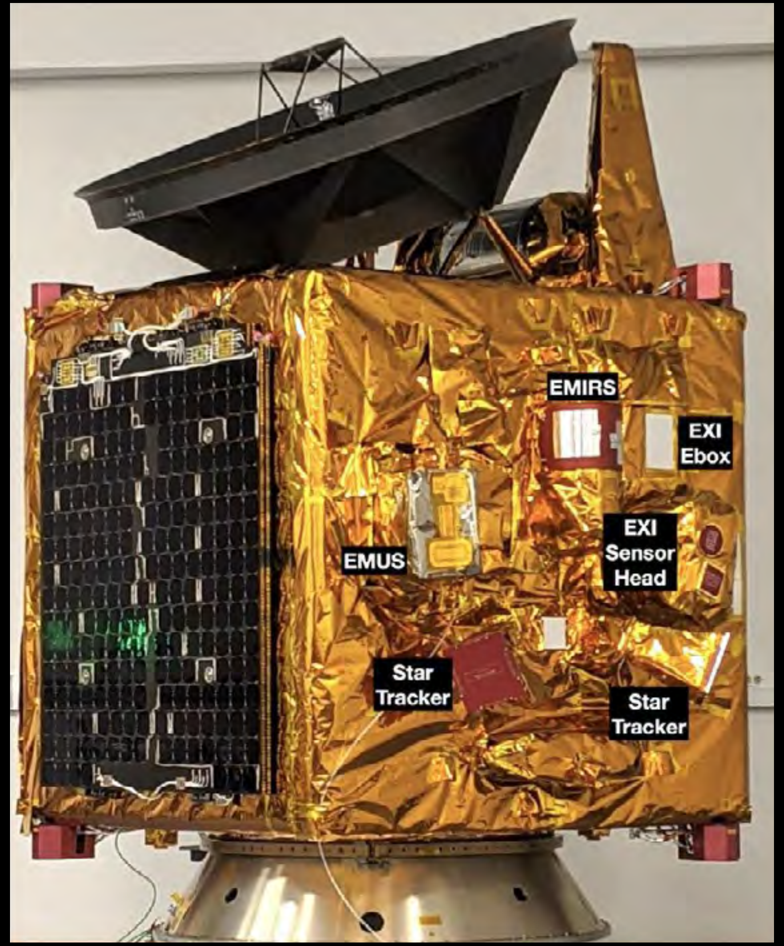
The second phase saw the EMM transitioning to a science orbit on March 29, 2021. This high-altitude science orbit enables a unprecedented local and seasonal coverage of Mars for monitoring of the Mars global climate. EMM's science orbit is a high-altitude orbit adding around 20 hours to the orbit, seeing the Emirates Mars Mission circle the red planet every 54.5 hours. It has a 19,970 km periapse, 42,650 km apoapse, and 25° inclination.

Capture orbit
1072 X 42450 km
19.5° inclination, period
~ 34 hr



Science orbit
19970 X 42650 km
25° inclination, period
~ 55 hr





THE EMM INSTRUMENTS
(Source: Jones et. al. 2021)

EMM: SCIENTIFIC INSTRUMENTS

EMM data are publicly available at the EMM Science Data Center.

The first set of data, observations made between February - May 2021 was publicly released on October 8, 2021.

Due to its unique orbit, EMM observations cover Mars' global geography and local time every 9-10 days. EMM enables studies of the dynamics of the Martian atmosphere with the following scientific objectives:

I. Characterize the state of the Martian lower atmosphere on global scales and its geographic, diurnal, and seasonal variability
II. Correlate rates of thermal and photochemical atmospheric escape with conditions in the collisional Martian atmosphere
III. Characterize the spatial structure and variability of key constituents in the Martian exosphere

EMM comprises three scientific instruments to achieve these objectives: Emirates eXploration Imager (EXI), Emirates Mars InfraRed Spectrometer (EMIRS), and Emirates Mars Ultraviolet Spectrometer (EMUS).

EMM data are publicly available at the EMM Science Data Center. The first set of data, observations made between February - May 2021 was publicly released on October 8, 2021. EMM science sequence observations commenced from May 23, 2021. The subsequent data is planned for release at EMM/SDC every three months.

To conform with other missions sent to the red planet, instruments onboard EMM utilise the planetocentric coordinate system. Making it easier to generalise the data and compute the latitude and longitude.

EXI: THE EMIRATES EXPLORATION IMAGER

The Emirates Exploration Imager (EXI) on-board EMM is a multi-wavelength radiation tolerant framing camera. EXI camera consists of two separate ultraviolet (UV) and visible (VIS) telescopes. The UV telescope enables measurements of ozone and ice clouds in the Martian lower atmosphere and the VIS telescope captures high resolution (12 MP) color images of Mars. The field-of-view of EXI camera is adequate for capturing the full martian disk at the EMM science orbit periapsis.

UV lens system of EXI includes two channels, UV-C (245–275 nm) and UV-A (305-335 nm) while the VIS system includes red (625-645 nm), green (506-586 nm) and blue (405-469 nm). EXI images of the full-disk have a resolution of 2-4 km per pixel depending on the altitude of the point of observation. Multiple EXI observations within an orbit combined with the planetary rotation enables EXI to provide a diurnal sampling globally on Mars over ~10 days.

EXI observations are planned to facilitate studies of clouds, ozone, and dust storms on Mars. EXI albedo measurements, together with EMIRS observations, are expected to improve understanding of the energy budget of Mars' lower atmosphere.

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THE EMIRATES EXPLORATION IMAGER (EXI)
https://www.emiratesmarsmission.ae/hope-probe/instruments/

03

IMAGES FROM MARS

THE FIRST IMAGE

FEBRUARY 10, 2021

THE RED, GREEN AND BLUE FILTERS OF EXI

Red Filter
635 nm

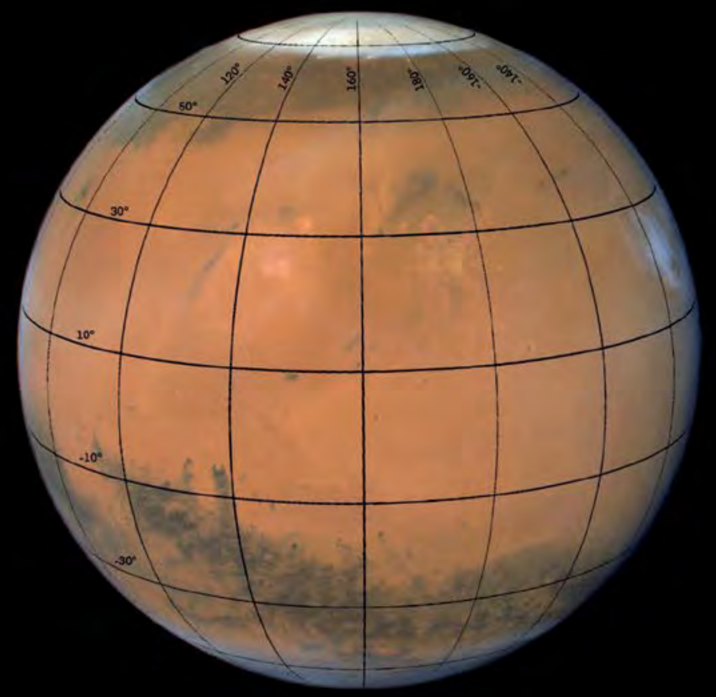
Green filter
546 nm

Blue filter
437 nm

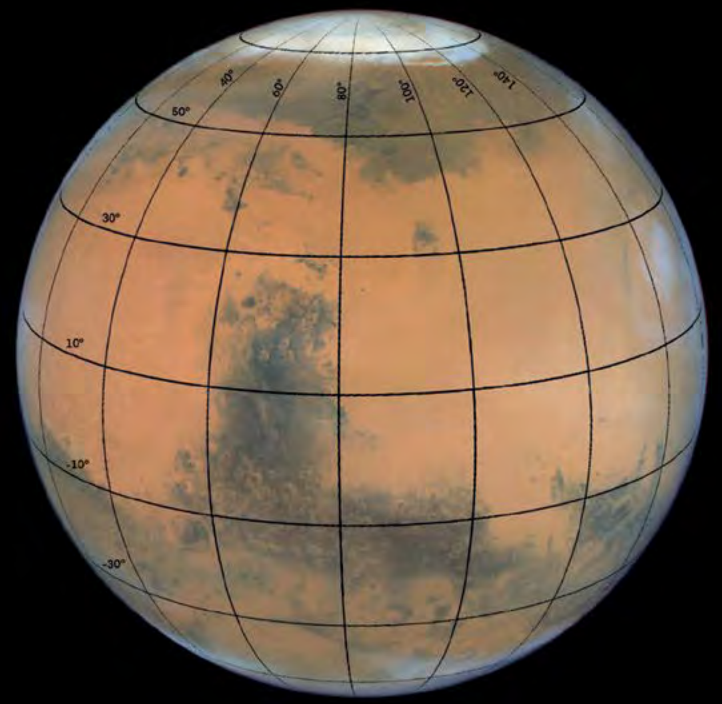
RGB COMPOSITE IMAGE

FEBRUARY 10, 2021

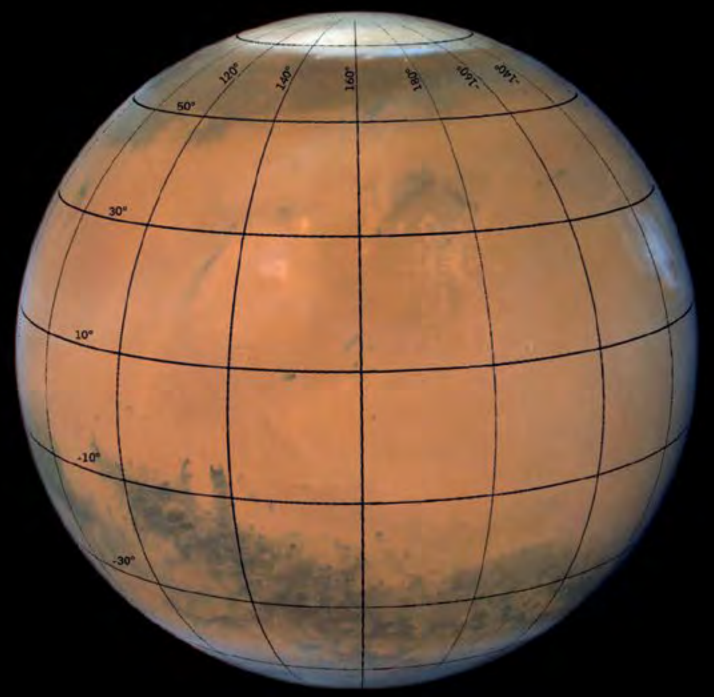
GLOBAL VIEW OF MARS



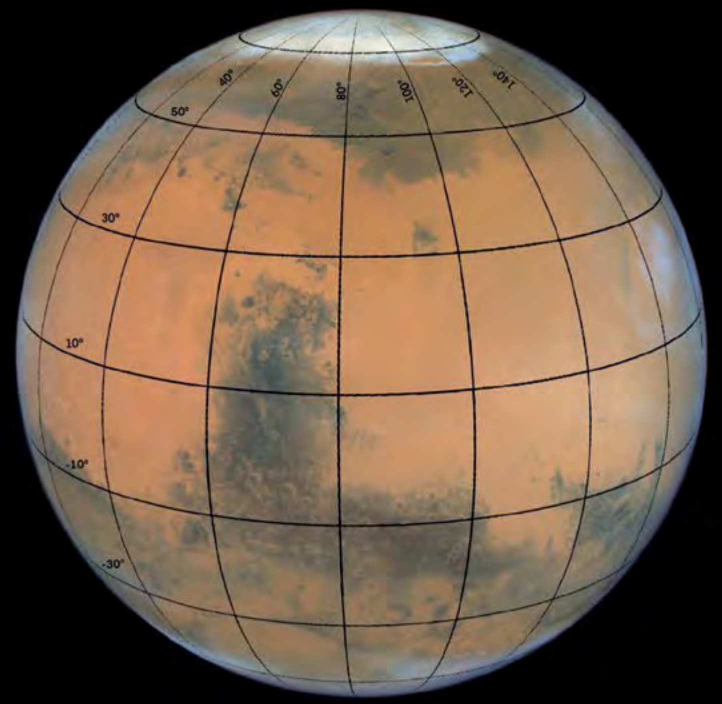
2021-04-25
Orbit 44



2021-05-01
Orbit 47

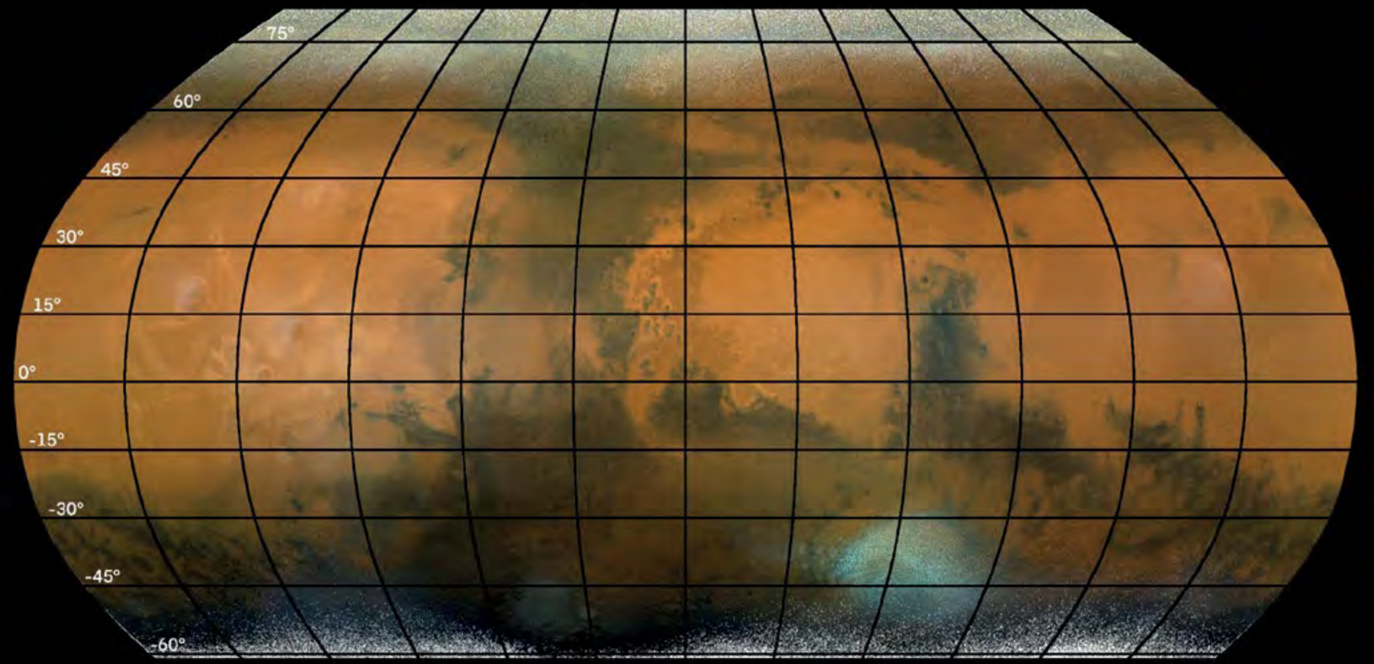


2021-05-08
Orbit 50



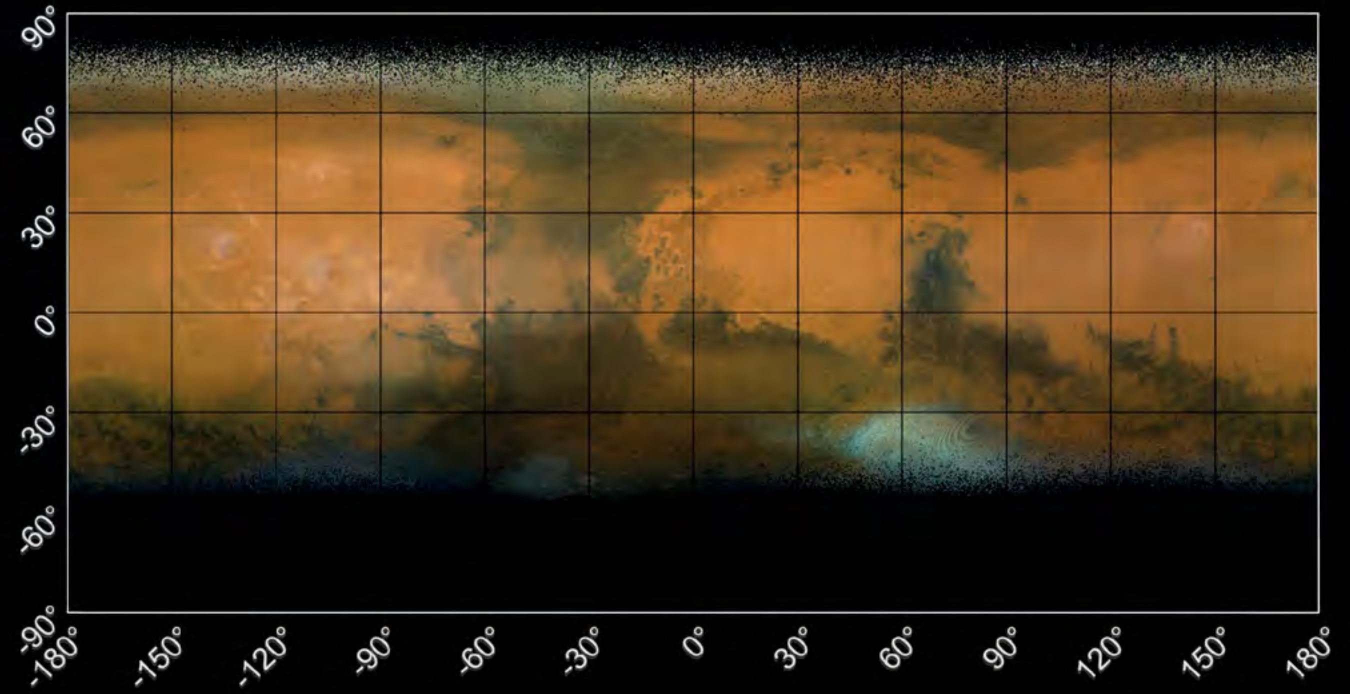
2021-05-10
Orbit 51

GLOBAL MAP OF MARS IN ROBINSON PROJECTION



The global map of Mars produced with 582 images taken from the Emirates eXploration Imager (EXI) instrument on board the Emirates Mars Mission “Hope.” The images were taken between February 10 and August 30, 2021 and combined to create this map in a Robinson projection. Areas with insufficient data in polar regions were discarded.

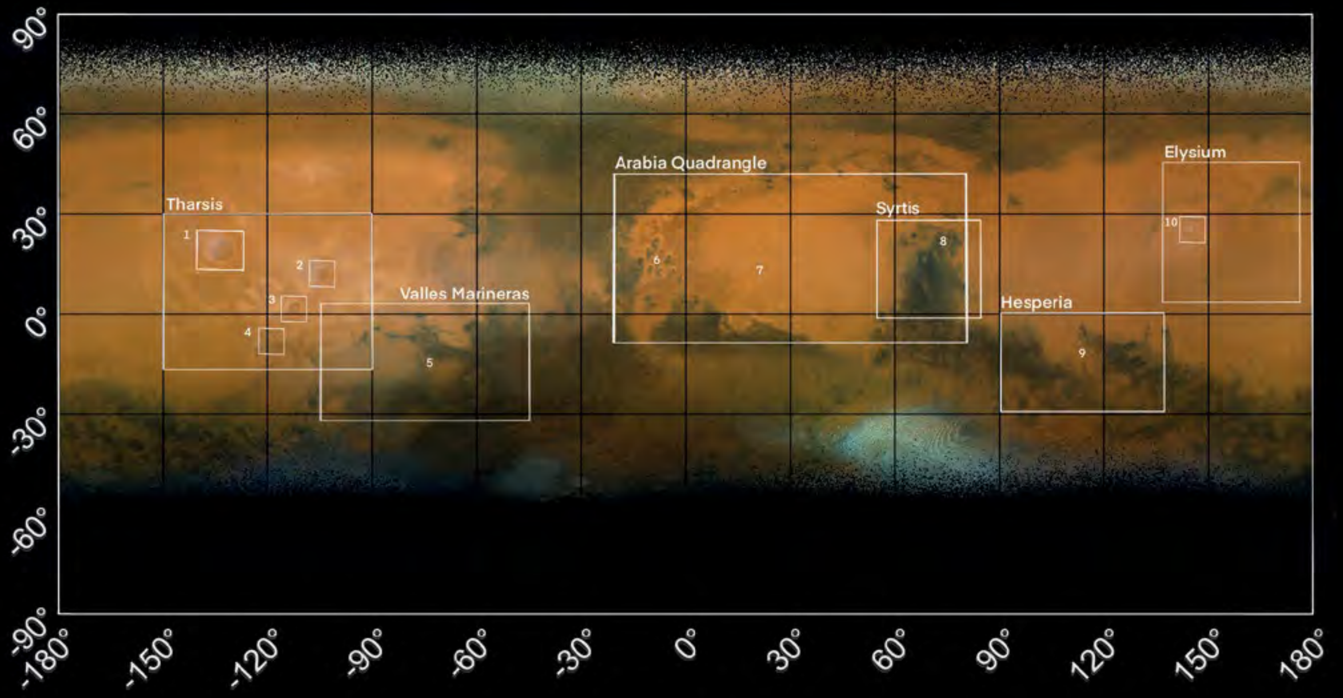
GLOBAL MAP IN CYLINDRICAL PROJECTION



The global map of Mars produced with observations from the Emirates eXploration Imager (EXI) instrument on board the Emirates Mars Mission “Hope”. 582 images between February 10 and August 30, 2021 were combined to create this map in cylindrical projection.

LABELED GLOBAL MAPS

LABELED GLOBAL MAP



Tharsis
1. Olympus Mons
2. Ascraeus Mons
3. Pavonis Mons
4. Arsia Mons

Valles Marineris
5. SW Melas Basin

Arabia Quadrangle
6. Mawrth Vallis
7. Arabia Terra
8. Jezero Crater

Hesperia
9. Hesperia Planum

Elysium
10. Elysium Mons

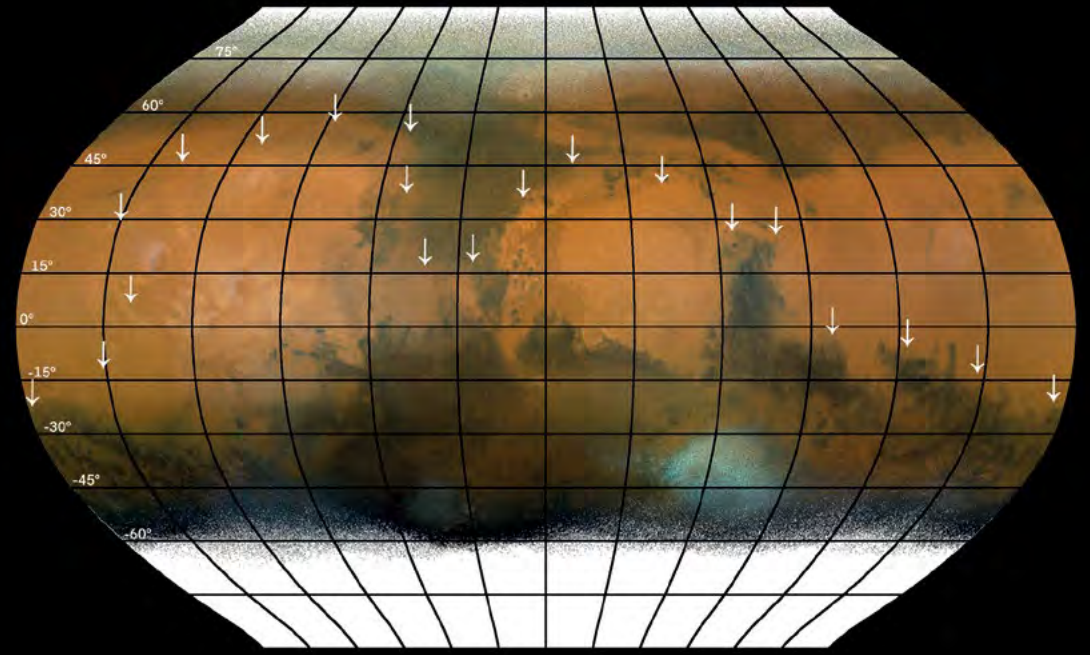
Martian dichotomy refers to the distinctly noticeable differences between the Northern and Southern hemispheres of Mars.

The southern hemisphere on an average has significantly higher elevation compared to the northern one – ranging from one to five km. The crust of the northern lowlands is about 32 km thick, while that of the southern highlands is about 58 km thick. The average thickness of the Martian crust is 45 km.

The northern hemisphere consists of mostly plains without craters and is considered considerably younger than southern hemisphere. The southern hemisphere, which has a surface peppered with craters sitting on a higher altitude, is considerably older than its northern counterpart. Unique characteristics of the region is called fretted terrain, which can be found mostly in the north of the region Arabia Terra and in Aeolis Mensae. It is distinct by the occurrence of many cliffs, mesas, buttes, and canyons.

Martian dichotomy is both one of the oldest features on Mars and an a topic of debate. There are three possible hypothesis of the origin: endogenic, by single impact, or multiple impacts. Studies suggest that the origin of this dichotomy is either due to a single mega-impact or mantle convection (endogenic origin).

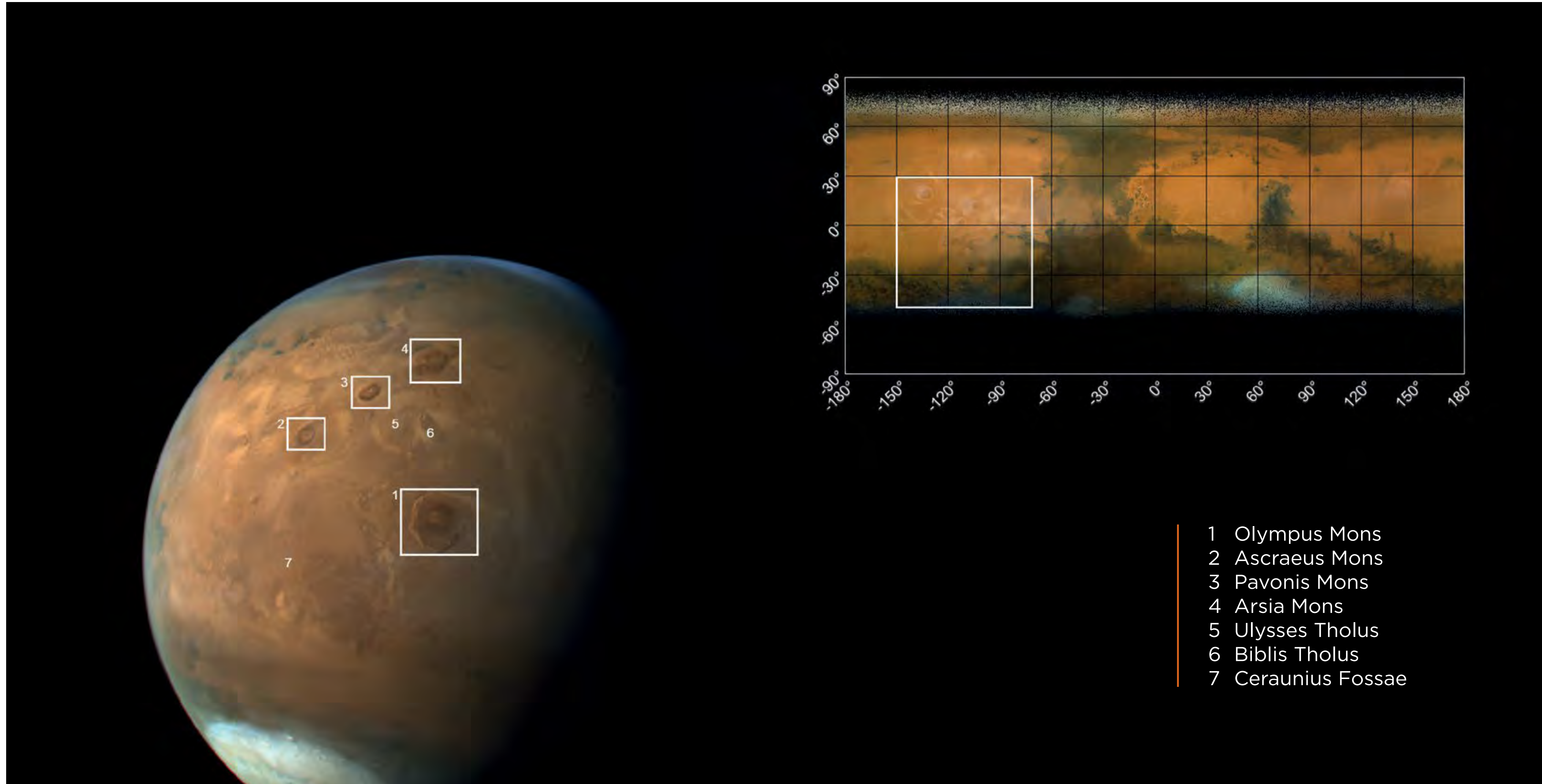
MARTIAN DICHOTOMY



THARSIS VOLCANIC REGION

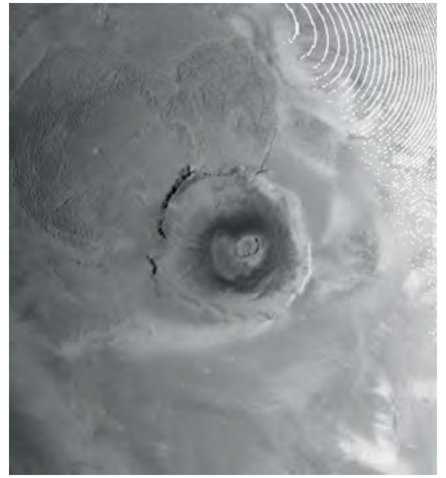
Tharsis Volcanic region, also called Tharsis bulge or rise, is located in the western hemisphere of Mars. The name Tharsis comes from the Greco-Latin word, meaning the land at the western extremity of the known world. Due to its volcano-tectonic origin, some of the largest volcanic features in the whole Solar System are present.

Olympus Mons, the highest mountain of Mars, is located at the very western edge of the plateau. Of the most prominent peaks, there are three aligned shield volcanoes Arsia Mons, Pavonis Mons and Ascraeus Mons, referred to together as Tharsis Montes.

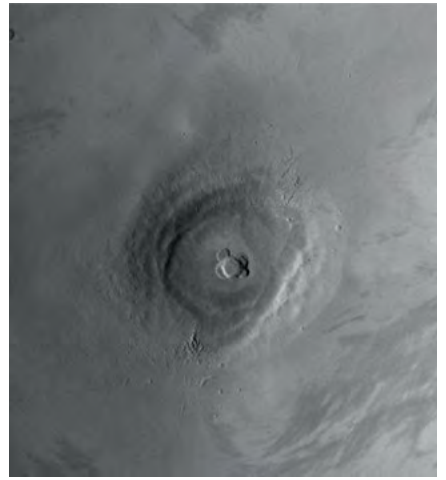


2021-04-26, Orbit 45

*North shown at the bottom

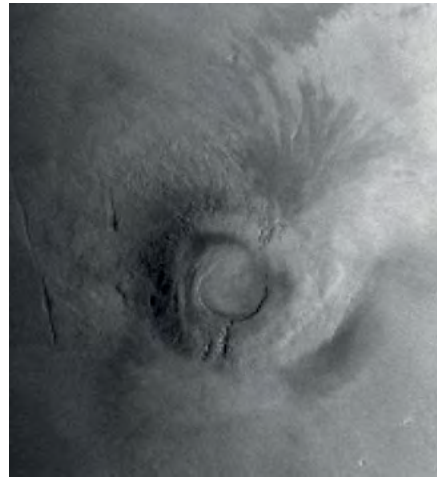


1) **Olympus Mons** is the highest mountain not only on Mars but also in the Solar System. With its summit standing at 21,229 meters, its volume exceeds more than 50 times any shield volcano on Earth. Olympus Mons is one of the youngest shield volcanoes on Mars with an estimated age of around 30 million years.



2) **Ascraeus Mons** is the northernmost volcano out of the Tharsis Montes.. The height reaches up to 18 km, which makes this volcano also the tallest out of the three shield volcanoes. Its age is estimated to be around 100 million years.

3) **Pavonis Mons**, originally called the Middle Spot, is located at the middle of Tharsis Montes, exactly on the space equator. Its height of 8.7 km ranks it among the smaller volcanoes on Mars. Estimated age of this shield volcano is around 300 million years.



4) **Arsia Mons** is the southernmost volcano out of the Tharsis Montes. The shield volcano is the second largest volcano in terms of volume on Mars, however, its summit is standing just above 11.7 km. The age of the volcano is estimated to be 700 million years, which makes it the oldest volcano from Tharsis Montes.

5) **Ulysses Tholus** is a volcano in Tharsis quadrangle. It has a diameter of 58 kilometers and is named after a famous albedo feature. The word Tholus defines a volcanic edifice that is slightly smaller than mons. It is located directly east and slightly north of Biblis Tholus.

6) **Biblis Tholus**, one of two extinct Martian volcanoes near the core of the Tharsis volcanoes.

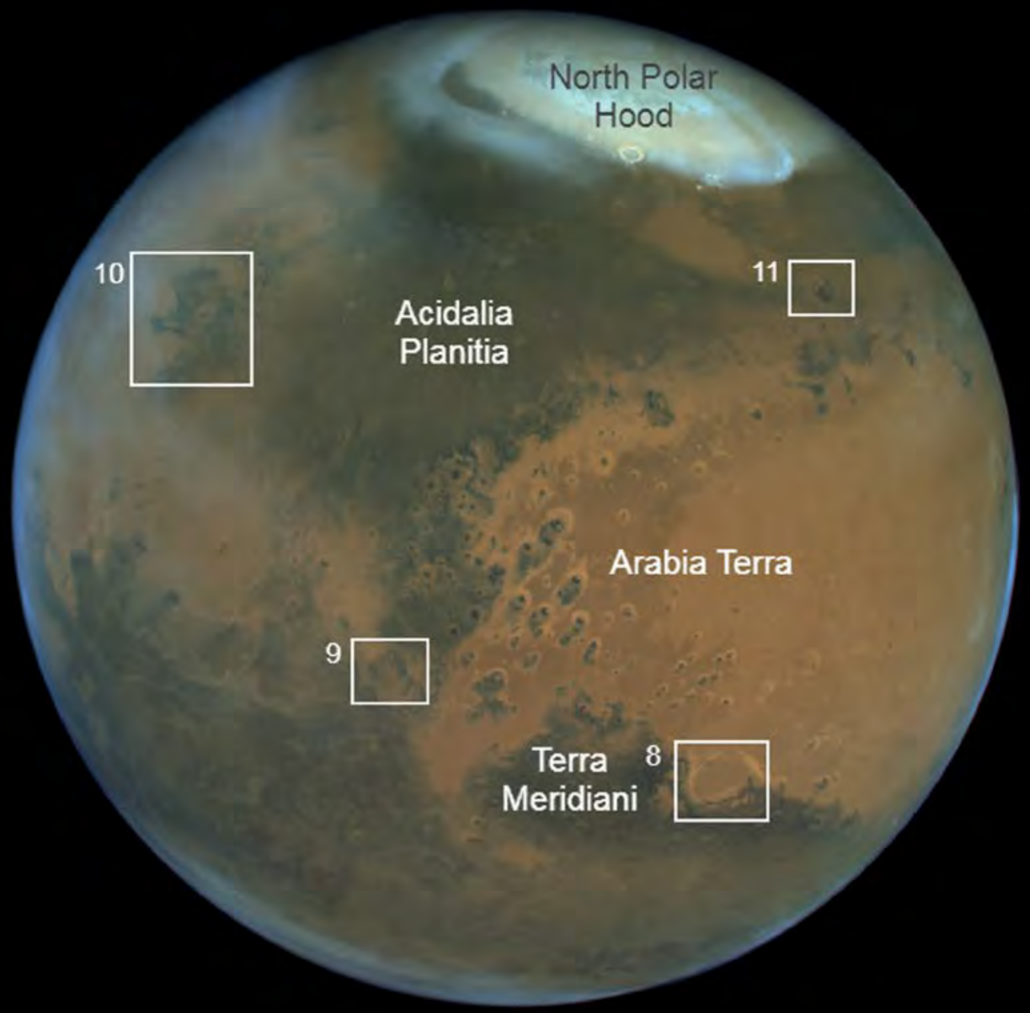
It is roughly halfway between Olympus Mons and the Tharsis Montes, with Ulysses Tholus in the Tharsis quadrangle. It's around 170 kilometers long and 100 kilometers wide and has a height of 3 kilometers.

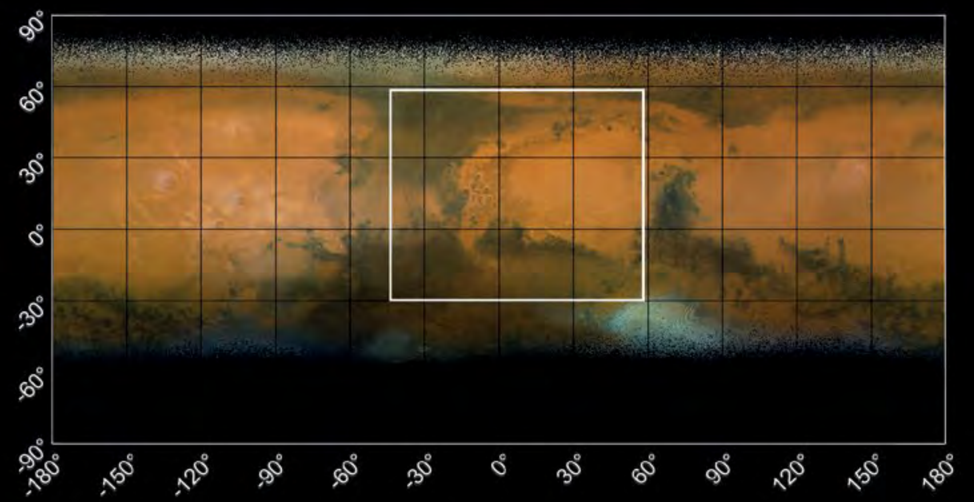
Biblis Patera is a 4 kms deep caldera (large depression due to volcanic eruption) in the heart of the volcano and was formed as a result of collapse of magma chamber during eruption.

7) **The Cerberus Fossae** are a series of semi-parallel cracks on Mars caused by faults in the Cerberus area pulling the crust apart.

They span over 1,235 kilometers. Wind-blown sands create ripples at the bottom of the faults generated by deformation created by the Tharsis volcanoes to the east.

The faults appear very new, having cut through pre-existing features like as the Tartarus Montes' hills and the lava apron southeast of Elysium Mons.



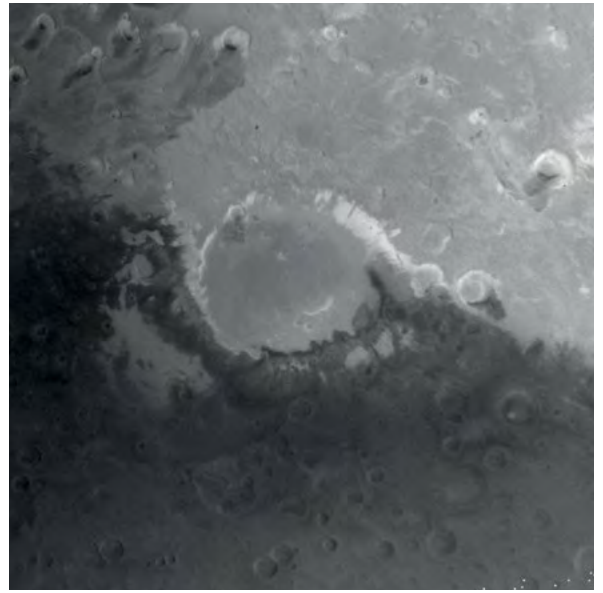


8 Schiaparelli Crater
9 Aram Chaos
10 Kasei Valles
11 Lyot Crater

2021-04-22, Orbit 43

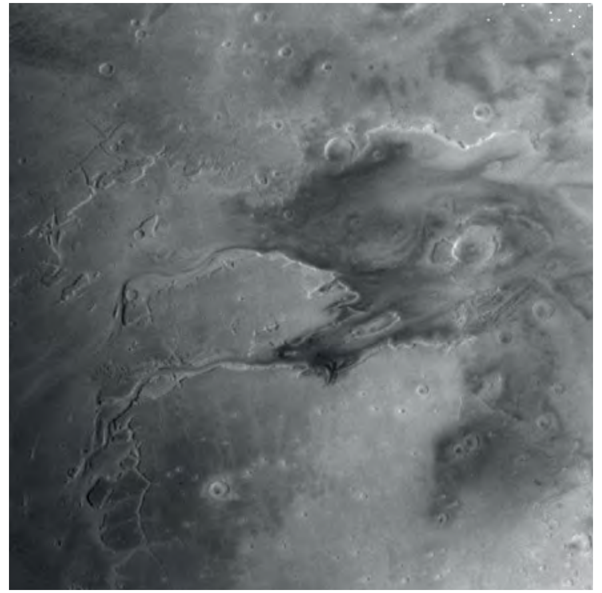
ARABIA QUADRANGLE

The quadrangle covers a portion of the Arabian region of Mars. It also includes a small portion of Terra Sabaea and Meridiani Planum. It is situated on the dividing line between the young northern plains and the old southern highlands. The Arabia quadrangle's surface appears to be quite old because of its high density of craters, yet it is not nearly as high in elevation as other old surfaces.



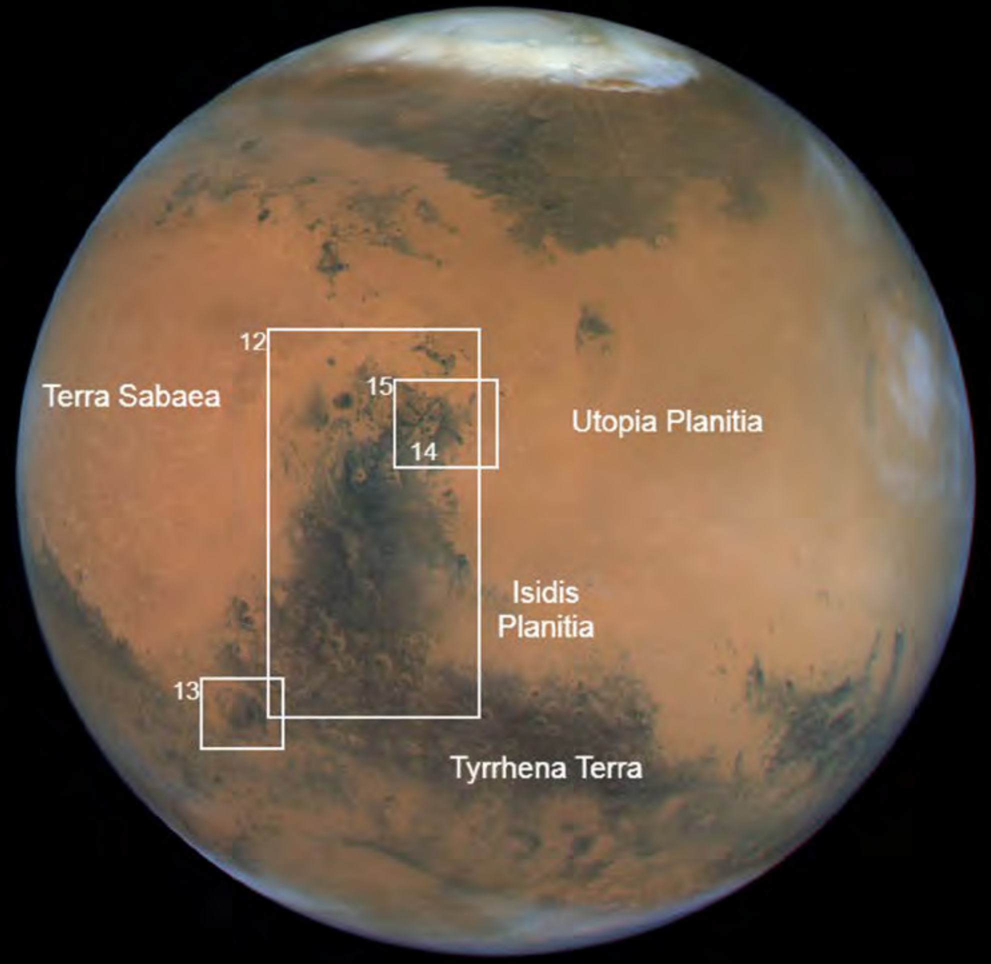
8) **Schiaparelli** is an impact crater with a diameter of about 460 km. It was named after Italian astronomer Giovanni Schiaparelli who is known for his telescopic observations of Mars in the 19th and 20th centuries. A crater within this region has many thick layers that may have formed by the wind, volcanoes, or deposition under water.

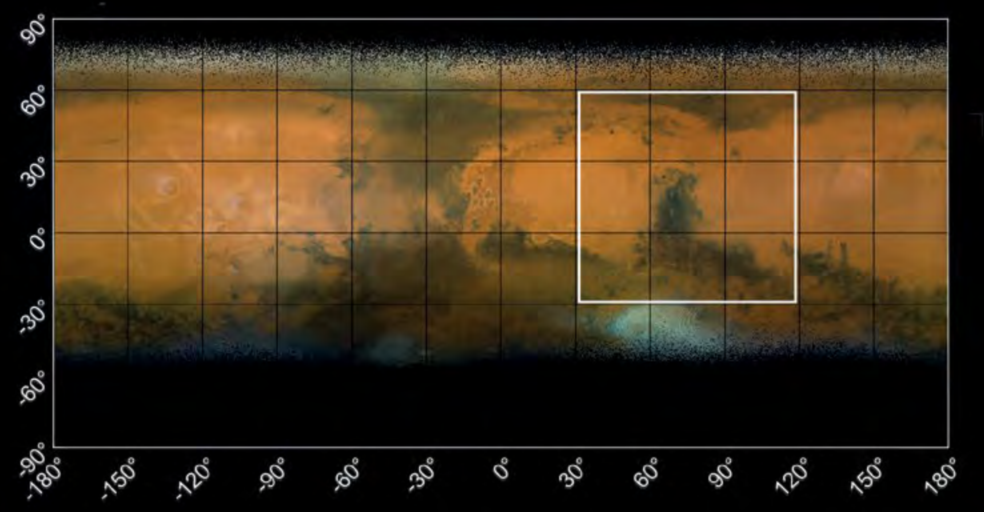
9) **Aram Chaos** is a highly degraded Mars impact crater. It is located near Ares Vallis at the eastern extremity of the huge canyon Valles Marineris. Various geological processes have reduced it to a chaotic circular area. The crater has a diameter of 280km. The crater has hydrated sulfates, jarosite, and hematite. The crater's floor also contains huge collapsed terrain block formed due catastrophic removal of water or ice.



10) The **Kasei Valles** are a massive canyon system in Mars' Mare Acidalium and Lunae Palus quadrangles. They are 1,580 km long and were named after the Japanese word for Mars. This massive structure spans 482 km in some parts and is one of the largest outflow channels on Mars.
They were presumably carved by liquid water, possibly released by volcanic subsurface heating in the Tharsis region, either as a single catastrophic event or multiple flooding events over a time period.

11) **Lyot** is a peak ring crater with a diameter of 236 km and is named after a French astronomer Bernard Lyot. It is the deepest crater in the northern hemisphere of Mars. The crater's floor contains valleys carved by rivers of water that measure approximately 10 km long and 250 m wide. These rivers appear to have developed more recently than others.





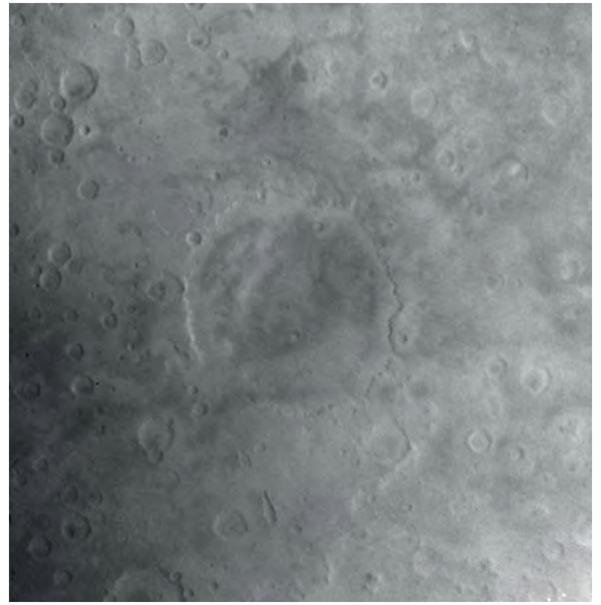
12 Syrtis Major Planum
13 Crater Huygens
14 Crater Jezero
15 Nil Fossae

2021-05-10, Orbit 51

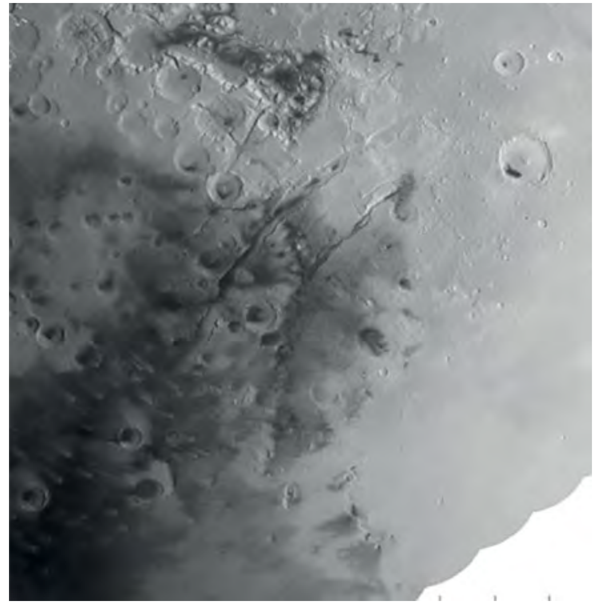
SYRTIS MAJOR PLANUM

Syrtis Major Planum is a “dark spot” (albedo feature) in the Syrtis Major quadrangle. It is located in the west of the impact basin Isidis, on Mars’ northern lowlands and southern highlands. Based on data from Mars Global Surveyor, it was determined to be a low-relief shield volcano. It was previously thought to be aplain and was known as Syrtis Major Planitia. The dark color derives from the region’s basaltic volcanic rock and the lack of dust.

12) **Syrtis Major Planum** is a “dark spot” (albedo feature) in the Syrtis Major quadrangle. It is located in the west of the impact basin Isidis, on Mars’ northern lowlands and southern highlands. Based on data from Mars Global Surveyor, it was determined to be a low-relief shield volcano. It was previously thought to be aplain and was known as Syrtis Major Planitia. The dark color derives from the region’s basaltic volcanic rock and the lack of dust.

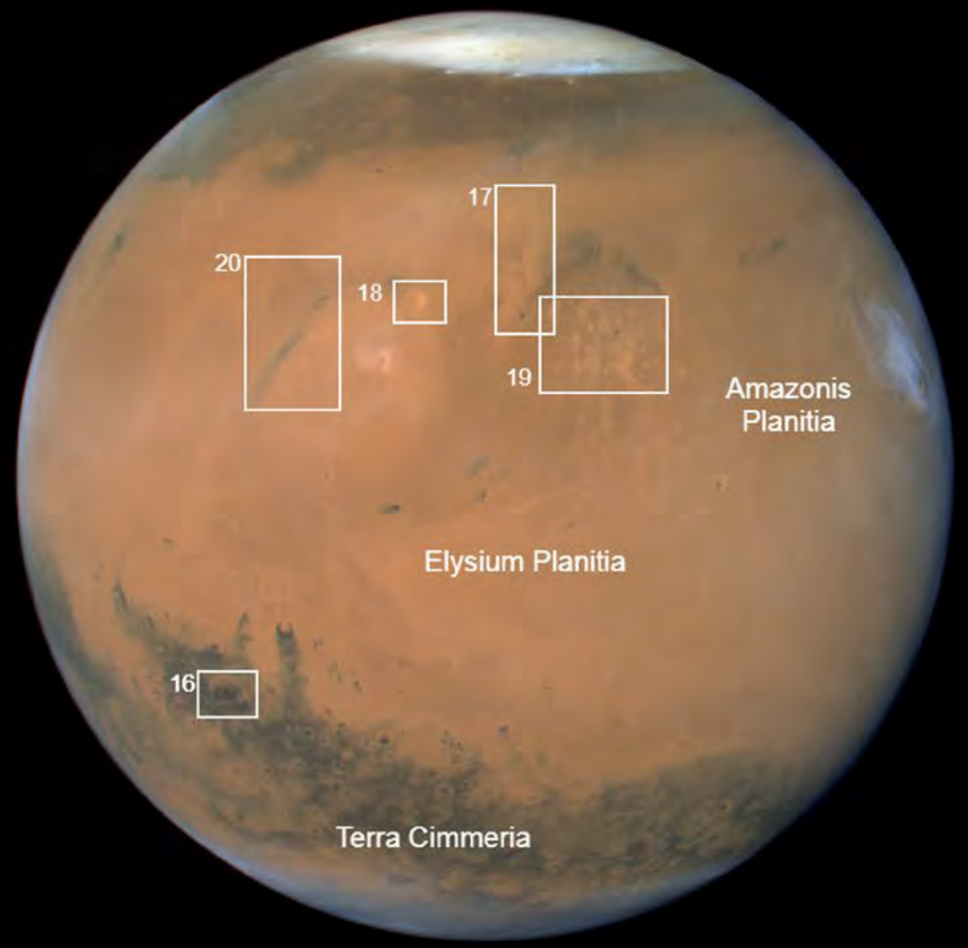


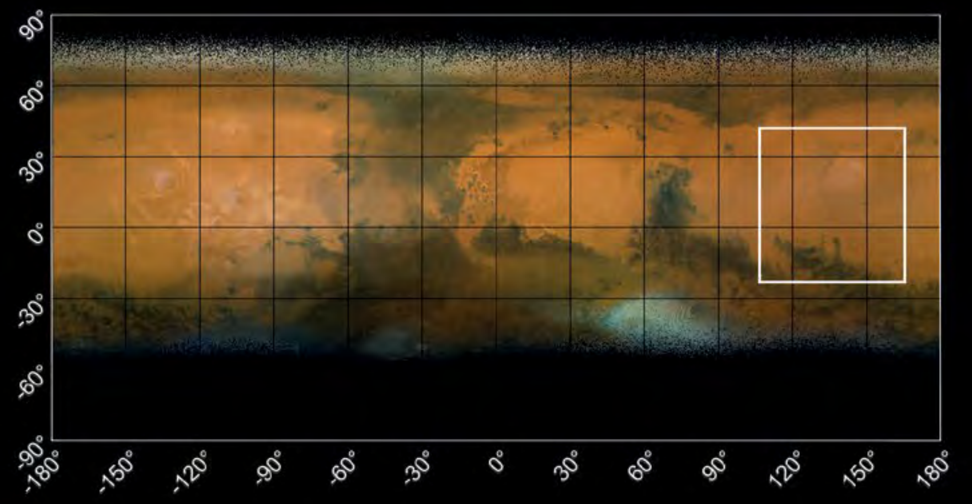
13) **Crater Huygens crater** was named for Christiaan Huygens, a Dutch astronomer, mathematician, and physicist. After Utopia, Hellas, Argyre, and Isidis, it is the fifth biggest identifiable impact crater on Mars, and the largest with a nearly unbroken rim. The crater has a diameter of 467.25 km. Huygens’s rim contains calcium or iron carbonates. These minerals indicate that Mars used to have a thicker carbon dioxide atmosphere with more moisture.



14) **Jezero crater** has a diameter of 45 km. The crater features a fan-delta deposit rich in clays, which is believed to have once been flooded with water. The crater has a delta, as well as point bars and inverted channels. The lake inside the crater was most likely produced during a time of continuous surface runoff, according to a study of the delta and channels. The crater is also the landing site of the Mars 2020 “Perseverance” rover, operating since February 2021.

15) The **Nili Fossae**, located in the Syrtis Major quadrangle, is a group of huge, concentric depressed blocks of crust known as grabens. They have been eroded and partly filled in by sediments and clay-rich ejecta from the Isidis basin, a neighboring large-impact crater. It is 0.6 km deep and has a considerable olivine exposure. The rocks there contain carbonate minerals and it is a source of methane plumes.





16 Herschel Crater
17 Phlegra Montes
18 Elysium Fossae
19 Tartarus Montes
20 Granicus Valles

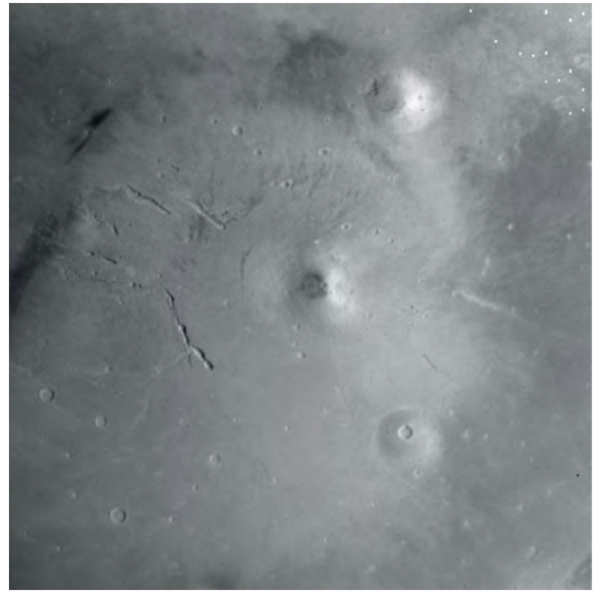
2021-04-27, Orbit 45

ELYSIUM

Elysium quadrangle contains the northern section of Elysium Planitia and a portion of Lucus Planum. This quadrangle also contains a minor portion of the Medusae Fossae Formation. Eddie, Lockyer, and Tombaugh are the largest craters in this quadrangle. It features the prominent volcanoes of Mars like Elysium Mons and Albor Tholus as well as river valleys, one of which, Athabasca Valles, is the youngest valley on Mars.

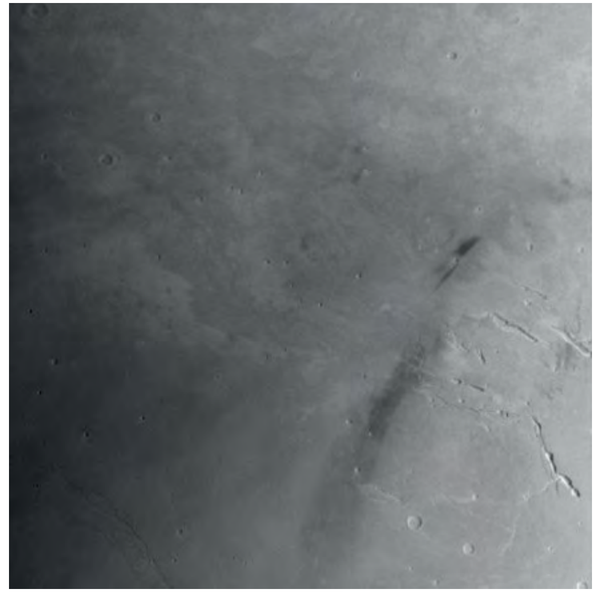
16) **Herschel Crater** is a 304-kilometer-wide impact crater on Mars' southern hemisphere, near the Mare Tyrrhenum region. The crater is named for William and John Herschel, father and son astronomers who lived in the seventeenth and eighteenth centuries. According to images from NASA's Mars Reconnaissance Orbiter, sand dunes on the floor of the Herschel crater are not stationary.

17) **The Phlegra Montes** are a series of eroded Hesperian– and Noachian-aged massifs and knobby terrain in the northern plains of Mars, spanning northwards for almost 1,400 km from the Elysium Rise to Vastitas Borealis. The mountain ranges, which were called after a classical albedo feature in the 1970s, split the huge plains provinces of Utopia Planitia (west) and Amazonis Planitia (east). The Phlegra Dorsa is a series of parallel wrinkle ridges that flank the massif terrains.



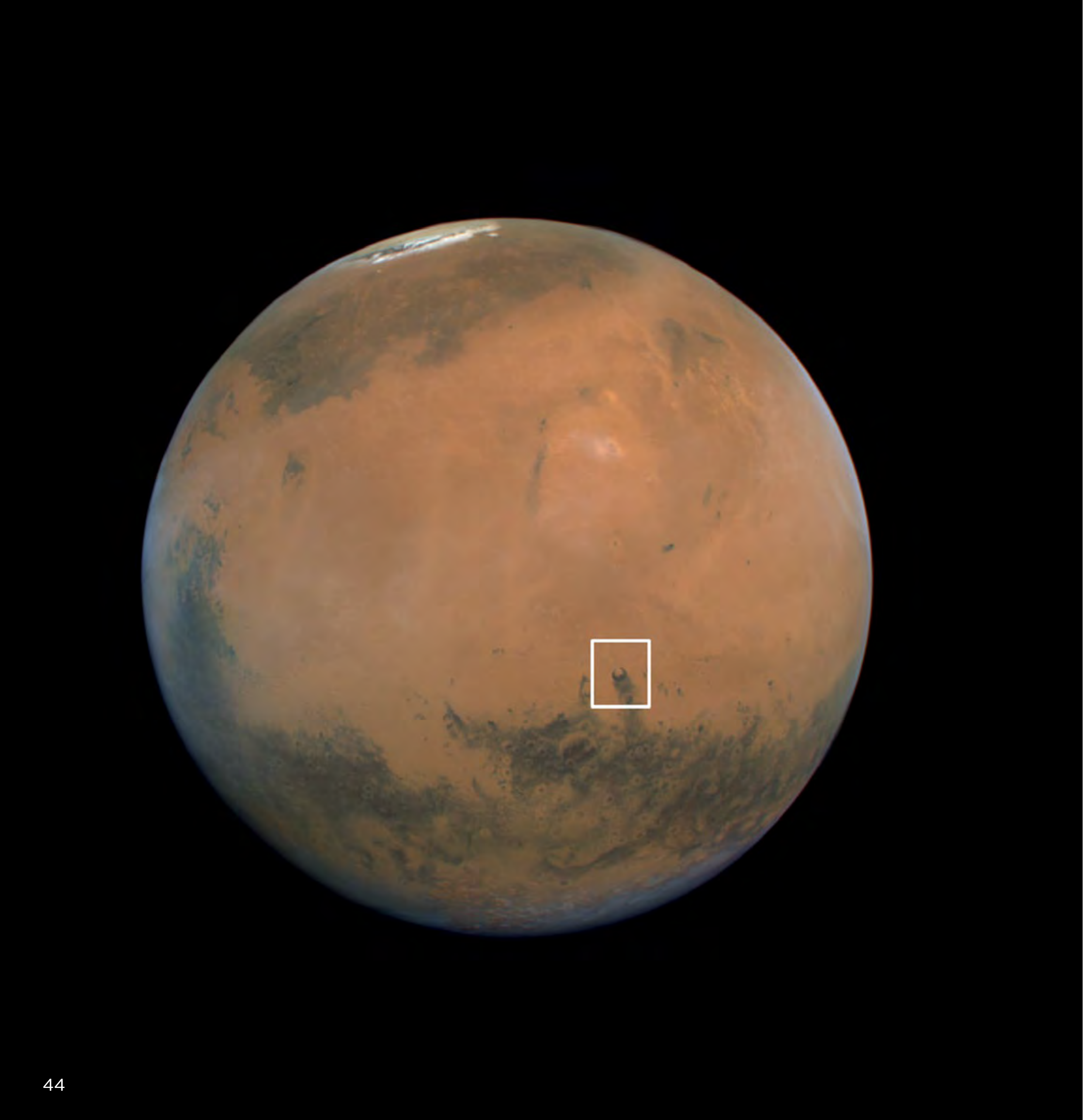
18) **The Elysium Fossae** are a series of deep troughs that are approximately 1,175 km long. Layers, also known as strata, exist in the Elysium Fossae. Many areas on Mars have layers of rocks such as these with a variety of colors.

19) **The Tartarus Montes** are a mountain range on Mars that stretches for 1,070 km and is located between Orcus Patera and the Elysium volcanic zone. They were named after deepest part of the underworld in Greek mythology. This mountain range's areas are characterized by narrow grabens and fractures.



20) **The Granicus Valles** is a network of valleys located in Mars's Amenthes quadrangle. They are 750 kilometers long and named after an old Turkish river. This region is known for long and broad strips of scoured ground known as outflow channels.

IMPACT CRATERS



An impact crater is a circular depression on a planet's surface caused by a smaller body colliding with it at hypervelocity. Impact craters, unlike volcanic craters, which are formed by explosion or internal collapse, have elevated rims and floors that are lower in elevation than the surrounding landscape. Small bowl-shaped depressions to large complicated impact basins with multiple rings are all examples of impact craters.

PEDESTAL CRATERS

A pedestal crater is one in which the ejecta, or ejected particles, sit higher than the surrounding landscape, providing a raised platform similar to a pedestal. The raised platform creates an erosion-resistant layer where the local area erodes more slowly than the remainder of the region. The height of certain pedestals has been measured to be hundreds of meters above the surrounding landscape. The Mariner missions between 1962 and 1973 were the first to discover the pedestal craters.

RAMPART CRATERS

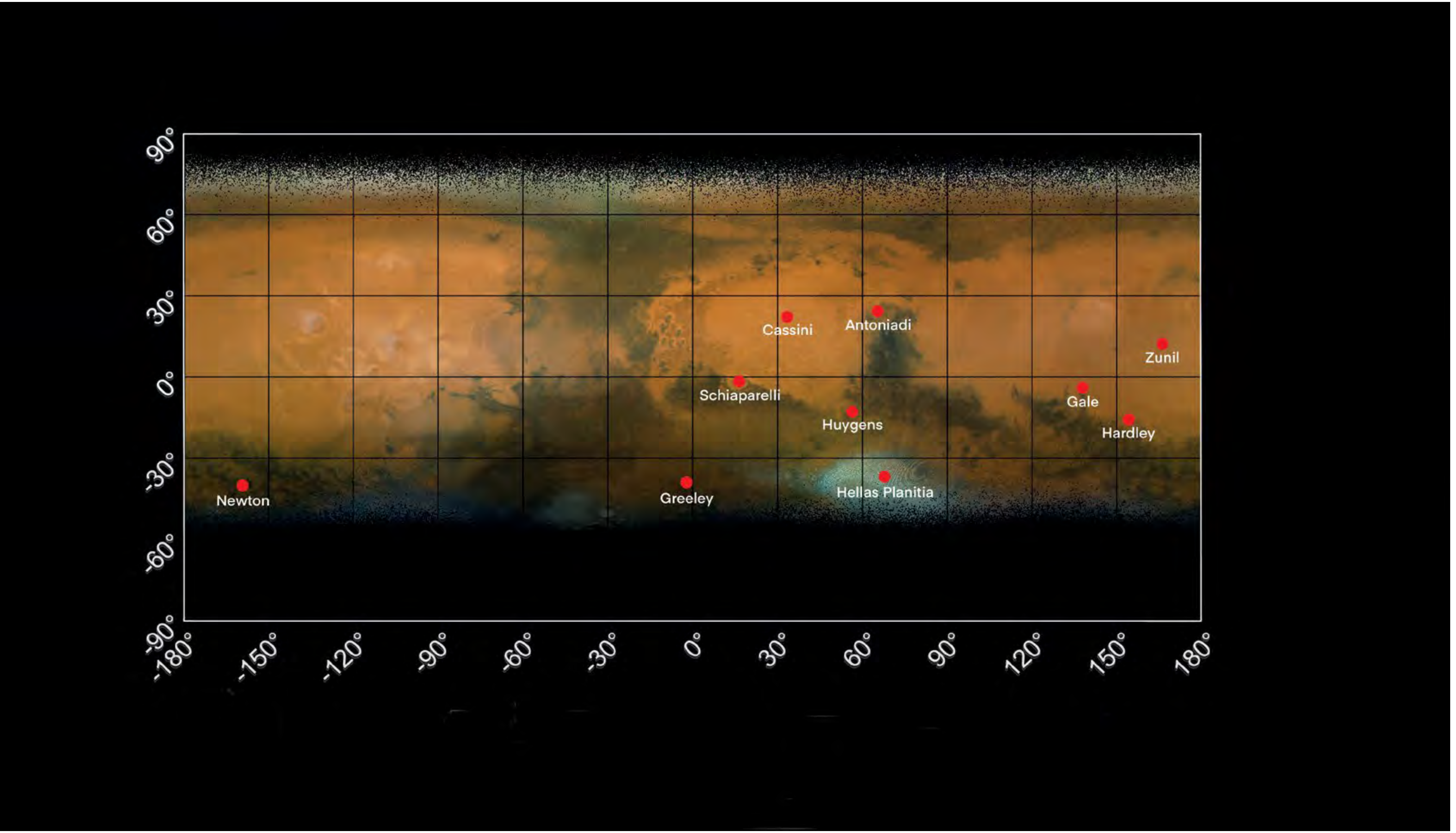
Rampart craters are a type of impact crater with fluidized ejecta features that are mostly found on Mars. An ejecta with a modest ridge along its edge can be seen in a rampart crater. The outside margin of rampart craters is usually lobate, as if debris slid along the surface rather than vertically in a ballistic trajectory. Instead of colliding with minor impediments, the flows are occasionally diverted around them.

EXPANDED CRATER

Expanded craters are swarms of secondary Craters formed by the impact caused by debris blasted out as a result of an impact. These craters have provided insight into areas where significant ice may be present in the earth as expanded craters have lost their rims, which could be due to any previous rims collapsing into the crater during expansion or losing their ice, if they were made of ice.

LOW-ASPECT-RATIO LAYERED EJECTA (LARLE) CRATER

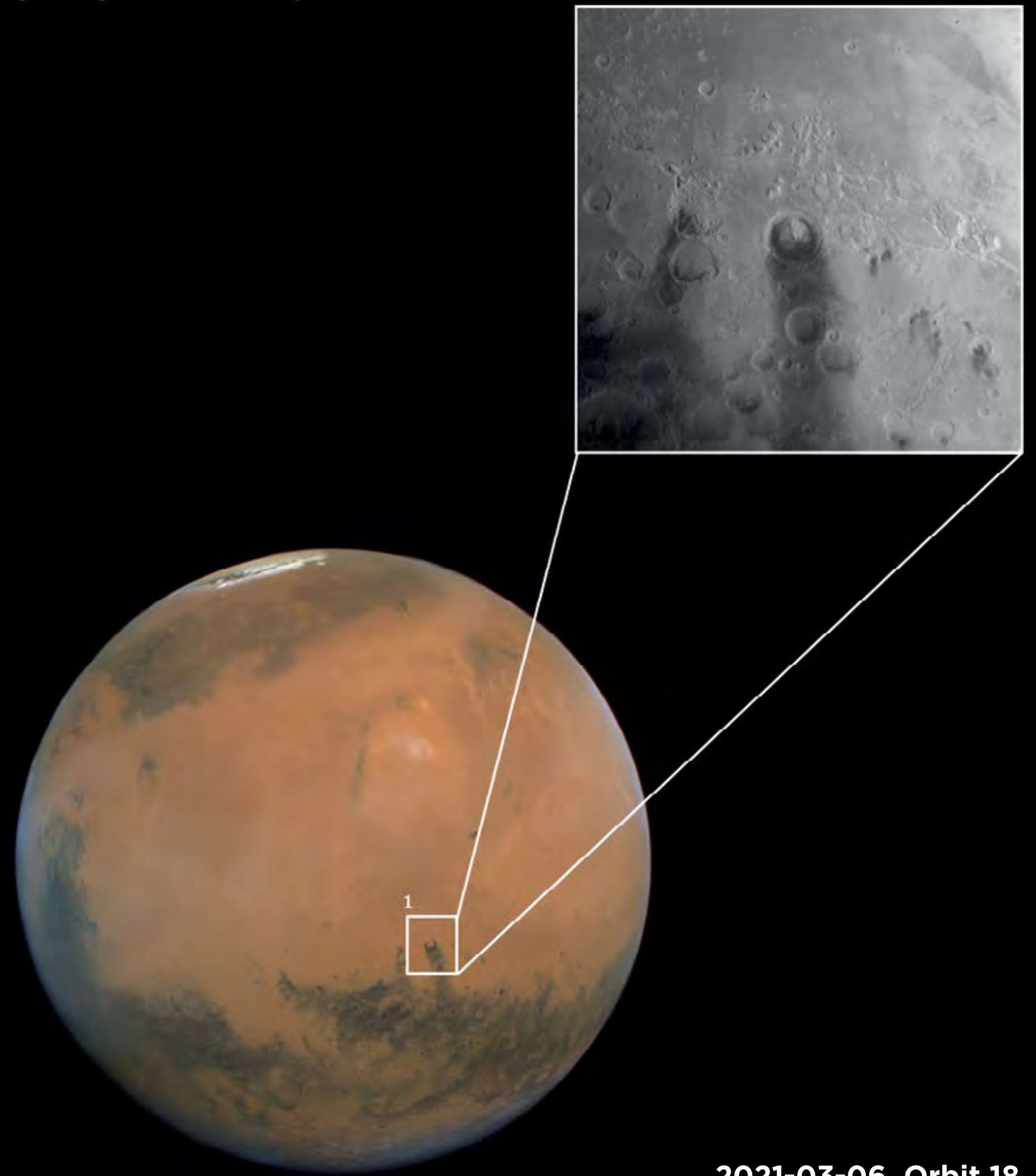
LARLE craters consist of a crater and conventional layered ejecta pattern encircled by an enormous but thin outer deposit that finishes in a flame-like appearance. The term "low aspect ratio" describes how thin the deposits are in comparison to the area they cover.When compared to base surge deposits from explosion craters, the ejecta layers of LARLE craters have greater aspect ratios due to large concentrations of tiny dust and ice in the locations where LARLE craters develop.



1 Gale
Gale crater is a possible dry lake on Mars, located in the Aeolis quadrangle's northwest corner. It has a diameter of 154 kilometres and is estimated to be 3.5-3.8 billion years old.

Walter Frederick Gale, an amateur astronomer from Sydney, Australia, who examined Mars in the late 1800s, was honored with the crater's name. Aeolis Mons is a 5.5-kilometer-high mountain near Gale's centre.

IMPACT CRATERS



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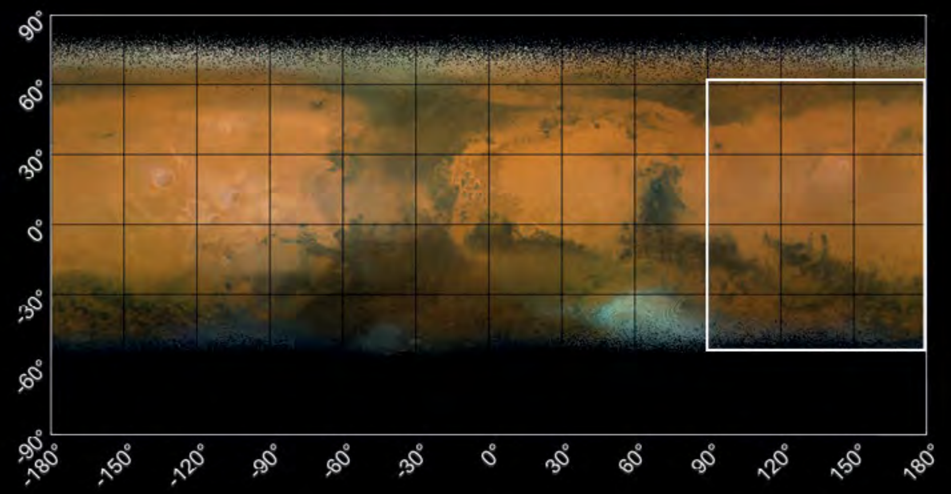
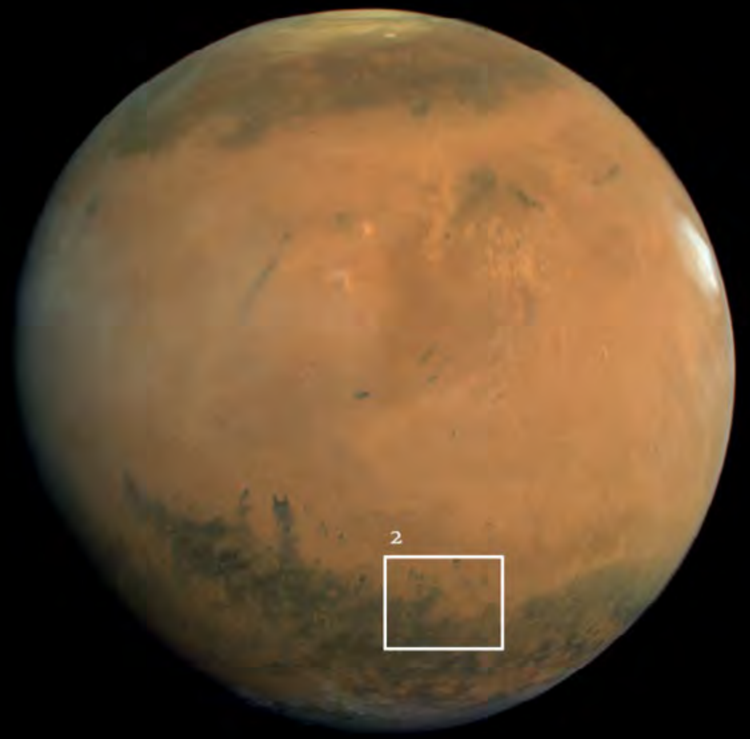




2021-07-02, Orbit 74

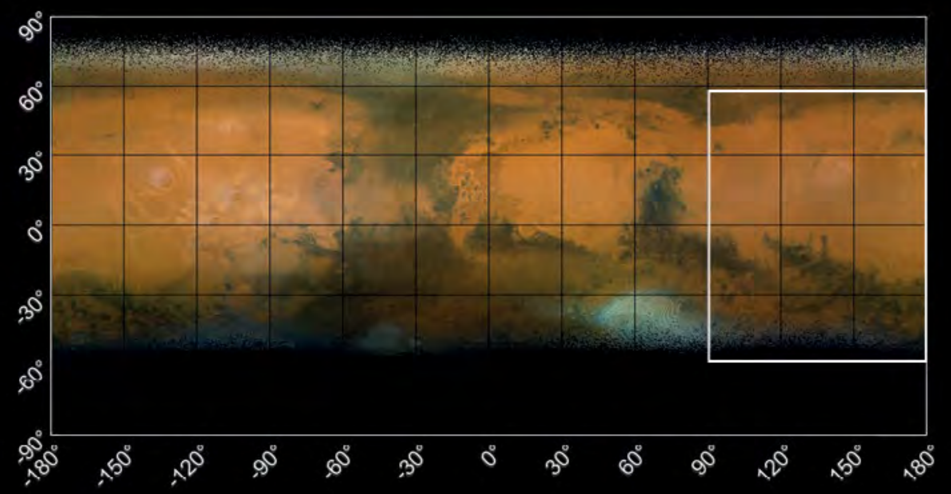
2 Hadley

Hadley is an impact crater on Mars, located in the Aeolis quadrangle and is part of Terra Cimmeria.

It has a diameter of 119 kilometres and was named after George Hadley, a British meteorologist.

3 Zunil

A 10.26 km-wide impact crater on Mars near the Cerberus Fossae in Elysium quadrangle. It is named after the Guatemalan town of Zunil. The crater is still in good condition considered it was formed by an impact that happened just a few millions years ago. It was most likely not created by a high-velocity impact, such as one caused by a comet. It is believed that Zunil is the source of the basaltic shergottite meteorites, and according to this theory, the crater was formed in basalt that was deposited between 165 and 177 million years ago.



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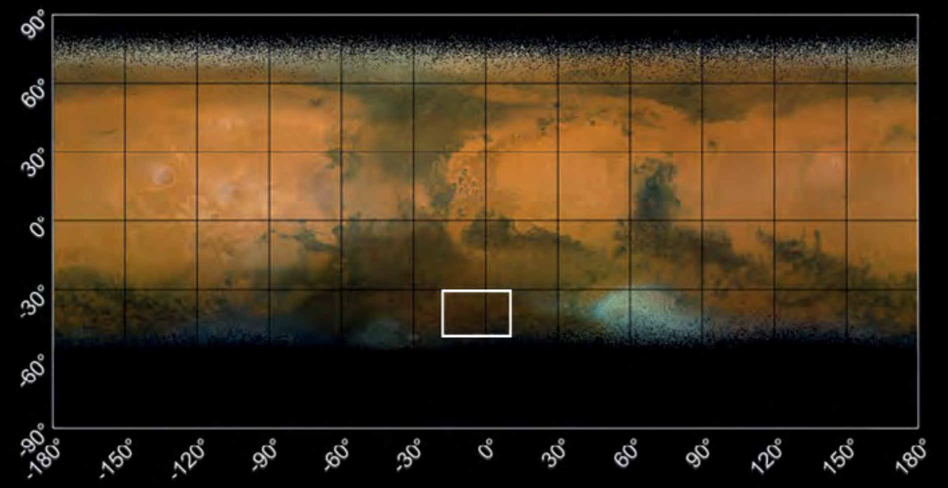


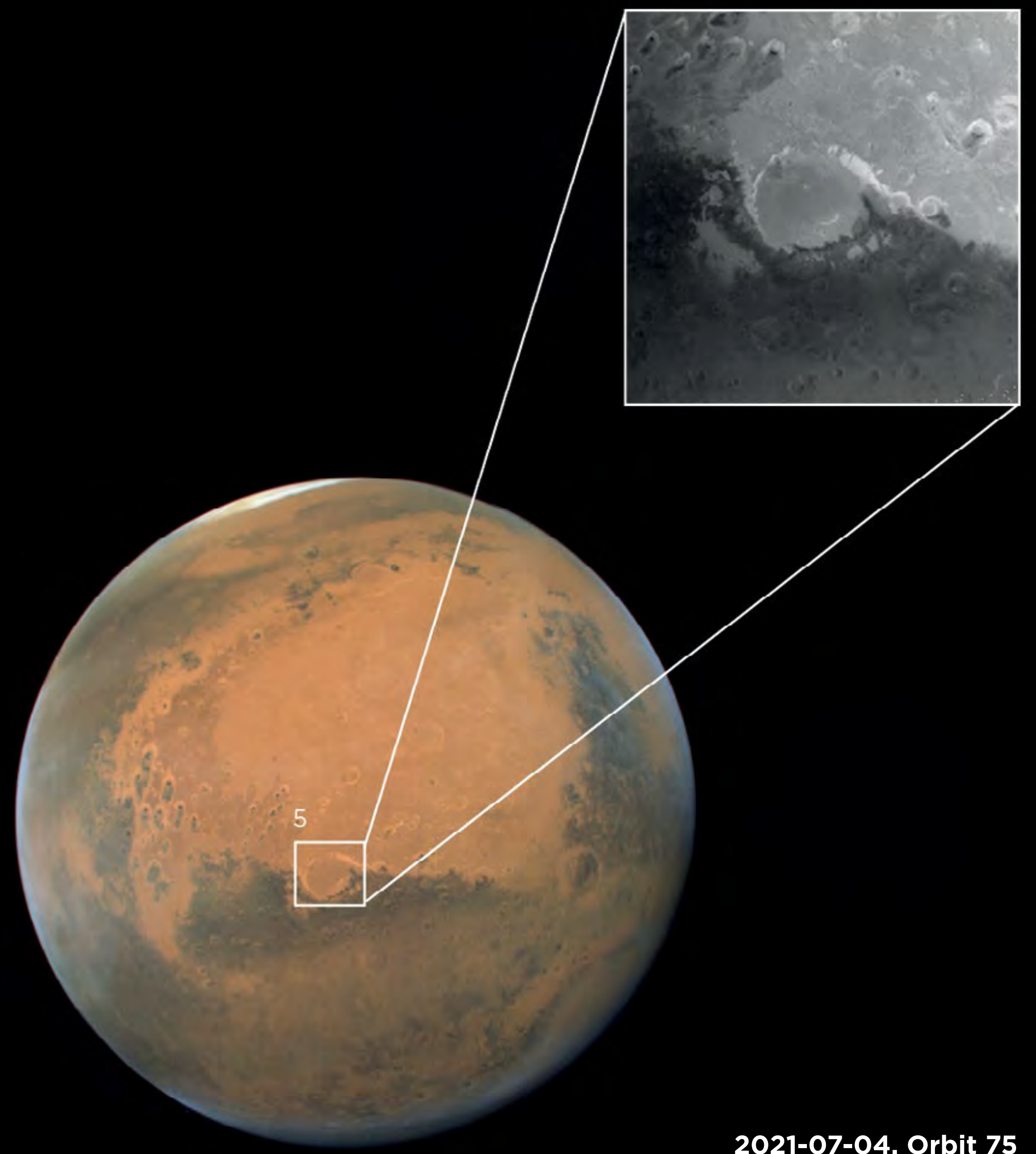
2021-08-16, Orbit 94

4 Greeley

Greeley is a massive impact crater on Mars, located in the northwest of the Noachis quadrangle. It has a diameter of 457 km and was named after Ronald Greeley, an American geologist.

5 Schiaparelli

An impact crater in the Sinus Sabaeus quadrangle, near the equator. It was named for Italian astronomer Giovanni Schiaparelli and has a diameter of 460 km. Many strata created by the wind, volcanoes, or deposition under water can be seen in a crater within Schiaparelli. Recent study reveals that the patterns in the layers were generated by ancient climate change, which was triggered by repeated variations in the planet's tilt.



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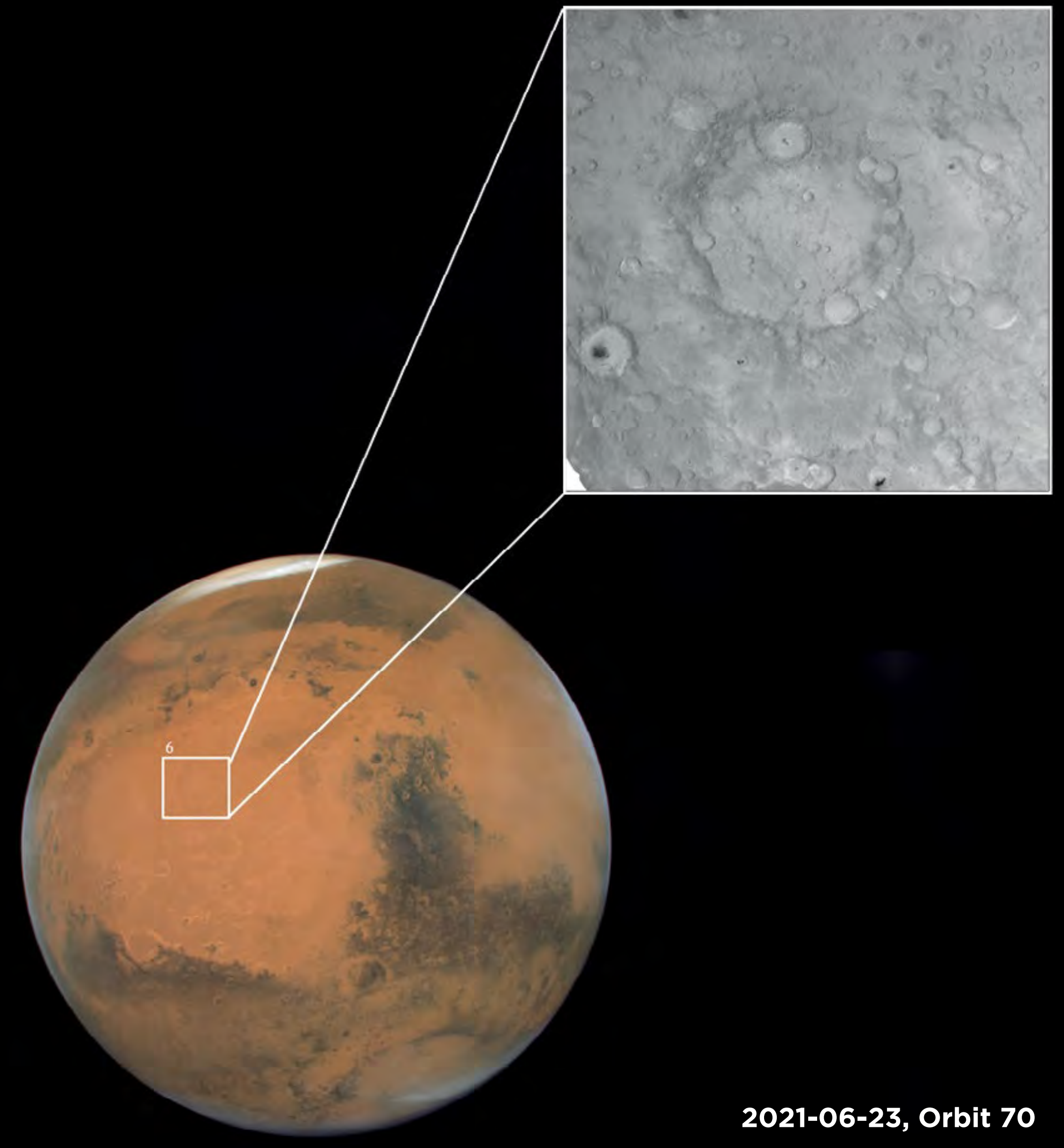


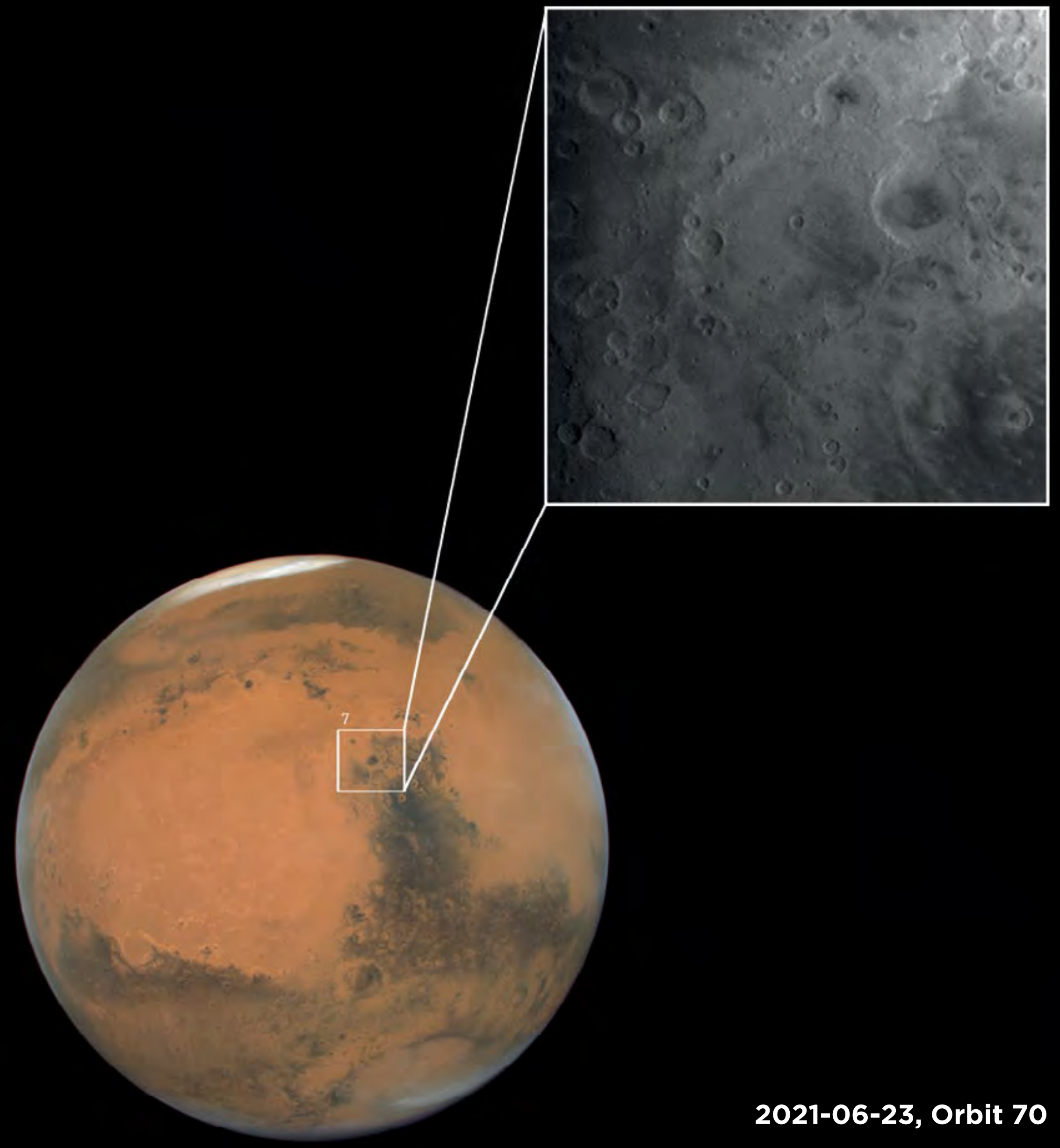
2021-06-23, Orbit 70

6 Cassini

A crater named for Giovanni Cassini, an Italian astronomer. The crater is located in the Arabia quadrangle of Mars and measures roughly 415 km in diameter. Its floor is made up of several layers that may have been created by volcanoes, wind, or water.

7 Antoniadi

The crater is located in the Syrtis Major quadrangle. It is 394 km long and named for Greek astronomer Eugène Michael Antoniadi. Some evidences quote that rivers and lakes were once present in this crater. They suggest that the minerals in this crater cemented the collected sediments, resulting in formation of inverted channels. These channels eroded through the surface and sediments filled the entire area.



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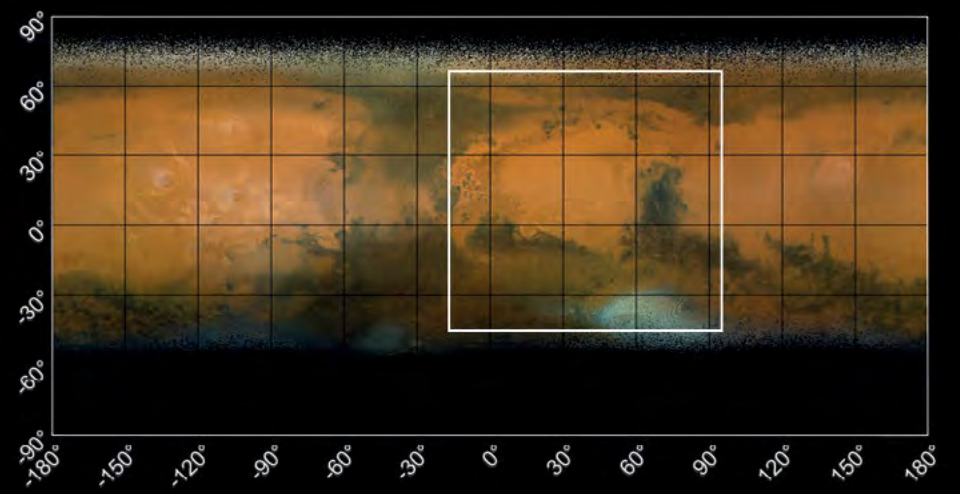

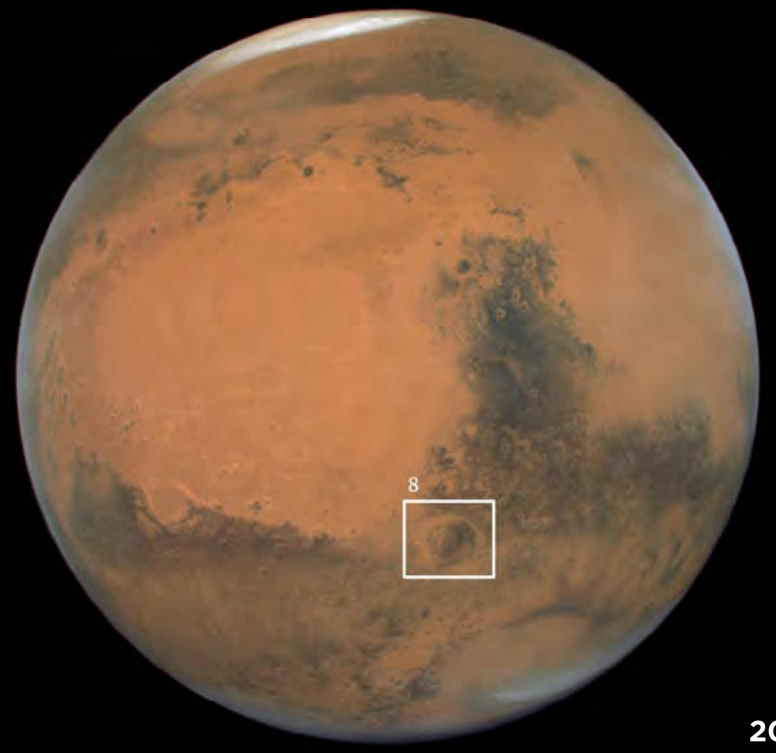

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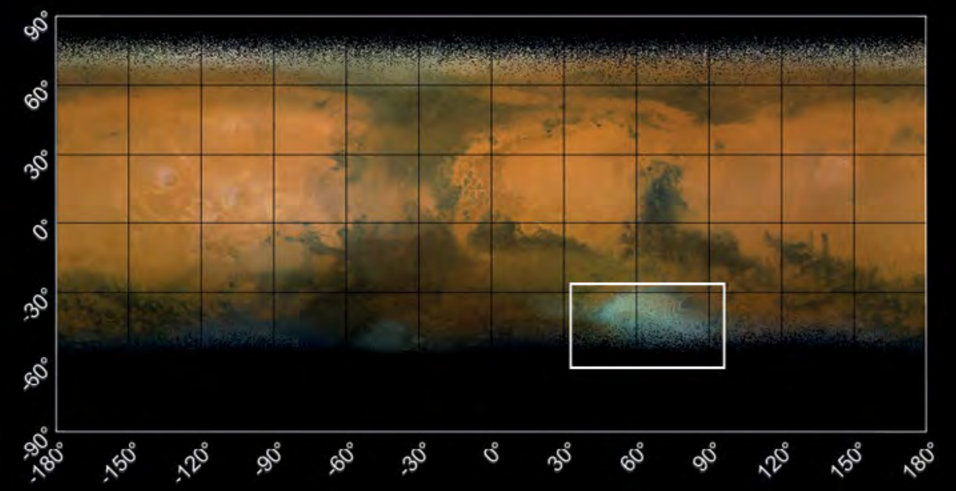
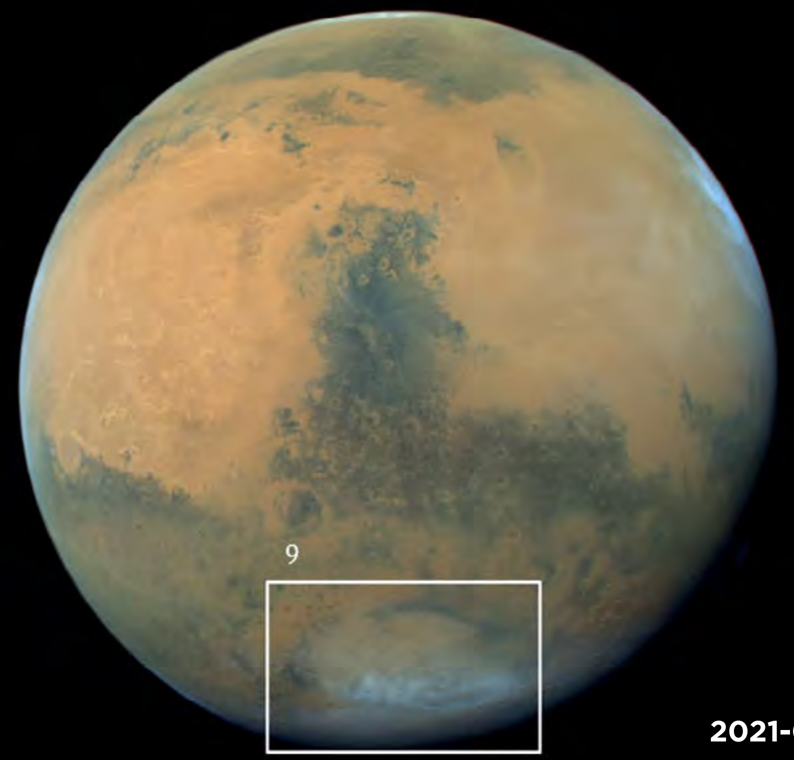
8 Huygens

An impact crater named after Christiaan Huygens, a Dutch astronomer, mathematician, and physicist. After Utopia, Hellas, Argyre, and Isidis, it is the fifth biggest identifiable impact crater on Mars, and the largest with a nearly unbroken rim. The crater has a diameter of 467.25 km and is located in the Iapygia quadrangle. In a crater on Huygens' rim, calcium and iron carbonates were identified.
The collision on the rim uncovered material that had been dug up by the Huygens impact. These minerals show that Mars used to have a thicker carbon dioxide atmosphere with more moisture. These types of carbonates only occur when there is a lot of water present.

9 Hellas Planitia

A plain in the southern hemisphere of Mars, located within the massive, nearly circular impact basin Hellas. Hellas is the Solar System's third or fourth largest known impact crater. The basin floor is about 7,152 m deep and it stretches for nearly 2,300 km east to west. The crater is thought to have formed when a protoplanet or huge asteroid collided with the surface during the Solar System's Late Heavy Bombardment phase occurred approximately 4.1 to 3.8 billion years ago.





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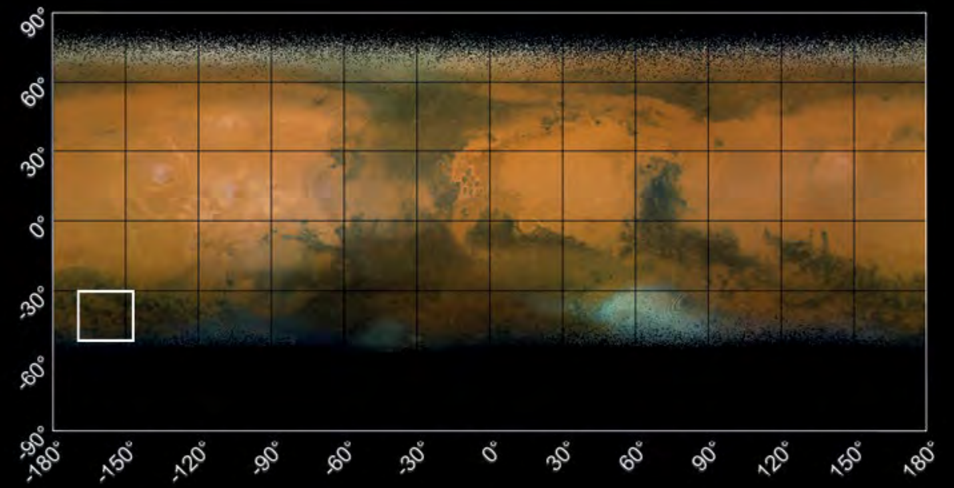
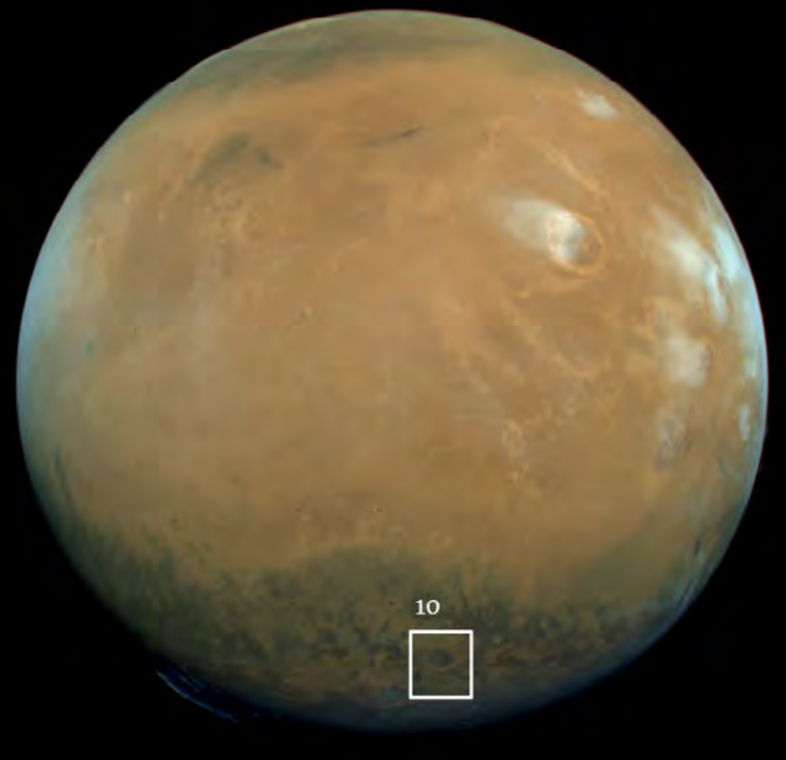


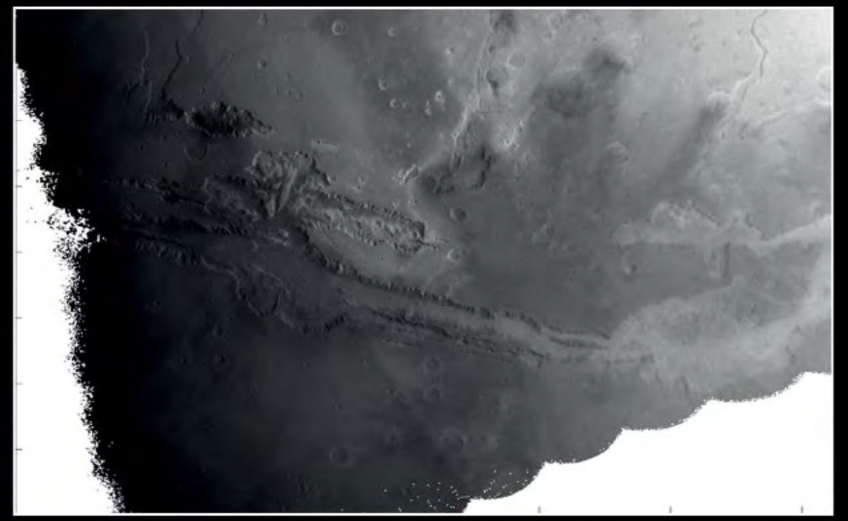


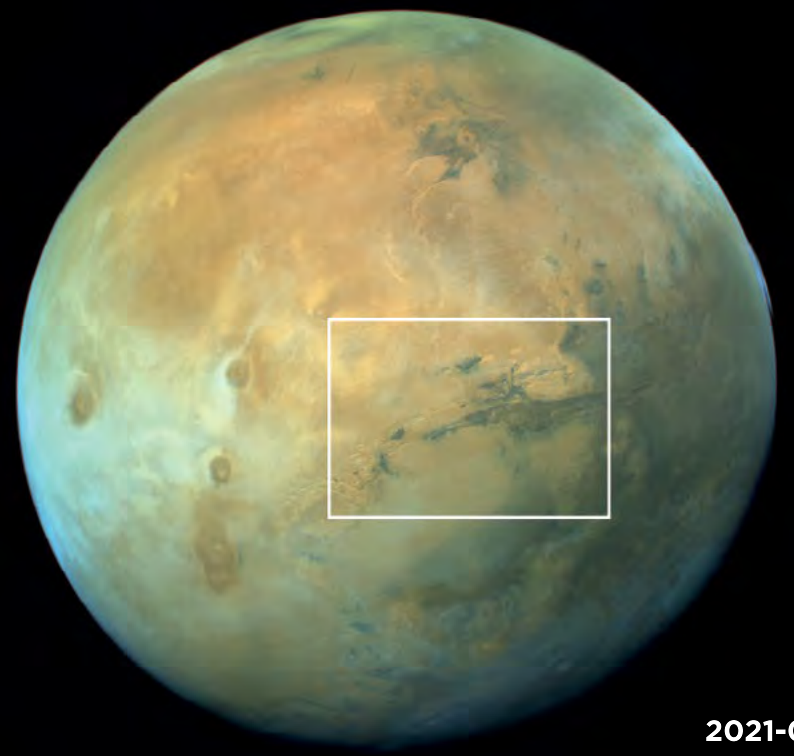
10 **Newton**

A huge crater with a diameter of about 300 kilometres that lies in the Phaethontis quadrangle in the highly cratered highlands of Terra Sirenum. Newton was most likely formed by a collision that occurred more than 3 billion years ago. Within the crater's basin, smaller craters can be found, as well as gully formations that are thought to be suggestive of former liquid water flows. Many small channels can be found in this location, further strengthening the theory that liquid water was once present here. Researchers assumed that the mechanisms carving the gullies involved liquid water because of their form, characteristics, placements, and apparent association with areas presumed to be rich in water ice.

Valles Marineris

Valles Marineris is the one of the largest canyon systems in the Solar System with its length over 4,000 km, width of 200 km and depth reaching up to 7 km. Valles Marineris begins south of the equator in Tharsis region and stretches to the west. Compared to the Grand Canyon in Arizona, USA, Valles Marineris is approximately 10 times longer and five times deeper. The name is derived from the Mariner 9 orbiter, which discovered these canyons in 1971.





2021-08-18, Orbit 95

FORMATION OF VALLES MARINERIS

Captured on March 16, 2021, Orbit 25

The formation of Valles Marineris started around 4 billion years ago in Noachian period. It is closely related to origin of Tharsis region, which consisted of three stages. In the first stage, volcanic activity and post-glacial rebound, in other words rising land masses, were prominent. Increase of volcanic activity in Tharsis led to creation of grabens due to the added pressure on the crust, which subsided over time. These gigantic grabens are canyons forming Valles Marineris. In the second stage, there was again an increase in volcanic activity which resulted in the formation of fractures Stage three was a period of forming shield volcanoes such as Olympus Mons.

REGIONS OF VALLES MARINERIS

Noctis Labyrinthus is a region on Mars located in the center of Tharsis, in the Phoenicis Lacus quadrangle. The area is well-known for its canyons and valleys formed by faulting and several show features of grabens. It is notable for occurrence of many minerals.

Ius Chasma is a canyon in the Coprates quadrangle. With its length of 938 km, it belongs to one of the largest canyons in Valles Marineris. Formation of the canyon was affected by a process known as sapping. During sapping the water leaking down the cliffs evaporates before it reaches the bottom of the canyon. Ius Chasma was also shaped by avalanches, faulting, and grabens.

Tithonium Chasma, a large canyon named by a classical albedo feature, is located in the Coprates quadrangle. It is 810 kilometers long and between 10 to 110 kilometres wide, it narrows down in the east part with a maximum depth of approximately four kms.

Echus Chasma is a 100 km long, 10 km wide and up to four km deep canyon in the Lunae Planum, in Coprates quadrangle. In the Hesperian Epoch, the running theory is that there was a lake filled with water, which provides the explanation for the clay found on the bottom of the canyon.

Hebes Chasma is around 319 km long and it is made unique by the presence Hebes Mensa. Located in the centre of the depression, Hebes Mensa is a massive mesa towering 5 kilometers above the valley floor.

Ophir Chasma is a valley distinguished by its width and is located in the north of the centre of Valles Marineris. Ophir Chasma is around 317 km long.

Candor Chasma s one of the largest canyons in the Valles Marineris with its length of over 773 km. It is located in the centre and it is divided to East and West Candor Chasma.

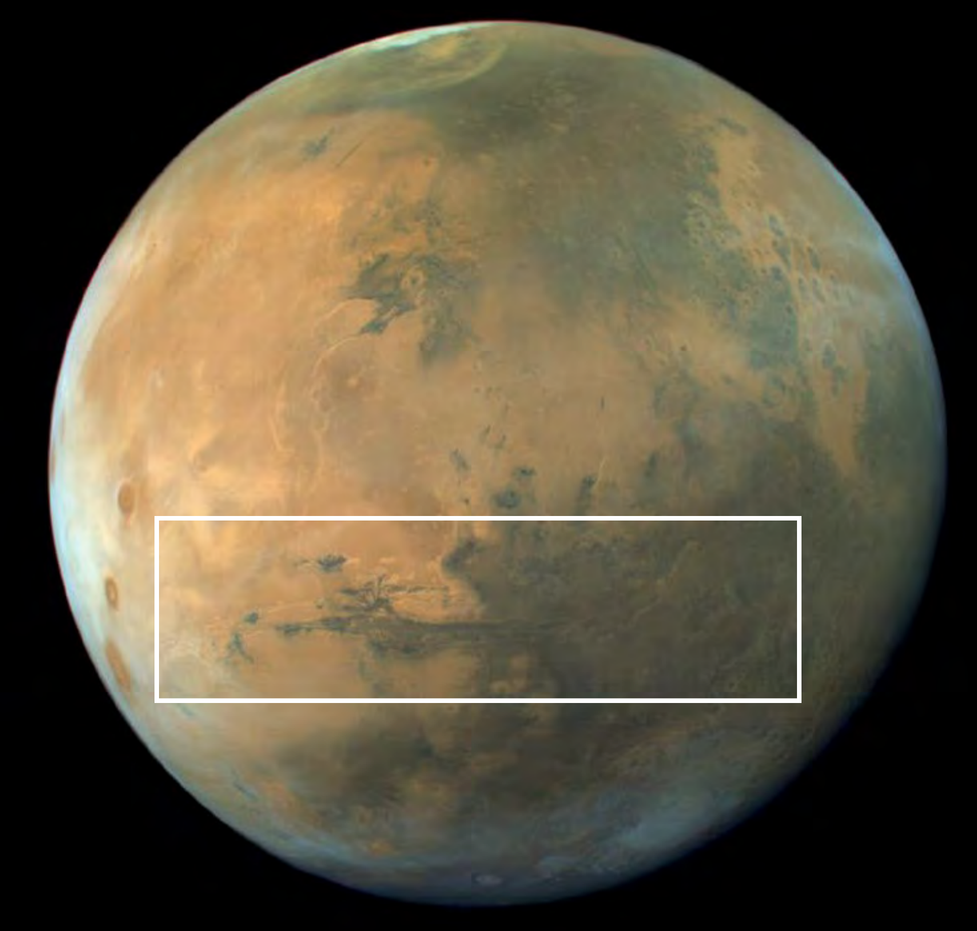
Juventae Chasma is a large canyon located in the north with its length of 250 km. It forms an outflow channel Maja Valles.

Coprates Chasma is one of the longest canyons on Mars, it is 966 km long. There is a strong evidence of an ancient lake.

Ganges Chasma is located in the east of Valles Marineris. Named after the South Asian river, the Ganges Chasma is unique for its depth.

Capri Chasma is located on the east edge of Valles Marineris.

Melas Chasma is the widest part of the Valles Marineris. Hydrated sulfates found in this region support the theory of the existence of an ancient lake filled with water.

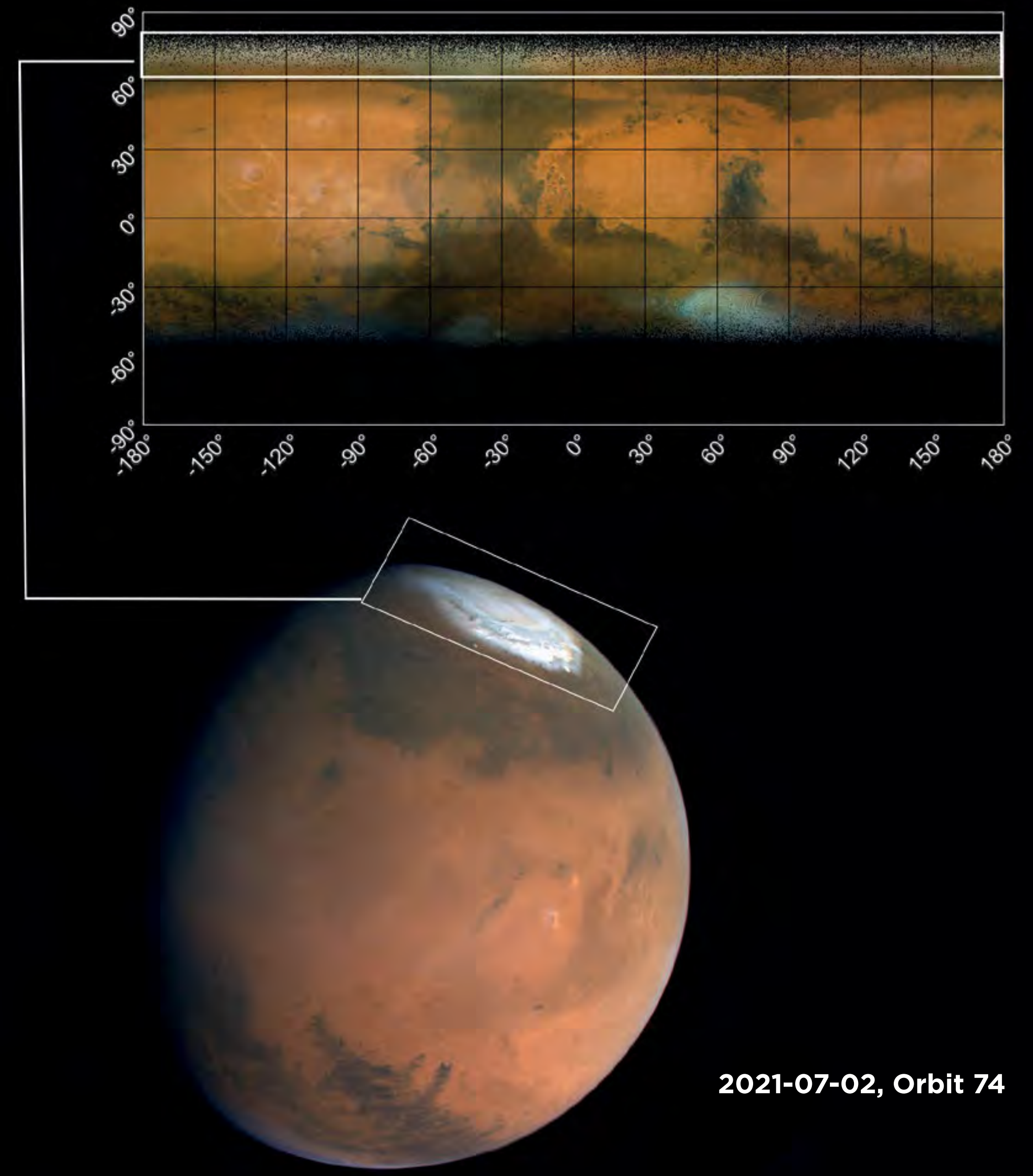


2021-07-06, Orbit 76

06

QUADRANGLES

MARE BOREUM QUADRANGLE



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The United States Geological Survey has split Mars' surface into thirty cartographic quadrangles. Each quadrangle is an area on the Martian surface that covers a certain range of latitudes and longitudes. The quadrangles are numbered from one to thirty, with the prefix "MC" (for "Mars Chart"), and the numbering runs from north to south and west to east.

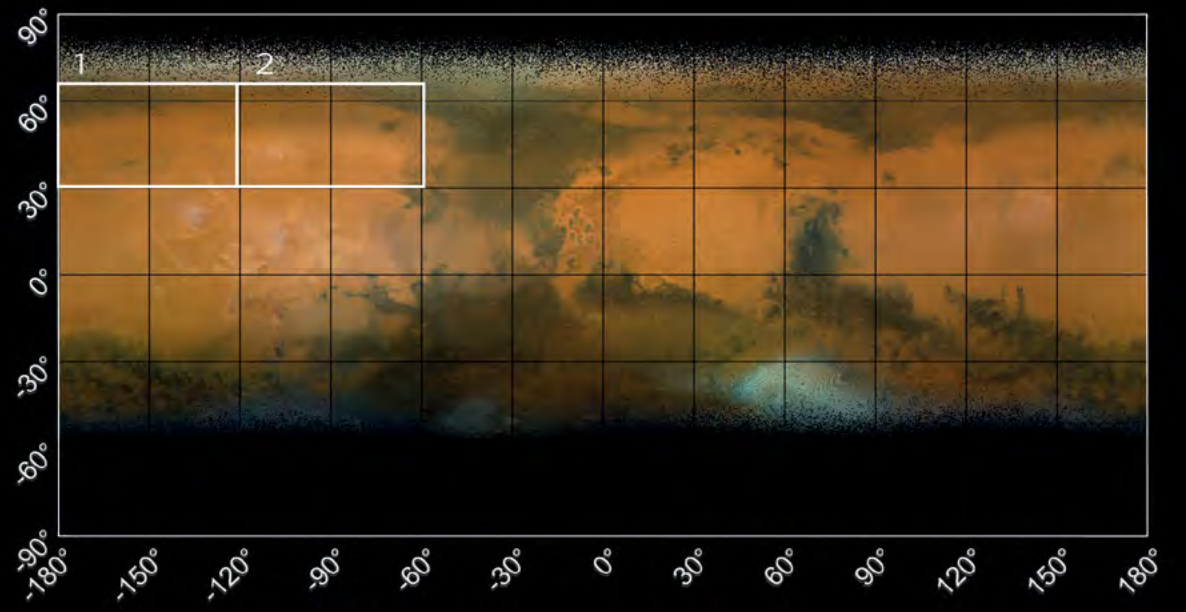
Mare Boreum quadrangle, whose name is derived from the older name for the northern polar plain Planum Boreum, is located north of the 65° latitude. The North polar cap is a distinct feature of this quadrangle and it is surrounded by plains Planum Boreum and Vastitas Borealis, which is the largest lowland region on Mars. Around the cap there is a belt of sand dunes, which is possibly the largest dune field in our Solar System. Chasma Boreale is a valley close to the pole that could have been formed by melting of the ice from the North polar cap. Prominent craters of the region are Lomonosov and Korolev, which are unique in the northern region because there is not much change in topography.

1 Diacria

The origin of the name Diacria quadrangle comes from the so-called highlands around Marathon in Greece. It was named by the Greek astronomer E. M. Antoniadi in 1930. As the name's origin suggests, part of this quadrangle is characterized by volcanic and tectonic features, specifically the southeastern and east central portions of the quadrangle. Diacria is located in the northwestern hemisphere, therefore the northern regions are mostly lowlands. Parts of Amazonis Planitia, Arcadia Planitia and Vastitas Borealis are located here as well as a very large crater Milankovič with a 118.4 km diameter.

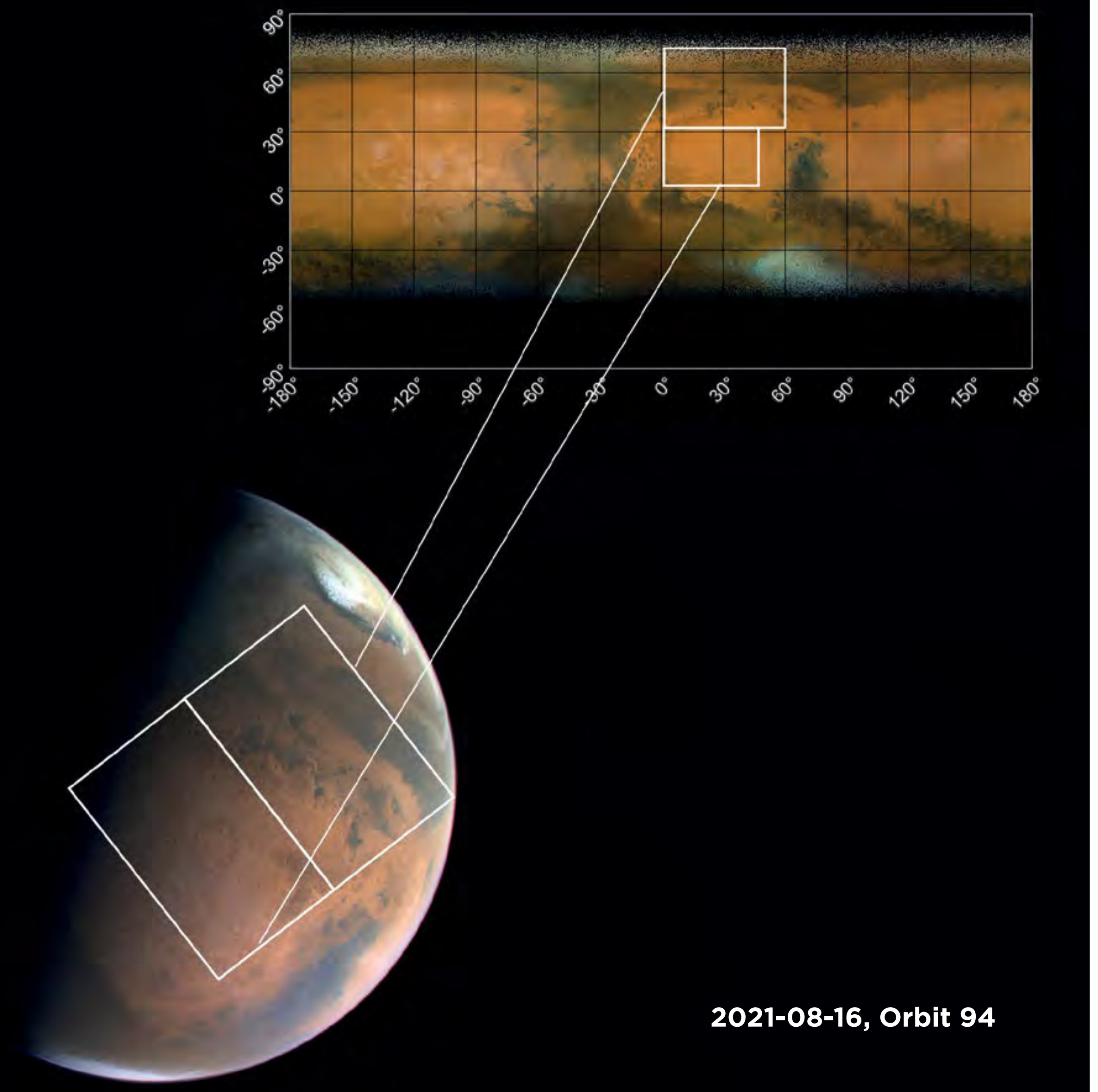
2 Arcadia

The Arcadia was named after a mountainous region in southern Greece. This quadrangle also contains a heavily cratered region called Tempe Terra with a highly fractured crust. Alba Mons, the largest volcano by the surface area and volume in the Solar System, is located here. Furthermore, several features such as gullies piqued interest in the area since they may have been caused by a relatively recent flow of water.



1 Diacria
2 Arcadia

ISMENIUS LACUS AND ARABIA QUADRANGLE



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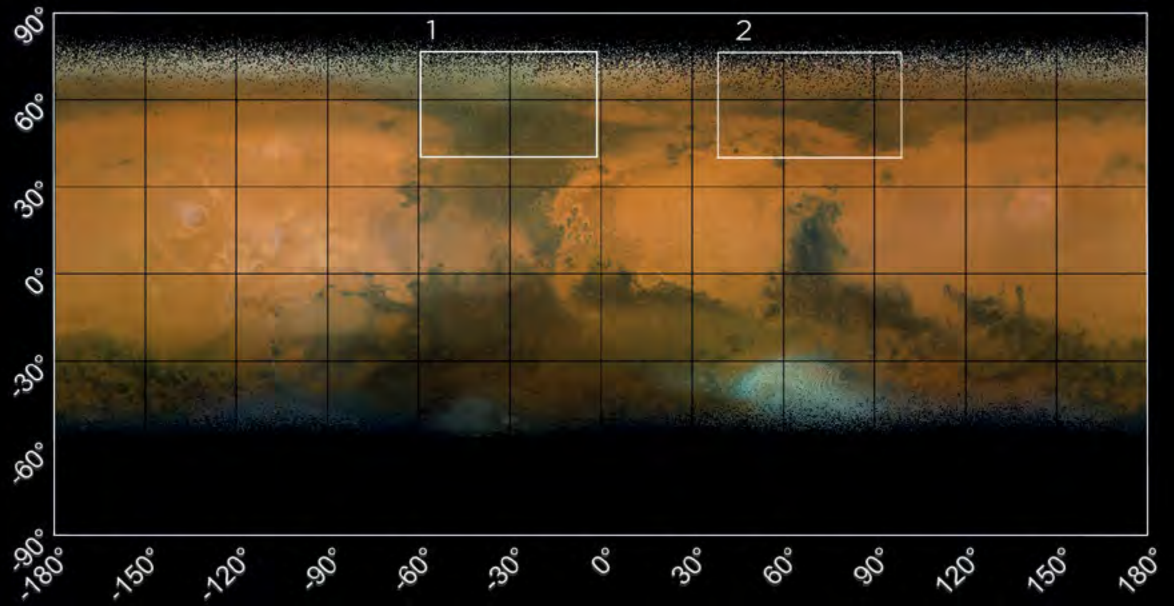
Ismenius Lacus
The origin of the name of the quadrangle comes from the Latin for the Ismenian Lake, which refers to springs close to Thebes in Greece. Ismenius Lacus can be found in the eastern hemisphere of Mars. This quadrangle contains segments of these plains: Acidalia Planitia, Arabia Terra, Vastitas Borealis, Terra Sabaea, Deuteronilus Mensae, and Protonilus Mensae. In the latter two regions, glaciers persist in the current times. Many channels have been found near Lyot Crater, which is the largest crater in the quadrangle.

Arabia
Italian astronomer Giovanni Schiaparelli named the region after the Arabian peninsula. The Arabia quadrangle lies in the northern hemisphere on the boundary of the northern lowlands and southern highlands. The quadrangle includes a part of Arabia Terra which is a large upland region. It also contains a part of Terra Sabaea and a small part of Meridiani Planum. The area is characterized by extensively cratered highlands, notably Cassini Crater in the northeast.

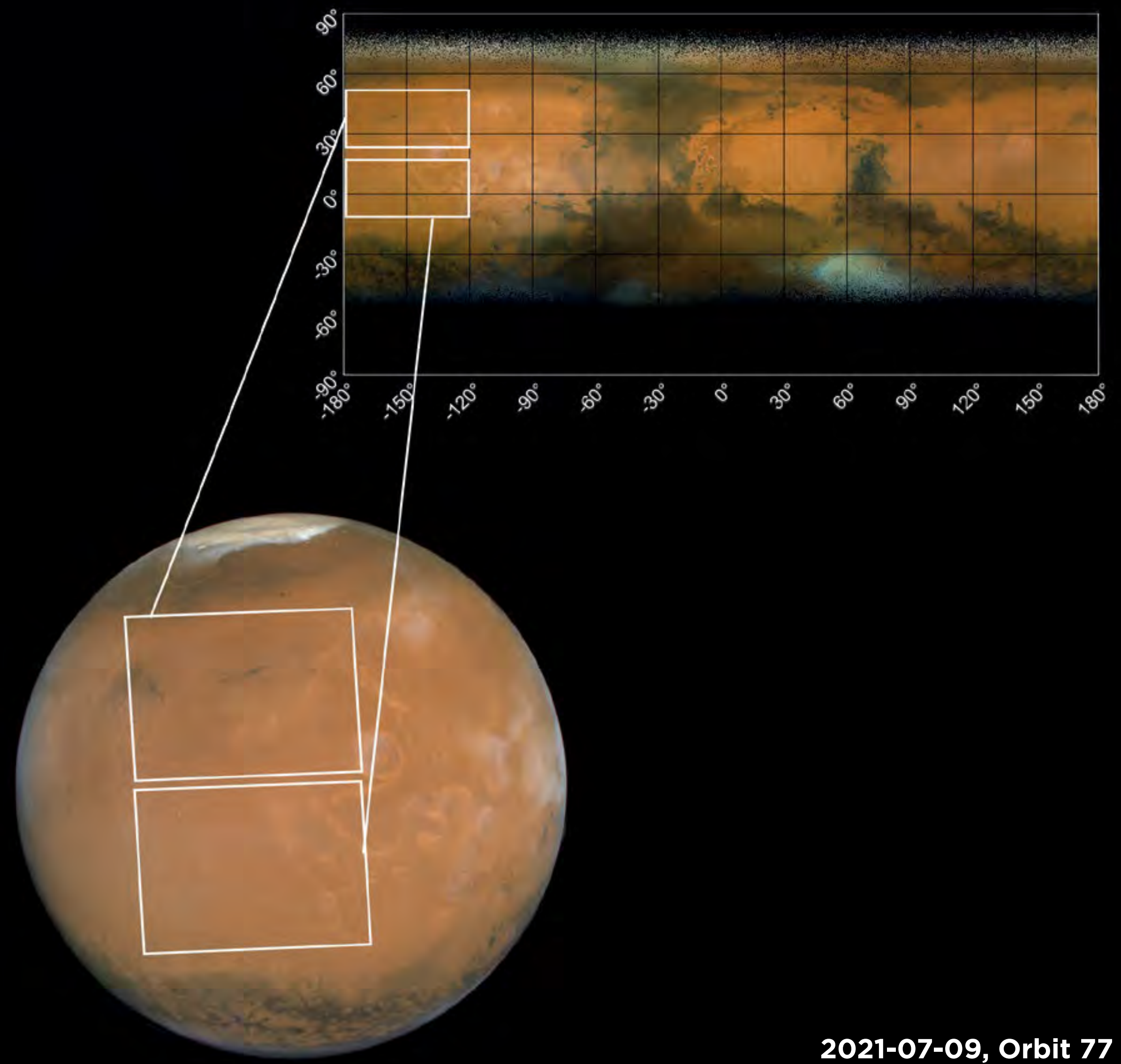
1 Mare Acidalium
This quadrangle is named after an ancient Greek well that, according to legend, was the location where Venus and the Graces bathed. The most prominent region of Mare Acidalium called Acidalia Planitia is located in the Acidalium quadrangle. The quadrangle also includes parts of Tempe Terra, Arabia Terra, and Chryse Planitia. It also contains borders between northern lowlands and southern lowlands that could signify the shore of an ancient ocean. Another important feature is a system of canyons, Kasei Valles, spanning 1,580 km in length. Bright spots in this location might represent mud volcanoes.

2 Casius
Patterned ground, scalloped topography, ring mold craters, and concentric craters imply the occurrence of ground ice in this high-altitude quadrangle. As such, Italian astronomer Giovanni Schiaparelli named the quadrangle Casius after an Ancient Egyptian mountain called Casius Mons. It was known by its coastal marshes in which armies have drowned. Casius is located in the Eastern hemisphere and it includes parts of Utopia Planitia and a small part of Terra Sabaea.



1 Mare Acidalium
2 Casius

AMAZONIS AND MEMNONIA QUADRANGLE



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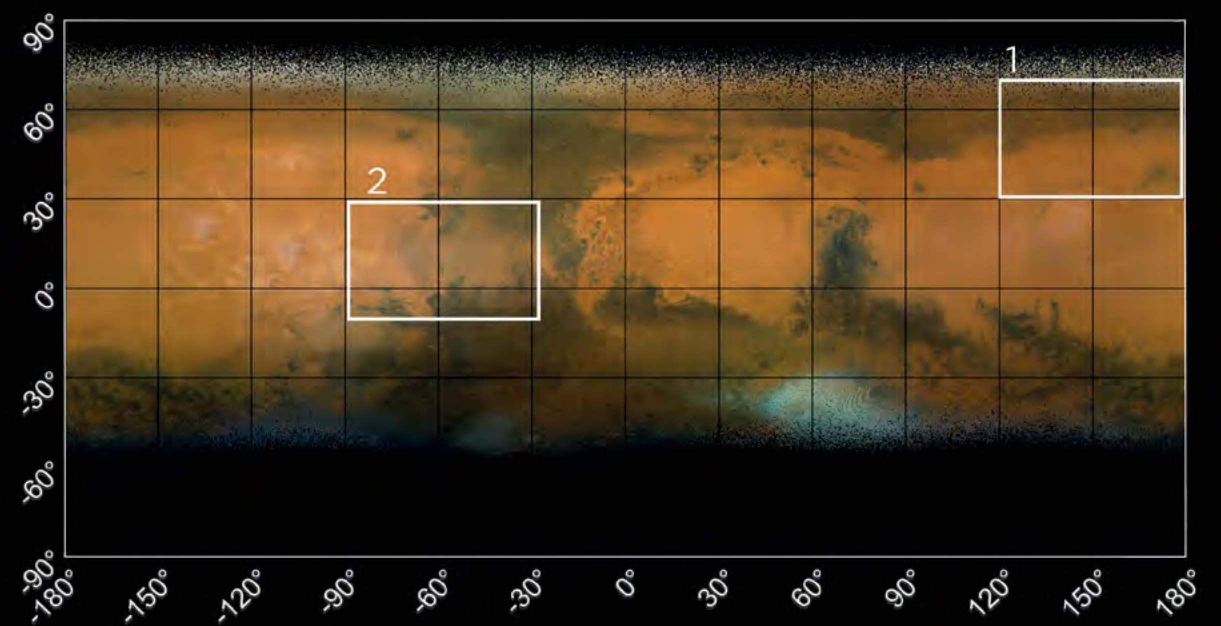
Amazonis
Amazonis Planitia, named after the Amazonian Epoch, is one of the youngest regions of Mars. Craters rarely occur in the Amazonis quadrangle. The Medusae Fossae Formation and Sulci are unique features found in this area.

Memnonia
quadrangle with several ancient river valleys like Mangala Vallis, Memnonia is a cratered highland terrain with varying degrees of crater degradation. The wall and floor of one of the more prominent features, Columbus Crater, were discovered to be made up of layered sedimentary rocks. It is believed that water may have been involved in deposition of these layers due to the presence of trace hydrated minerals.

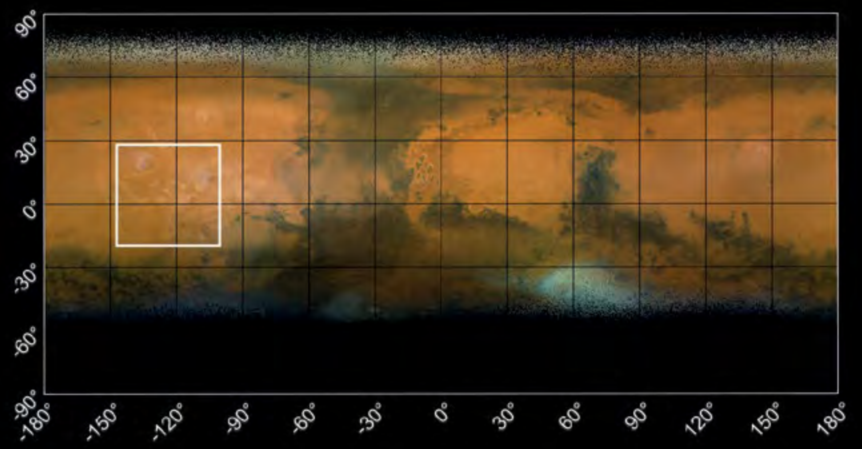
1 Cebrenia
Cebrenia, named after a country near ancient Troy, is located in the eastern hemisphere of Mars where parts of Utopia Planitia and Arcadia Planitia can be found. In 1976 Viking II landed near the most prominent crater in the region, Mie. Along with Mie, Crater Stokes, Volcano Hecates, and Phlegra Montes are distinctive features found in the mostly flat and smooth area.

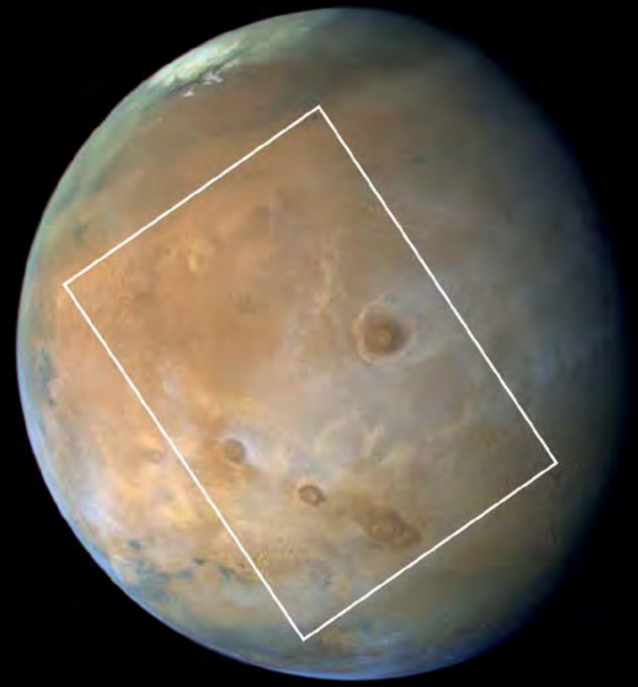
2 Lunae
This area was marked as the landing spot for Viking 1, the first spacecraft that touched ground on Mars in 1976.
The Lunae Palus quadrangle is well known for many valleys created by ancient rivers. Several plains extend into this area such as Lunae Planum, Xanthe Terra, and Chryse Planitia. Lunae Palus is contained here with its large outflow channel formed by liquid water.small part of Terra Sabaea.



1 Cebrenia
2 Lunae Palus

THARSIS QUADRANGLE





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The Tharsis is a biblical name for a land described in the Bible, near the historic town of Tartessus. It is located in the western hemisphere of Mars.

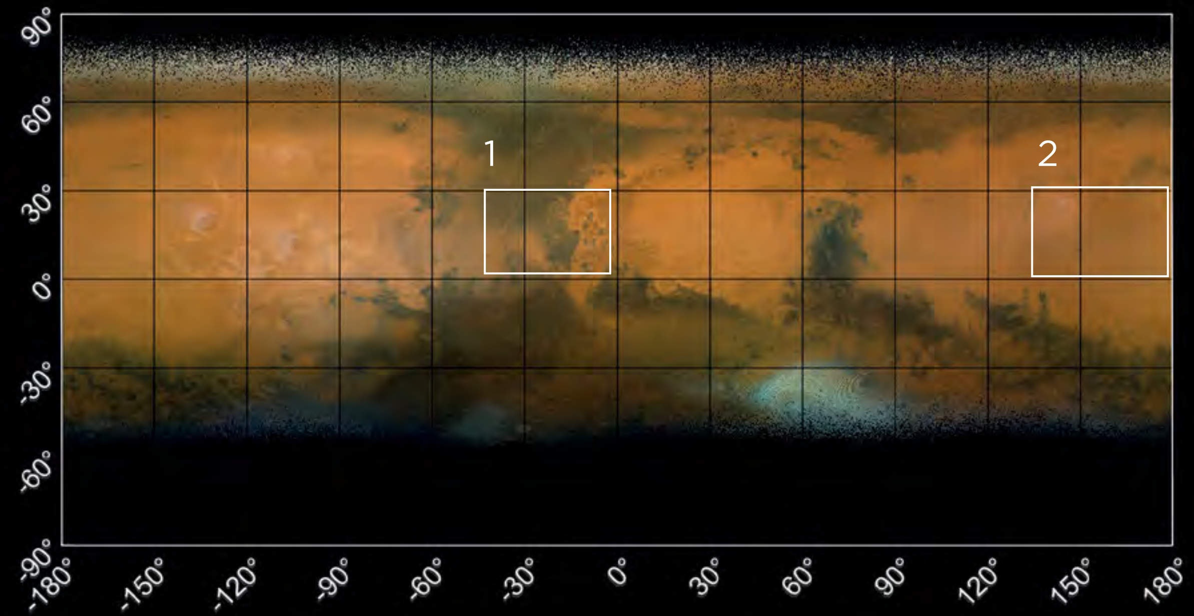
This region contains Tharsis rise, which is the birthplace of three of the four largest shield volcanoes on Mars: Olympus Mons, Ascraeus Mons, and Pavonis Mons. Another interesting feature is Ceraunius Fossae which is located in the north central part of the quadrangle.

1 Oxia

Oxia Palus includes several parts of different plains such as Chryse Planitia, Arabia Terra, Xanthe Terra, Margaritifer Terra, Meridiani Planum, and Oxia Planum. The Mars Pathfinder landed here in 1997. The mission analyzed the Martian atmosphere, climate, geology, and soil composition. The quadrangle is divided in two parts: the northwest contains smooth plains with outflow channels leading to Chryse basin, whereas the southeast region is peppered by several craters.

2 Elysium

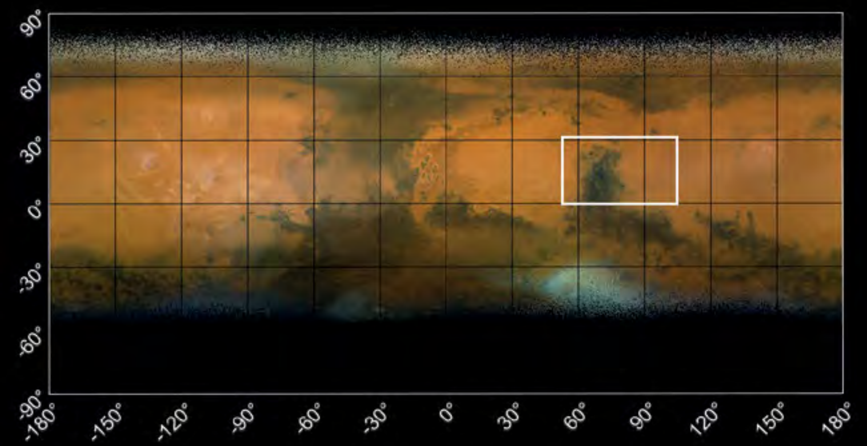
According to Homer's Odyssey, the word Elysium refers to the concept of a tranquil afterlife in Ancient Greek religious thought. Elysium quadrangle consists of several plains: the northern part contains Elysium Planitia, on the border a plain Lucus Planum, and a small portion of Medusae Fossae Formation. The InSight landed in 2018 in the south of Elysium to carry out geophysical research. In the quadrangle, large volcanoes Elysium Mons and Albor Tholus can be found. It is believed that Athabasca Valles is one of the youngest river valleys.

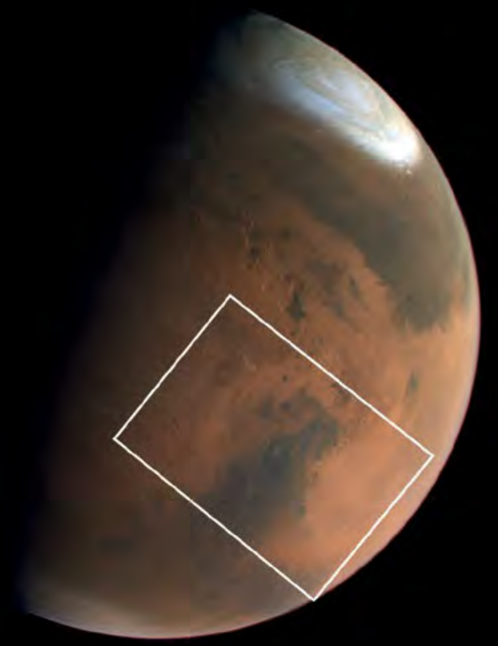


1 Oxia Palus
2 Elysium

2021-08-09, Orbit 91

SYRTIS MAJOR QUADRANGLE





2021-06-13, Orbit 66

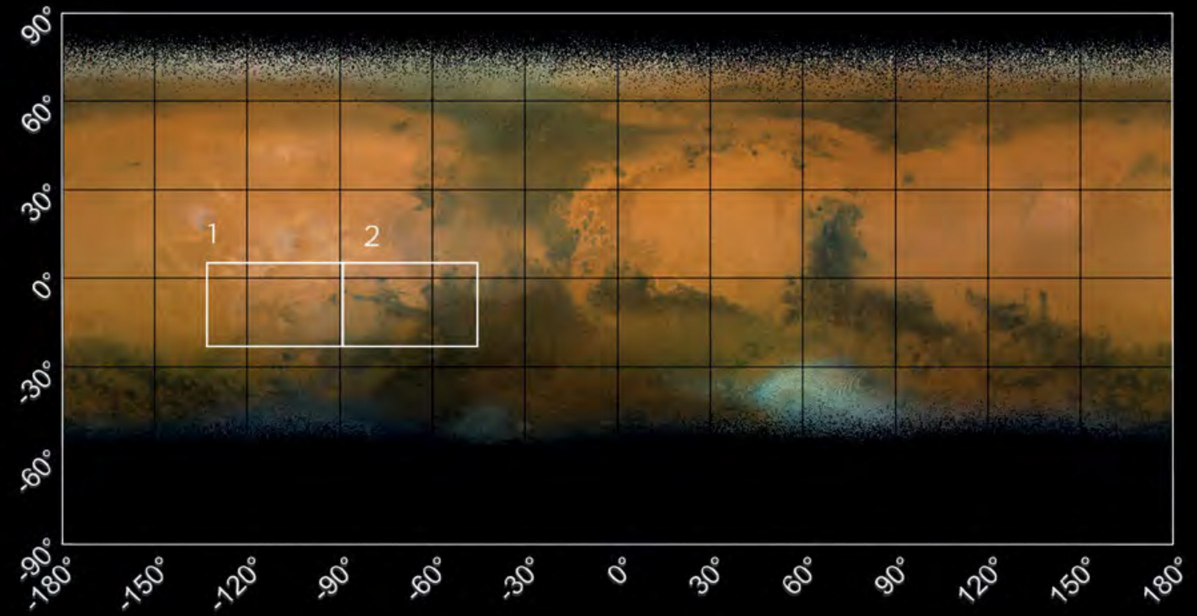
The quadrangle is named after a Latin translation for the Gulf of Sidra on the coast of Libya. Syrtis Major quadrangle consists of Syrtis Major Planum, and parts of Terra Sabaea and Isidis Planitia. It is a distinct dark region on the Martian surface. Distinctive features are calderas Meroe Patera and Nili Patera, The calderas' floors are unusual among major Martian volcanoes in that they are not raised over the surrounding topography. Mars 2020 rover (Perseverance and Ingenuity) landed at the Jezero crater in February 2021.

1 Phoenicis Lacus

Named after the mythical phoenix which regenerates cyclically by combusting and rising from the ashes, Phoenicis Lacus quadrangle is home to Tharsus rise region formed from lava flows containing major volcanoes like Pavonis Mons and Arsia Mons. Glaciers are thought to have once covered these volcanoes. It is highly likely that glaciers may still be present under thin layers of rocks. This glacier ice could serve as a supply of water for future settlement efforts on the planet. A vast intersecting system of canyons known as Noctis Labyrinthus is one of the quadrangle's most conspicuous features.

2 Coprates

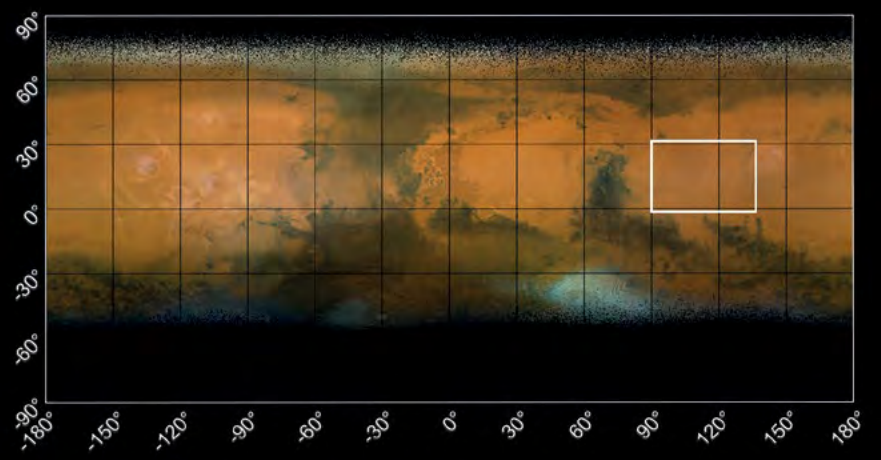
This quadrangle is named after a central trough of Valles Marineris called Coprates Chasma. The quadrangle is well-known for depicting the Valles Marineris Canyon System, also known as the "Grand Canyon of Mars." Water can also be found in this quadrangle, with ancient river valleys and stream channel networks visible as inverted terrain and lakes within Valles Marineris.

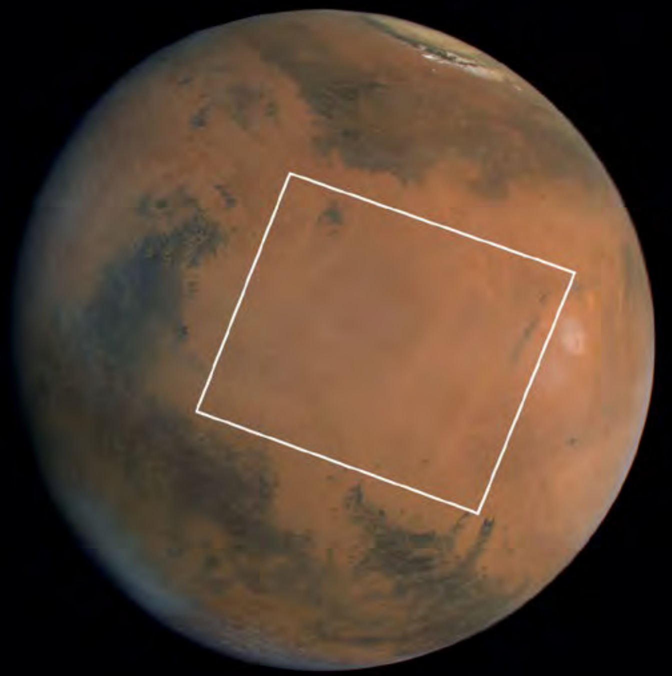


1 Phoenicis Lacus
2 Coprates

AMENTHES QUADRANGLE

Named after the Ancient Egyptian term for the location where souls of the deceased go, the Amenthes quadrangle contains Utopia Planitia, Isidis Planitia, Terra Cimmeria, and Tyrrhena Terra. Mars Reconnaissance Orbiter found traces of magnesium carbonate in the Isidis basin, which suggests the water was once present in the area was not acidic.

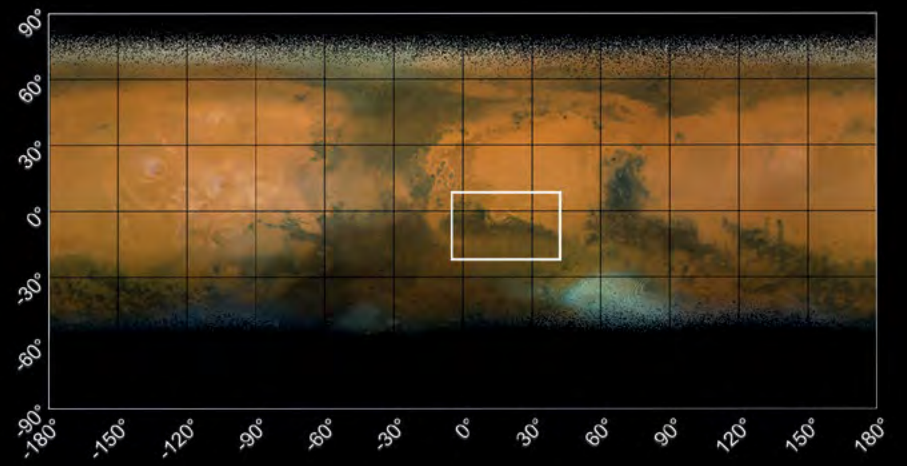


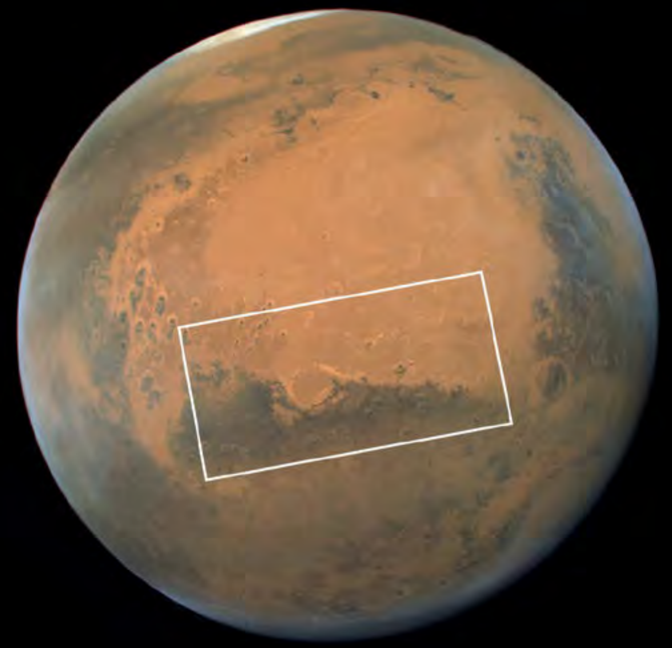


2021-08-02, Orbit 88

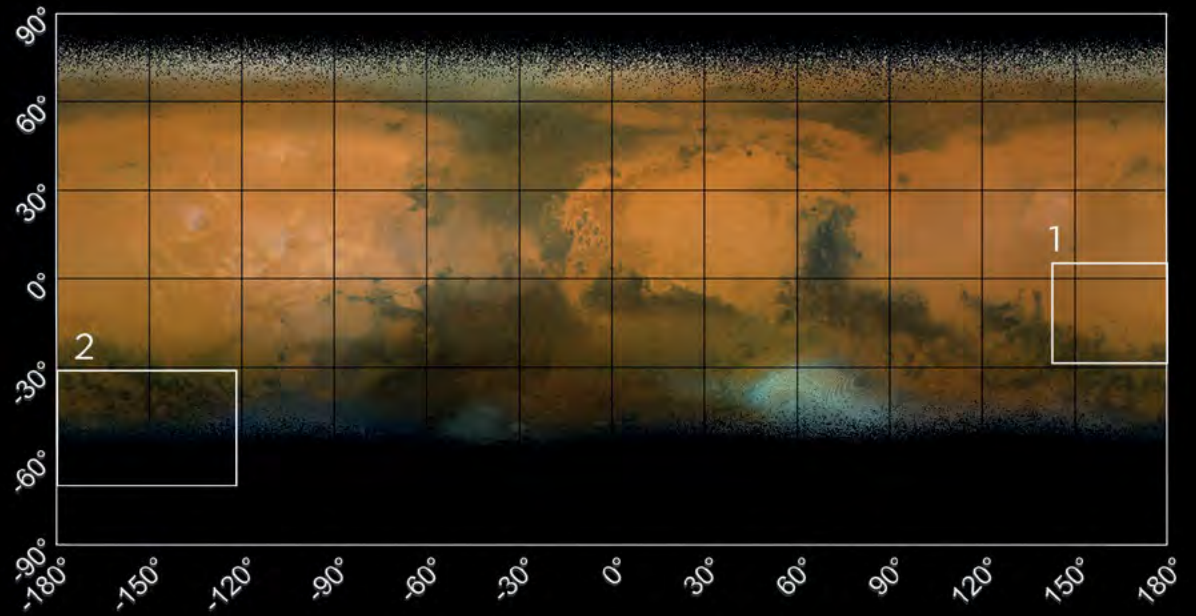
SINUS SABAEUS QUADRANGLE

The name derives from a region Southern Arabian Peninsula that is rich in incense (the Gulf of Aden). The quadrangle is home to Schiaparelli, a massive, plainly visible crater near the equator. Parts of Noachis Terra and Terra Sabaea make up the Sinus Sabaeus quadrangle.





2021-07-04, Orbit 75



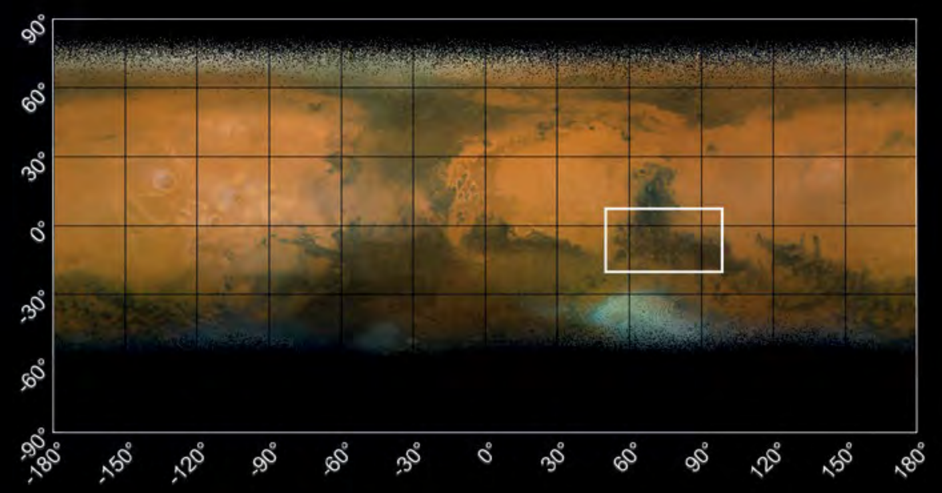
1 Aeolis
2 Phaethontis

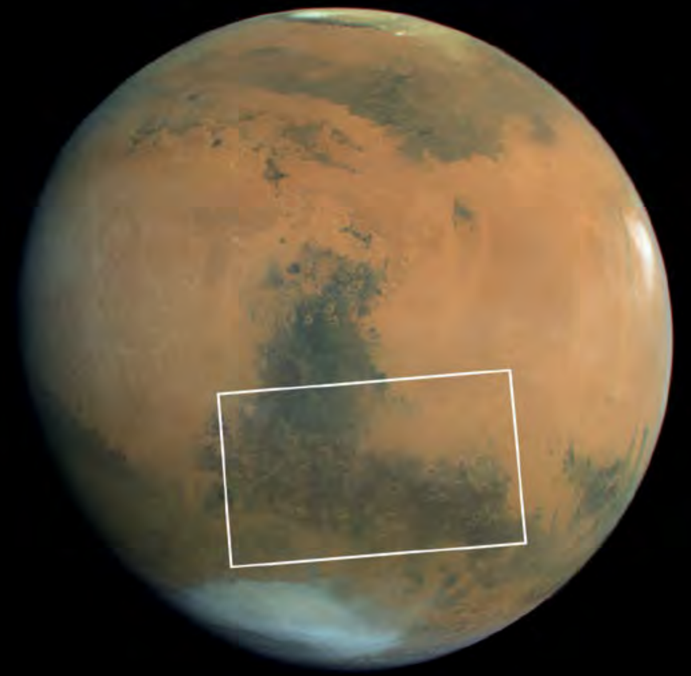
1 Aeolis
The name of this quadrangle is derived from the name of Aeolos, the ruler of the winds. This quadrangle is known for Gusev crater and Gale crater, famous as landing sites for Spirit rover and Curiosity rover respectively. Gusev Crater was thought to be an old lake bed because a vast, ancient river valley called Ma'adim Vallis is present at the southern rim. The lakebed sediments, however, appear to have been covered by a volcanic flow. Gale Crater, located in the northwest corner of the Aeolis quadrangle, is of particular interest to geologists because it features a 2–4 km high mound of stratified sedimentary rocks that NASA named "Mount Sharp" in honour of Robert P. Sharp, an early Mars planetary scientist.

2 Phaethontis
Named after the son of Helios, the Ancient Greek sun God, this quadrangle lies in an area with numerous networks of narrow channels known as gullies. It is home to Terra Sirenum which is known for having Iron and Magnesium smectites. The Electris deposits, which are 100–200 metres thick, are located in part of this quadrangle. They have a light tone to them and appear to be weak due to the presence of a few rocks.

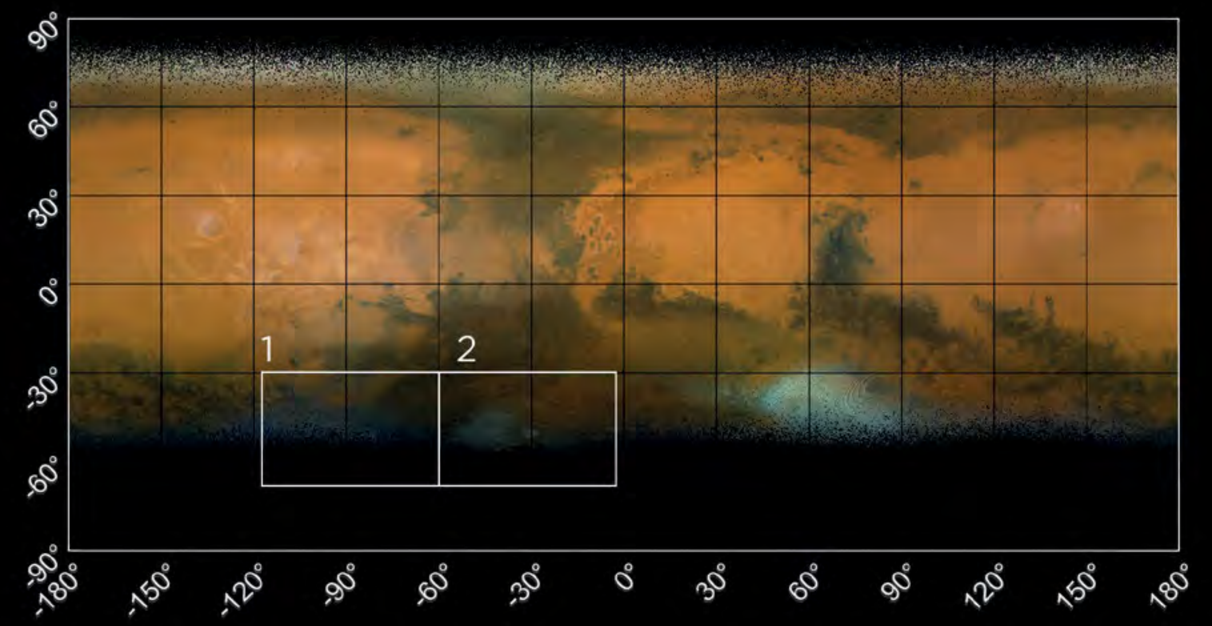
Iapygia
This quadrangle contains the areas of the Tyrrhena Terra and Terra Sabaea regions. Huygens is the quadrangle's biggest crater. Dikes, sheets of rock formed in a fracture of a pre-existing rock body, carbonates on the rim of Huygens and the strata formed as a result are quadrangle's most intriguing features.

IAPYGIA QUADRANGLE





2021-08-14, Orbit 93



1 Thaumasia
2 Argyre

1 Thaumasia

The quadrangle gets its name from Thaumas, an ancient Greek sea God. It has parts of Solis Planum, Icaria Planum, Aonia Terra, Aonia Planum, Bosporus Planum, and Thaumasia Planum. Early orbiters identified one of the first significant networks of stream channels in this quadrangle, known as Warrego Valles. The presence of these channels etched into steep hillsides is another evidence of water.

2 Argyre

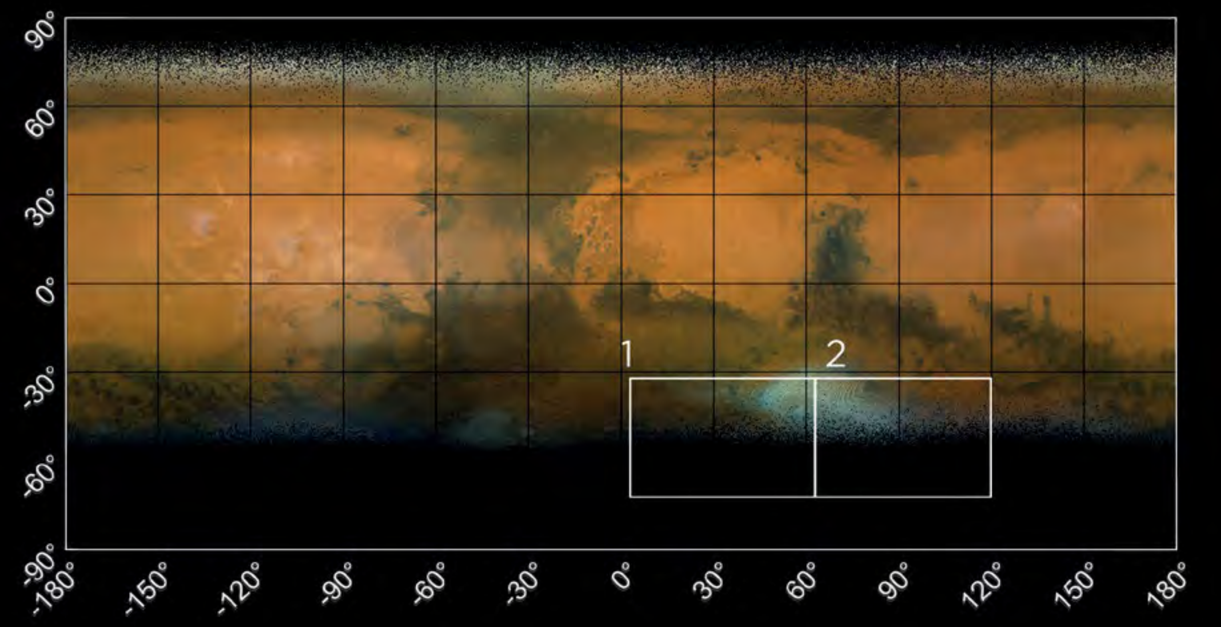
The quadrangle is named after an island at the mouth of Ganges river in the Indian ocean. Galle crater, which resembles a smiley face, and the Argyre basin, a massive impact crater, are both located in this quadrangle. According to research, hot ejecta landing on ice-covered ground causes pits in Hale Crater. The pits are generated by heat creating steam that rushes out of multiple pits at the same time, blowing the ejecta away.

1 Noachis

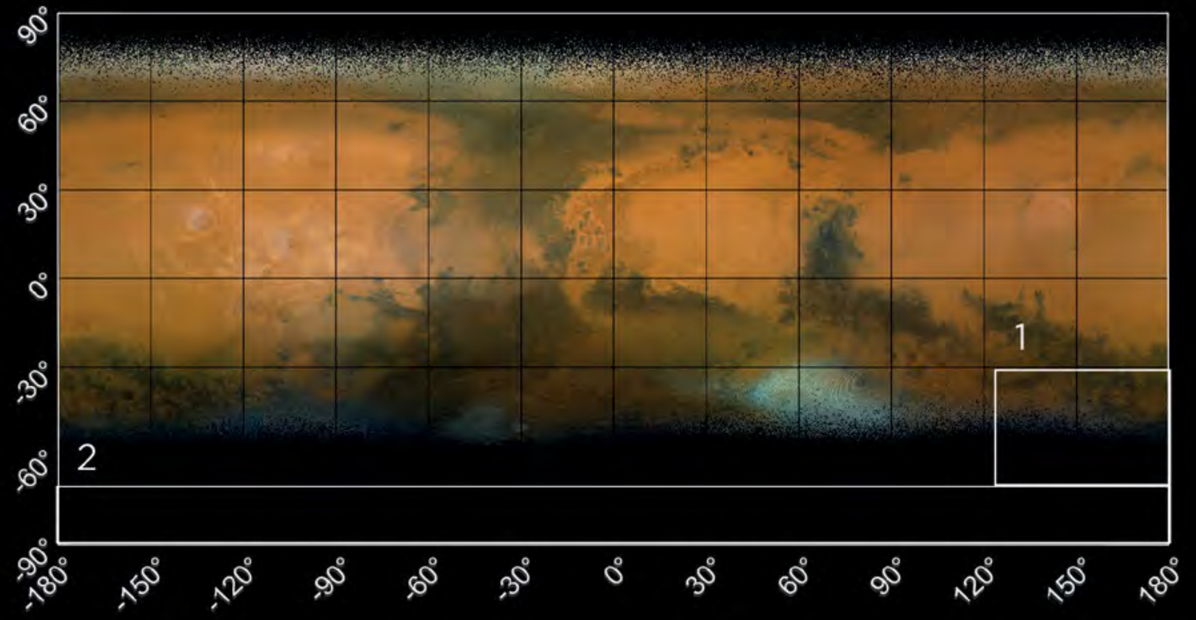
The quadrangle is located between the Argyre and Hellas impact basins on Mars. Noachis Terra and the western half of Hellas Planitia make up the Noachis quadrangle. It is thickly studded with impact craters, making it one of Mars' oldest landforms—hence the name "Noachian" is given for one of the planet's earliest periods of history. Furthermore, numerous previously buried craters are suddenly surfacing, thanks to Noachis' extraordinary age, which has allowed ancient craters to be filled and re-exposed.

2 Hellas

The iconic features Hellas Planitia and Promethei Terra are located inside the Hellas quadrangle. The Hellas quadrangle contains the massive river valleys Dao Vallis, Niger Vallis, Harmakhis, and Reull Vallis, all of which may have contributed water to a lake in the Hellas basin in the distant past. Many areas in the Hellas quadrangle, particularly those with glacier-like flow characteristics, display evidence of ice in the ground.



1 Noachis
2 Hellas



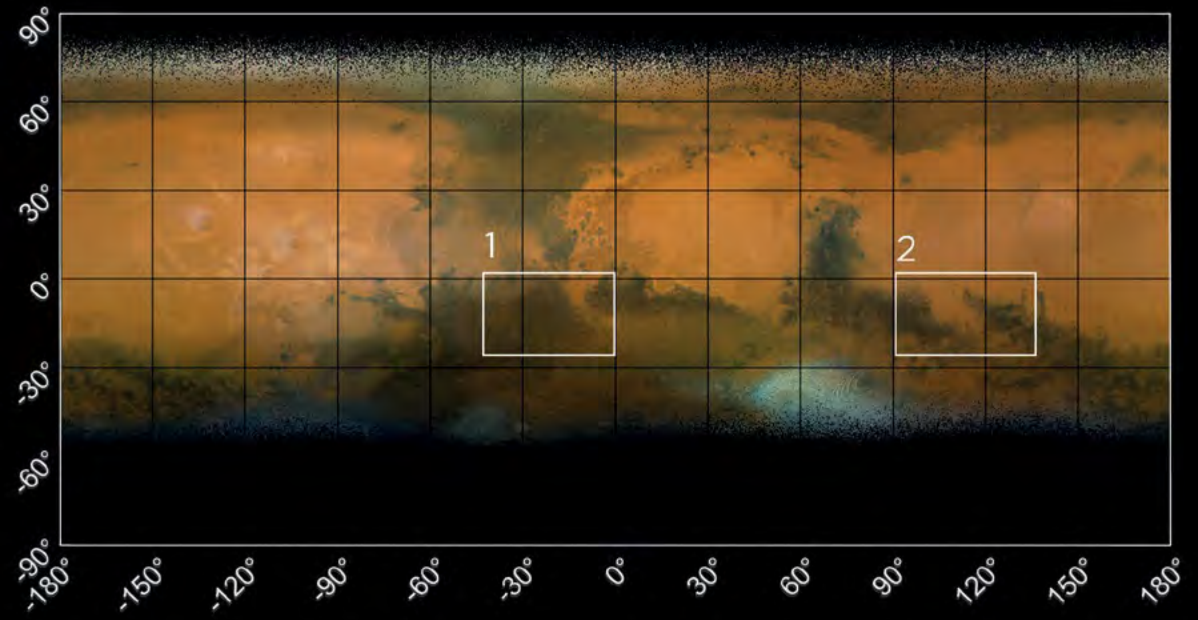
1 Eridania
2 Mare Australe

1 Eridania
This quadrangle contains the majority of the classic Terra Cimmeria region. The Eridania quadrangle is covered by a 100–200 metre thick, light-toned deposit that is part of the Electris deposits. Gullies can be found on many slopes in Eridania, and they are thought to be caused by flowing water.

2 Mare Australe
The name of the quadrangle comes from an ancient name for the Planum Australe, a wide plain that surrounds the polar cap. It is possible that Dorsa Argenta, a part of this quadrangle, is an old ice-rich deposit . It has a series of sinuous, branched ridges that look like eskers, which occur when streams run beneath glaciers. Angustus Labyrinthus, a complex of connecting valleys or ridges nicknamed the “Inca City,” is also located inside the quadrangle.

1 Margaritifer
This quadrangle’s name means pearl bay and is named after the pearl coast at Cape Comorin in South India. Margaritifer Terra, as well as parts of Xanthe Terra, Noachis Terra, Arabia Terra, and Meridiani Planum, make up this quadrangle. Many signs of historical water sources may be found in this quadrangle, including evidence of lakes, deltas, old rivers, inverted channels, and chasms regions that released water. Because of a wetter environment, greater groundwater, or a combination of factors, Margaritifer Sinus has some of the longest lake-chain systems on Mars like Samara/Himera and Parara/Loire lake-chain systems.

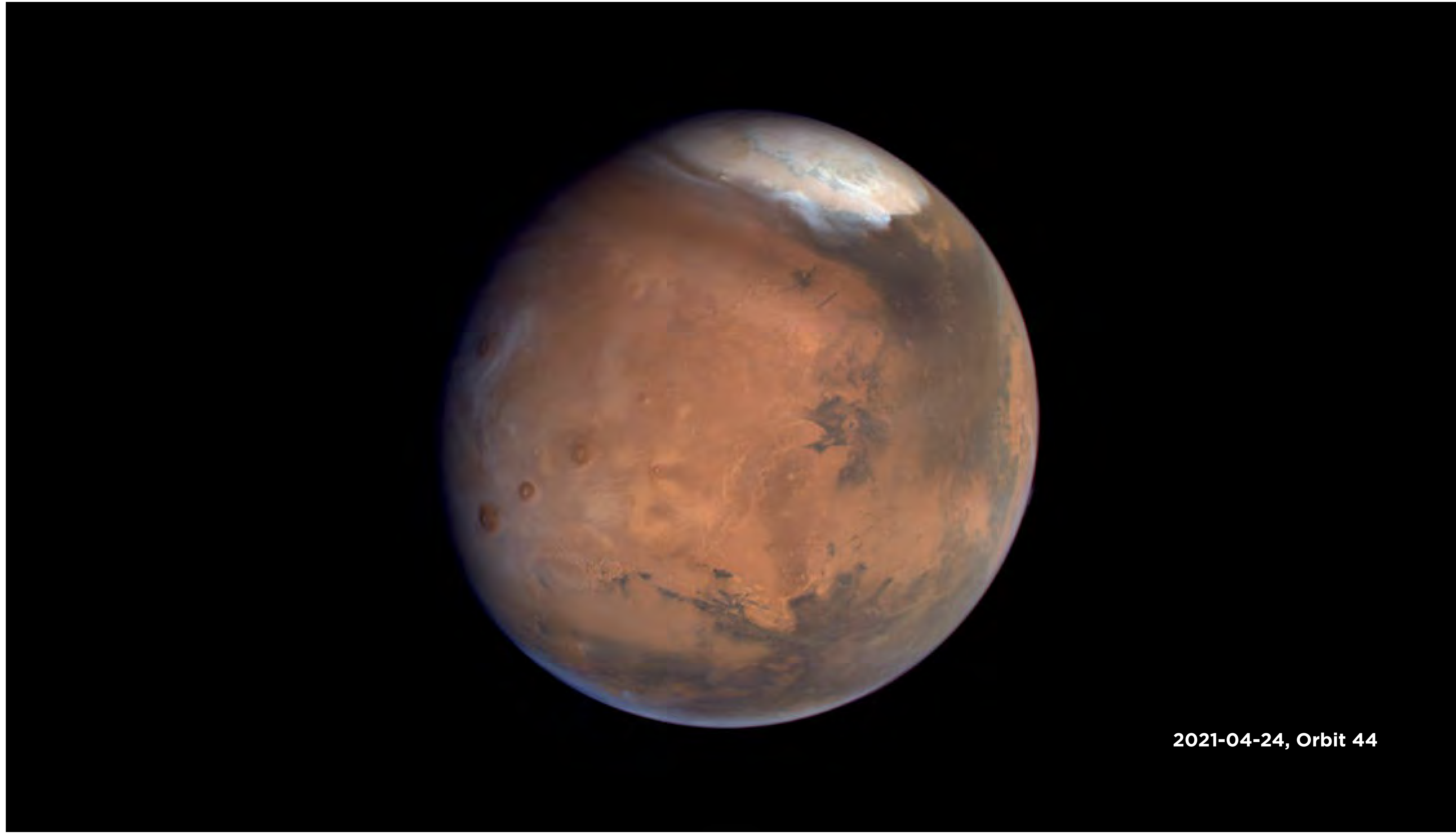
2 Mare Tyrrhenum
This quadrangle was named by Italian astronomer Giovanni Schiaparelli after the Tyrrhenian sea off the western coast of Italy. It is home to the massive volcano Tyrrhenus Mons, which is one of Mars’ oldest and most complicated volcanoes, and Herschel, which is Mare Tyrrhenum’s largest crater. Other notable features in this area include Licus Vallis and the Ausonia Montes.



1 Margaritifer Sinus
2 Mare Tyrrhenum

PLANUM BOREUM (NORTH POLE)

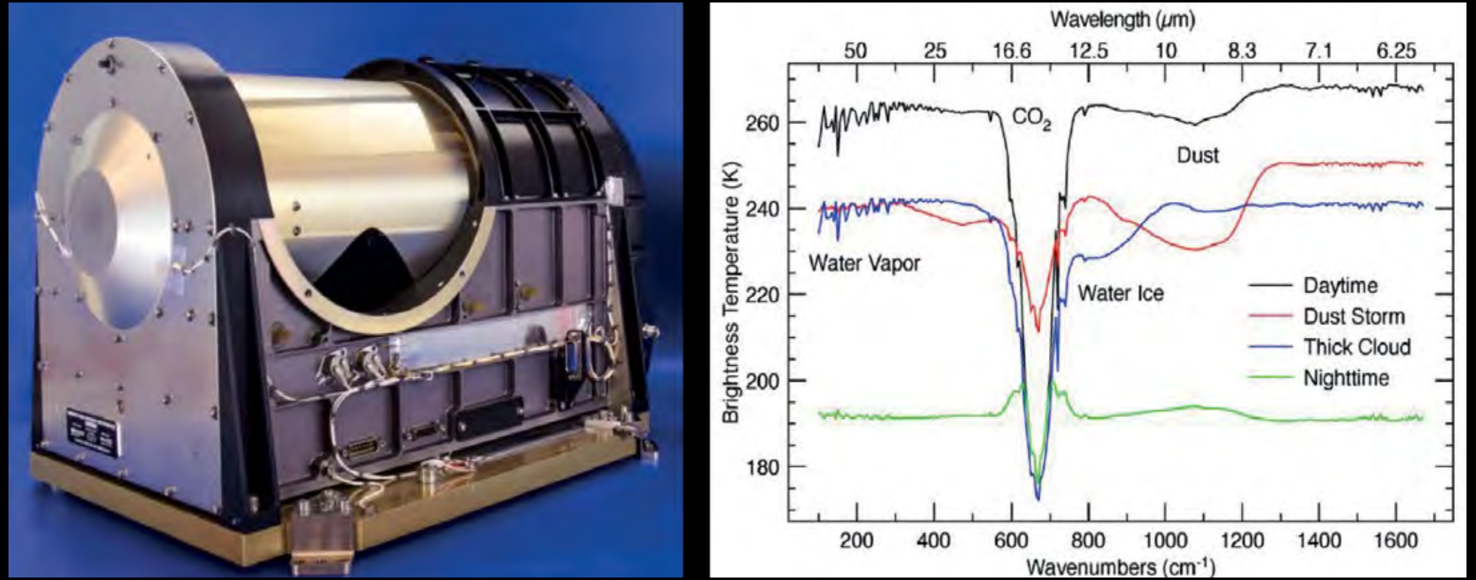
A flat and featureless lowland plain known as Vastitas Borealis surrounds the high polar plain, extending for approximately 1,500 kilometres southwards. It dominates the northern hemisphere. The Chasma Boreale, a wide rift or canyon in the polar ice cover, is the Planum Boreum's most prominent feature. It stretches for up to 100 kilometres and has 2 kilometer-high scarps.



2021-04-24, Orbit 44

07

EMUS (ULTRAVIOLET) AND EMIRS (INFRARED) OBSERVATIONS



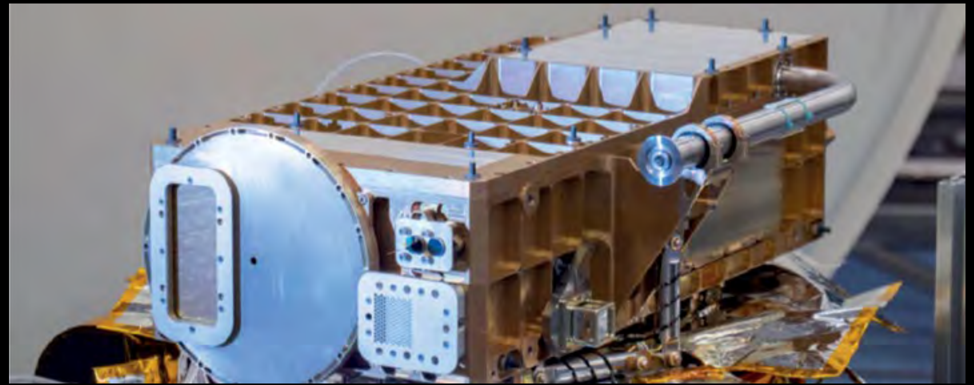
The EMIRS instrument (left) and its synthetic spectra (right)

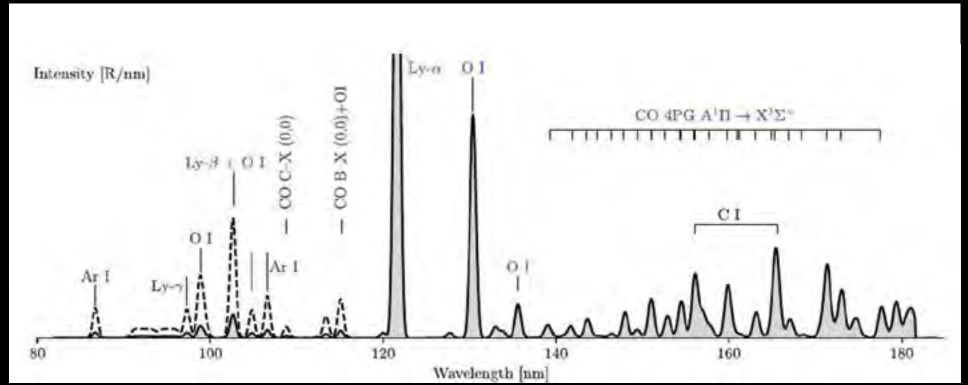
(Source: Edwards et. al. 2021)

EMIRS: EMIRATES MARS INFRARED SPECTROMETER

The Emirates Mars InfraRed Spectrometer (EMIRS) is a Fourier-Transform InfraRed (FTIR) spectrometer designed to operate in the 6.0-100+μm range with 5 cm−1 and 10 cm-1 spectral sampling. EMIRS achieves a balance between coverage and performance requirements with an instantaneous field of view of~5.4 mrad, allowing highly accurate temperature measurements with an uncertainty of < 2K for surface temperatures. EMIRS observations complement EXI in characterizing the lower atmosphere of Mars in addition to providing Mars surface and atmospheric temperature profiles with a vertical resolution of ~ 10 km. EMIRS observations serve the following science objectives:

I. Determination of the 3-D thermal state and diurnal variability of the lower atmosphere (up to 50km).
II. Determination of the geographic and diurnal variability of the key constituents of the lower atmosphere (up to 50km) such as dust, water ice, water vapour, and carbon dioxide (CO_2).





The EMUS instrument (left) and its synthetic spectra (right)
(Source: Holesclaw et. al. 2021)

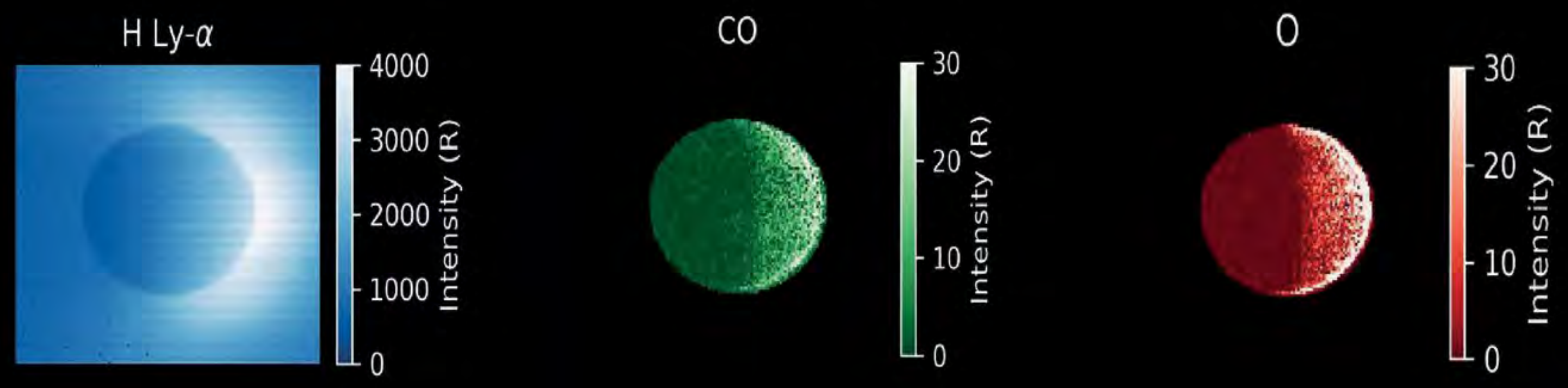
EMUS: EMIRATES MARS ULTRAVIOLET SPECTROMETER

The Emirates Mars Ultraviolet Spectrometer (EMUS) is an imaging far-ultraviolet (FUV) spectrograph that will measure the variability of the Martian upper atmosphere. EMUS has a spectral range of 100–170 nm with multiple slit positions for to provide spectral resolutions of 1.3 nm and 1.8 nm. EMUS observations are designed to cover to broad regions of Mars' atmosphere. It will measure UV dayglow observations of emissions from hydrogen, oxygen, and carbon monoxide from the thermosphere, or the layer of the atmosphere with an altitude of between 100-200 km.

It also measures bound and escaping hydrogen, and oxygen from the exosphere, or the layer of the exosphere higher than 200Km. EMUS observations contribute to these scientific investigations:

I. Determination of the abundance and, spatial and temporal variability of the key neutral species (H, O, CO) in the thermosphere.
II. Determination of the 3-D structure and temporal variability of H and O in the exosphere.

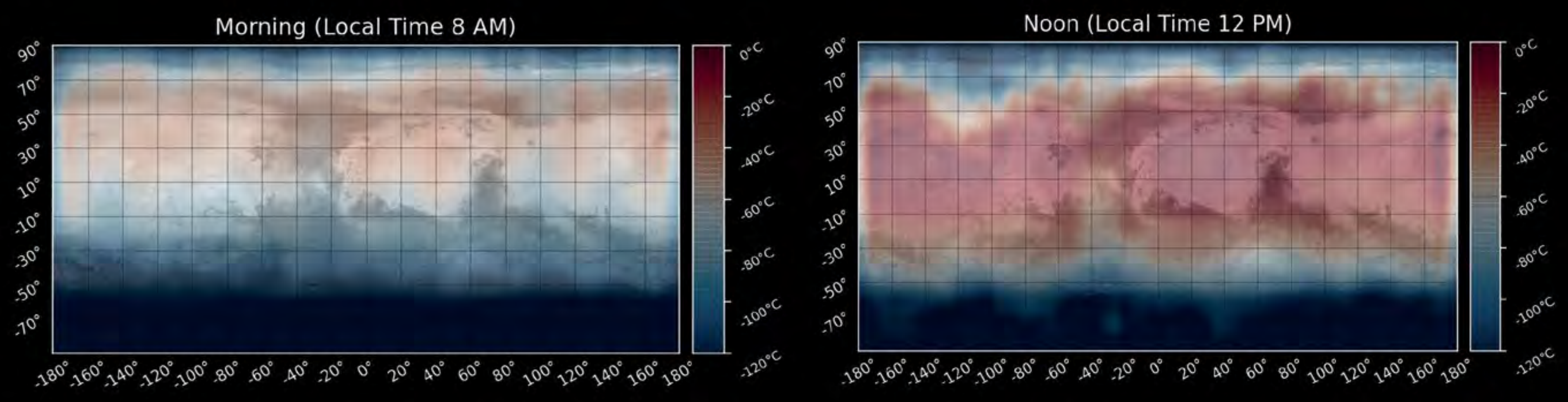
EMUS MARS UV DAYGLOW ON APRIL 24, 2021



EMM/EMUS measurements of UV dayglow emissions from hydrogen (H), oxygen (O) and carbon monoxide (CO) revealing their spatial structure within the Mars' thermosphere and inner exosphere.

EMIRS AVERAGE MARS SURFACE TEMPERATURES FOR JULY 2021

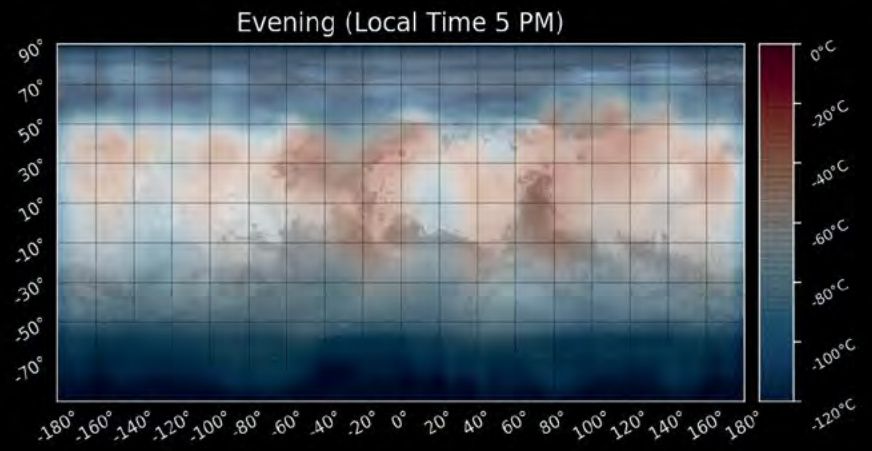
The following plots show the Martian temperature varies throughout the day across the entire planet

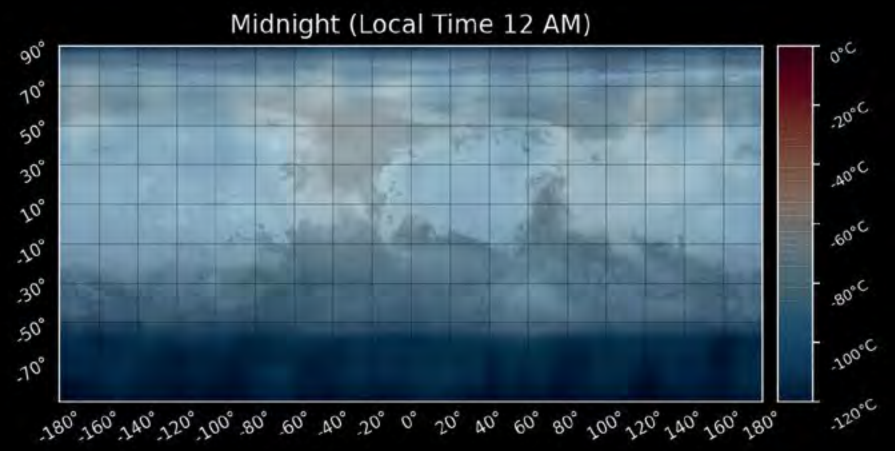


Note: This is the nominal temperature obtained from EMIRS L2 data

EMIRS AVERAGE MARS SURFACE TEMPERATURES FOR JULY 2021

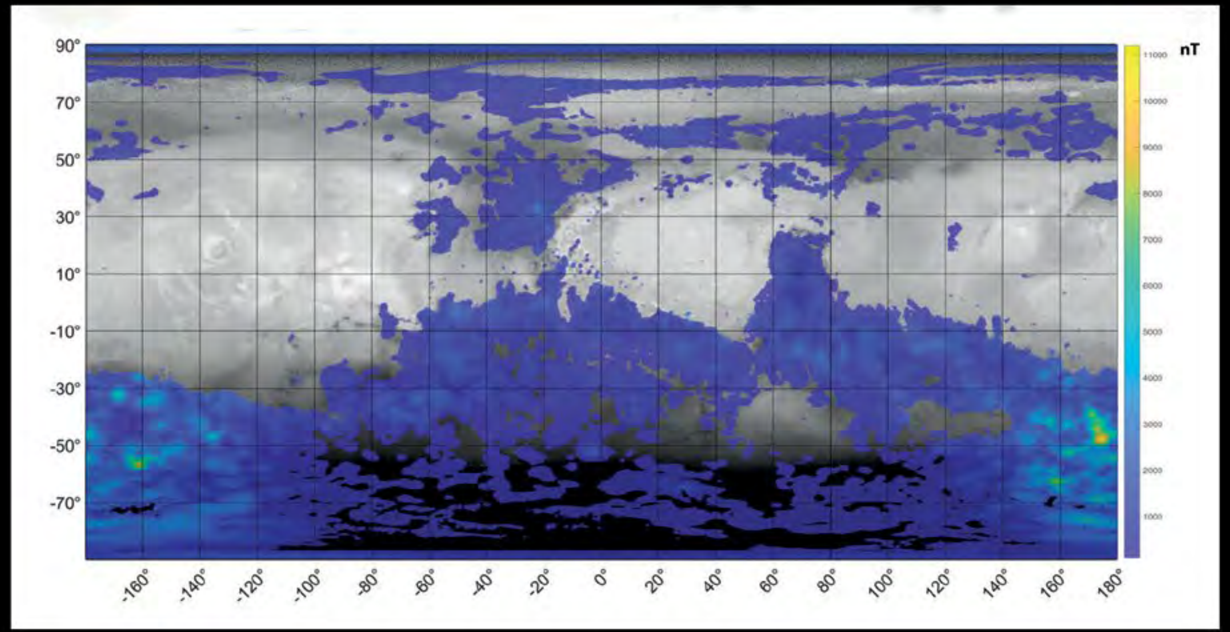
The following plots show the Martian temperature varies throughout the day across the entire planet





Note: This is the nominal temperature obtained from EMIRS L2 data

SURFACE MAGNETIC FIELD



Surface magnetic field predictions at 4 pixels/degree calculated using Langlais et al. 2019, regions where the predicted field is below 250nT are excluded. Background is the global map generated using EXI images.

08

GLOBAL MAPS METHODOLOGY

METHODOLOGY: ROBINSON PROJECTION

In this method we currently only utilize EXI images that are at a high enough altitude to show a full disc of Mars. Those images are then manually sorted into three categories; visibility of the full disc, visibility of half or more of the disc, and visibility of less than half of the disc; an illustration of these three categories is shown below. The team followed up by discarding category three images and proceed by extracting the latitude, longitude, and the pixel reading value for categories one and two images at zero height. To process the images, we begin by scaling the range of pixel values of each image individually to between 0 and 1, this allows us to have a standardized range across all images that limits the effects of altitude on reading value. Starting with category one images we apply the following constraint on the pixel value reading to attempt to discard any overexposed or poorly lit features on the planet. Similarly, the following constraint is applied to category two images, however the bottom bound is greater since a greater section of the disc isn't visible. These values are in no means the perfect bounds and can be modified further to improve performance.

To visualize our map, we decided to go with the Robinson projection over the cylindrical projection because it provides a more accurate representation of feature sizes at latitudes away from the equator. To achieve this, we converted our latitude and longitude coordinates into the Robinson projection using the following equations:

$x=0.8787RX(\lambda-\lambda 0)$ $y=1.3523RY$

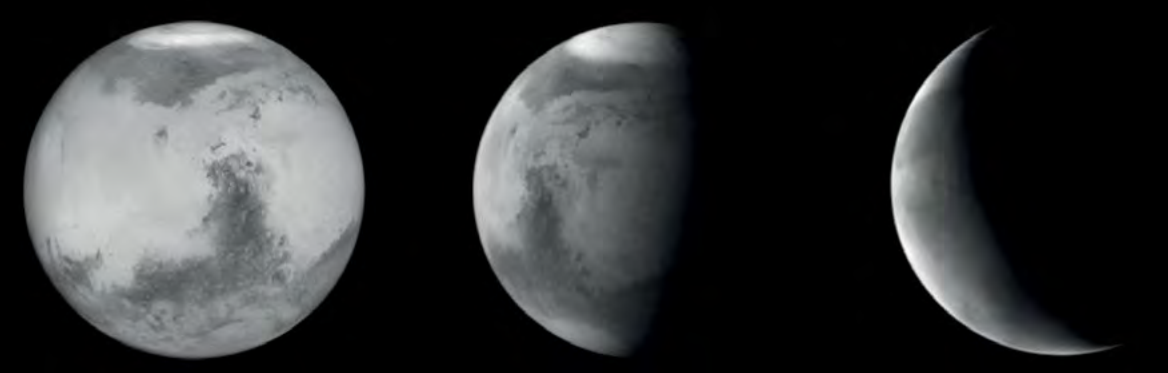
(Source: Ipbuker, C. 2005)

where R is the radius of Mars at map scale, X and Y are Robinson projection indexes, λ is the longitude in radians, and λ 0 is the map's central meridian in radians.

Upon obtaining the x, y, and the pixel values we begin generating the map by assigning each coordinate with its corresponding value. In the case where two readings have the same coordinates they are added together and simultaneously an index map is being made that records the number of pixels contributing to each coordinate. Upon completion of the map, each coordinate value is then divided by the corresponding index value of the number of contributing pixels to find an average.

This methodology works on the premise that you have enough pictures of Mars to have multiple readings of the same geographic location at different altitudes and viewing angles to allow for an ac expected that with more images the map quality and the cohesiveness of its pixels will improve.

AN ILLUSTRATION OF CATEGORIES ONE, TWO AND THREE USING EXI F635 RED CHANNEL IMAGES



Category 1: 0.1<Pixel value<0.9
Category 2: 0.5<Pixel value<0.9

METHODOLOGY: CYLINDRICAL PROJECTION

In order to generate a global map of Mars we began by transforming data from the EXI images to a planar 180°x 360° map. This is performed by utilizing the latitude and longitude coordinates assigned to each pixel of the f635, f546, and f437 (the red, green, and blue) channels respectively. We ensure these pixels are at zero height to make sure that they lie in the planet's disc and not dark space. The results of this process are illustrated in the figure below.

Mars' disc isn't always fully visible due to the position of the planet with respect to the sun, and so an additional data processing step was added to only utilize pixel values that are within the solar zenith angle range SZA of 23° to 55°. This range was determined based on observations made on a sample of 20 images to diminish the presence of dark/overexposed pixels.

Raw Image

Planar View

SZA Constraint

Map of Combined Images

Upon transforming all images to a planar map, we realized that the variation in altitude and SZA from one EXI image to another is easily noticeable in terms significant differences in brightness and feature definition, making it evident where data from one image ends and the other one begins. To correct for these variations across images, the following methods described below were used:

Method 1: Machine learning
We calculated the percentage overlap between two images covering the same geographic location.
Using this overlap region, we train a neural network machine to generate a correcting model that can predict the corrected pixel values of non-overlapping pixels using the training performed on the overlap region.

Method 2: Fine Pixel Stitching
We divided our map into sets of 2x2 pixel squares where all four pixels were from the same image. We then started an iterative process where pixels from neighboring square sets are compared to determine a multiplying factor that would adjust the brightness of square two to match that of square one without losing fine details.

ACKNOWLEDGEMENTS

We thank the entire team of the Emirates Mars Mission for providing us with these observations. All data was obtained from the EMM Science Data Center (SDC). This work was supported by the New York University Abu Dhabi (NYUAD) Institute Research Grant G1502 and the ASPIRE Award for Research Excellence (AARE) Grant S1560 by the Advanced Technology Research Council (ATRC). Image processing was done on High Performance Computing (HPC) resources of NYUAD. We thank Professor K. R. Sreenivasan for his constant encouragement and support for the project.