life on mars

what to know before we go

david a. weintraub

So much nonsense has been written about the planet … that it is easy to forget that Mars is still an object of serious scientific investigation.

Canadian astronomer Peter M. Millman, in
“Is There Vegetation on Mars,” *The Sky*, 3, 10–11 (1939)

Tentative Course outline

- Today: Intro to Mars, Early discoveries about Mars (Chapters 1-4)
- Oct 17: Canals on Mars, Water on Mars (Chapters 5-8)
- Oct 24: Lichens on Mars (Chapter 9)
- Oct 31: Viking mission (Chapter 10)
- Nov 7: ALH 84001 (Chapter 11)
- Nov 14: Methane on Mars (Chapters 12-15)

Earth and Mars

Basic Facts

<u>Earth</u>

- 93 million miles from sun
- Diameter: 7,918 miles
- Orbit: 365.25 days
- Solid surface
- Thin atmosphere
- 1 big moon

<u>Mars</u>

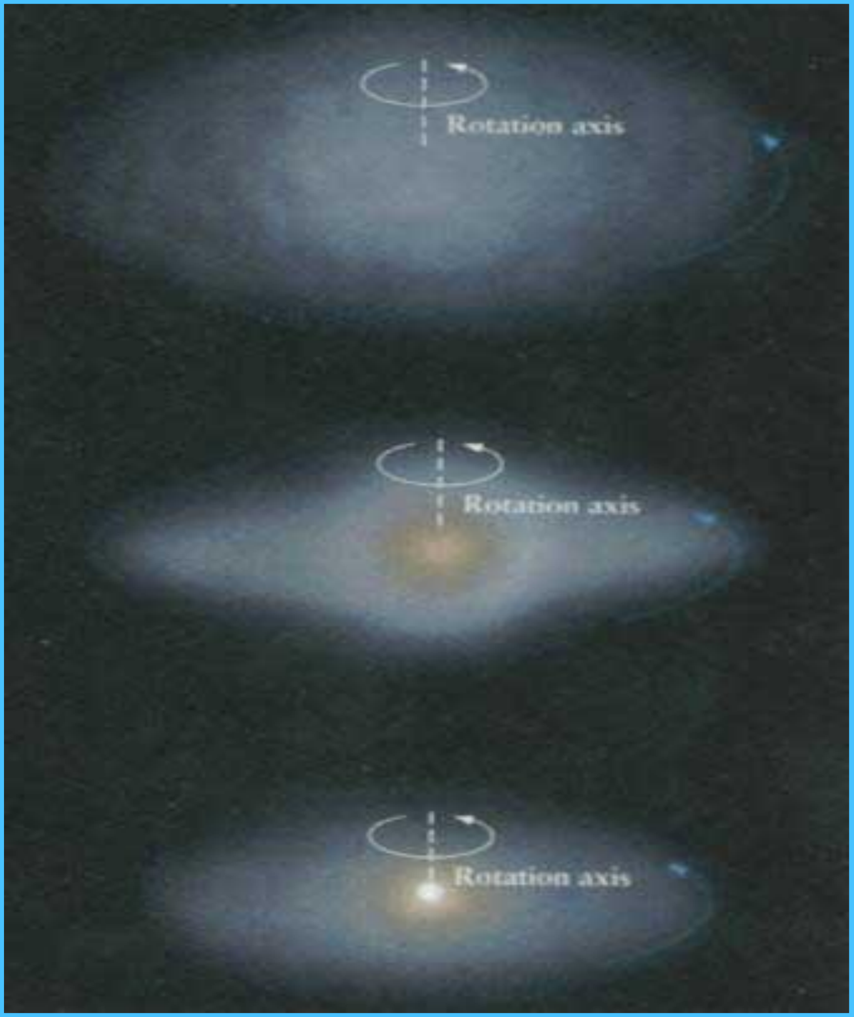
- 142 million miles from sun
- Diameter: 4,212 miles (53% of Earth)
- Mass: 10.7% of Earth
- Orbit: 687 days
- Solid surface
- Thin atmosphere
- 2 little moons

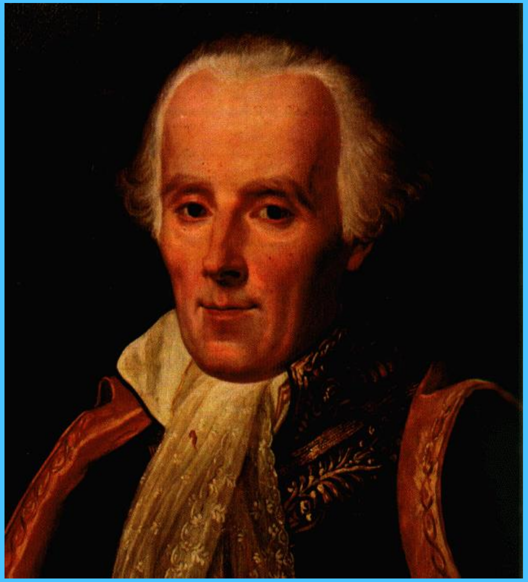
Basic Facts about Earth and Solar System

- Sun and planets formed at same time

The Nebular Hypothesis

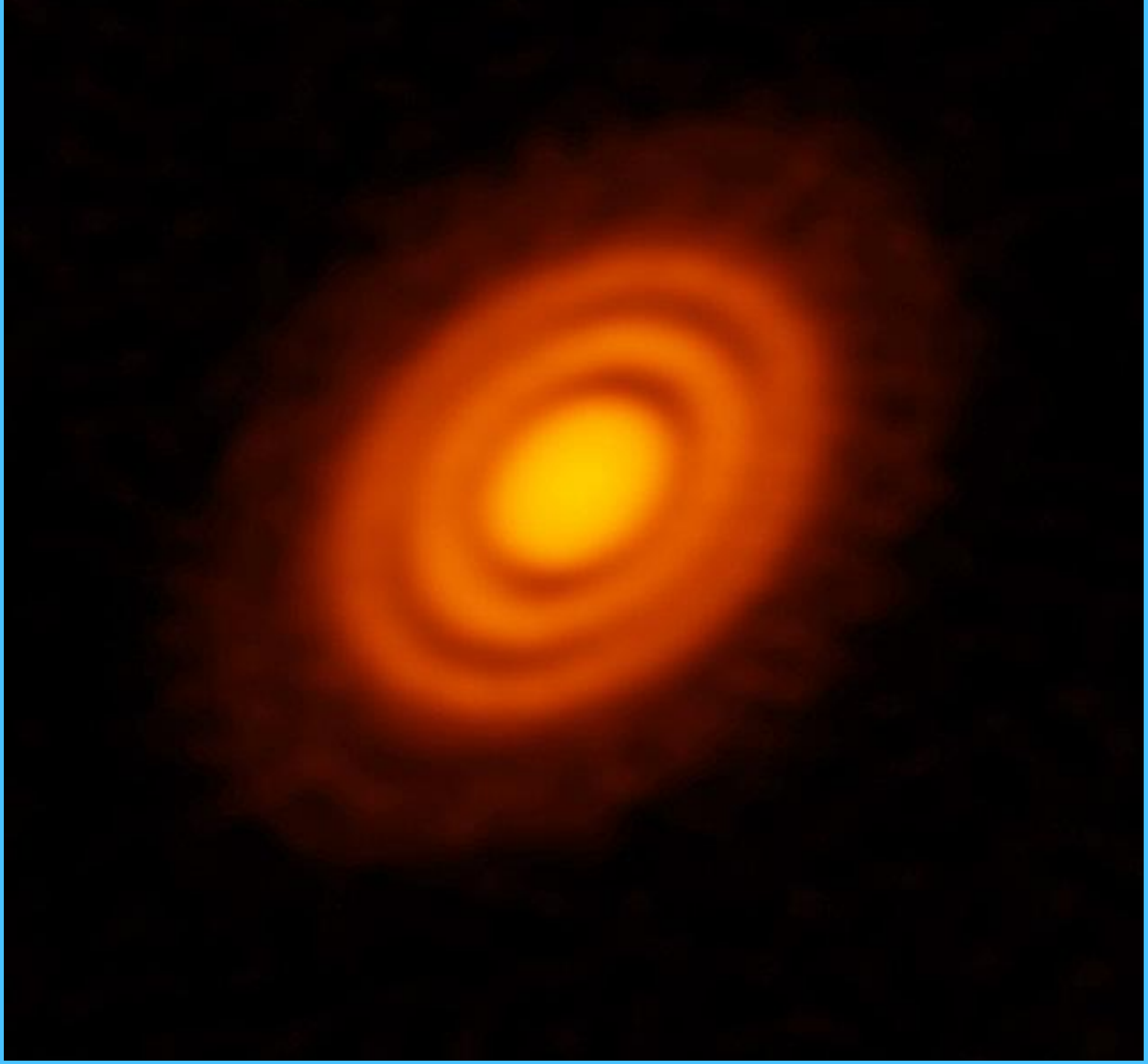
Immanuel Kant 1755





Pierre Laplace 1796

sun (center) and planets (in disk) form at same time out of rotating cloud that collapses under the force of gravity



An ALMA image of the star HD 163296 and its protoplanetary disk as seen in dust. New observations suggested that two planets, each about the size of Saturn, are in orbit around the star. These planets, which are not yet fully formed, revealed themselves in the dual imprint they left in both the dust and the gas portions of the star's protoplanetary disk. Credit: ALMA (ESO/NAOJ/NRAO), Andrea Isella, B. Saxton (NRAO/AUI/NSF)

Basic Facts about Earth and Solar System

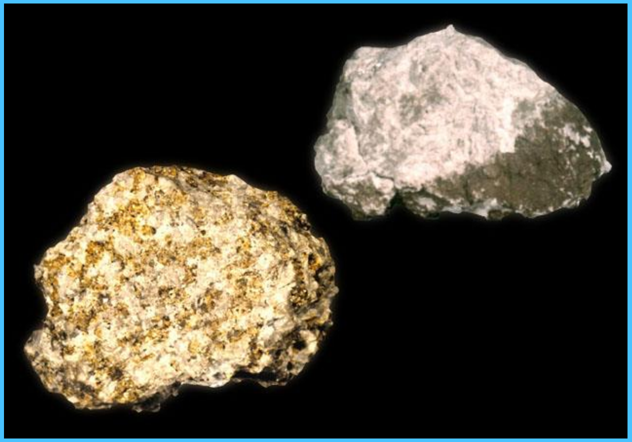
- Sun and planets formed at same time
- When: 4.56 billion years ago (ages of oldest meteorites)
- Hadean era: 4.6 to 4.0 billion years ago: little to no solid rock on surface of Earth
- Archean era: 2.5 to 4.0 billion years ago: rocks start to form, first life appears on Earth

modern scientific chronology from radioactive dating of rocks

- oldest intact sedimentary rocks: 4.031 BY
- oldest mineral grains in old rocks: 4.3-4.4 BY
- oldest moon rocks: 4.4-4.5 BY
- meteorites: 4.567 BY

Jack Hills zircon grains


Jack Hills region, Australia


oldest lunar rocks

Hamlin Pool Australia: stromatolites

The reddish peaks in this 3.7-billion-year-old rock may be structures made by microbes in a shallow ocean—if so, they would be the earliest known evidence of life on Earth. A. Nutman *et. al. Nature* 536, 7618 (1 September 2016) © MacMillian Publisher Ltd.

Mars Opposition

2016

2018

Mars' two moons, Phobos (larger) and Deimos (smaller), as seen from the surface of Mars.

Discovered in 1877 by Asaph Hall at USNO in Washington, D.C.

Phobos: near side

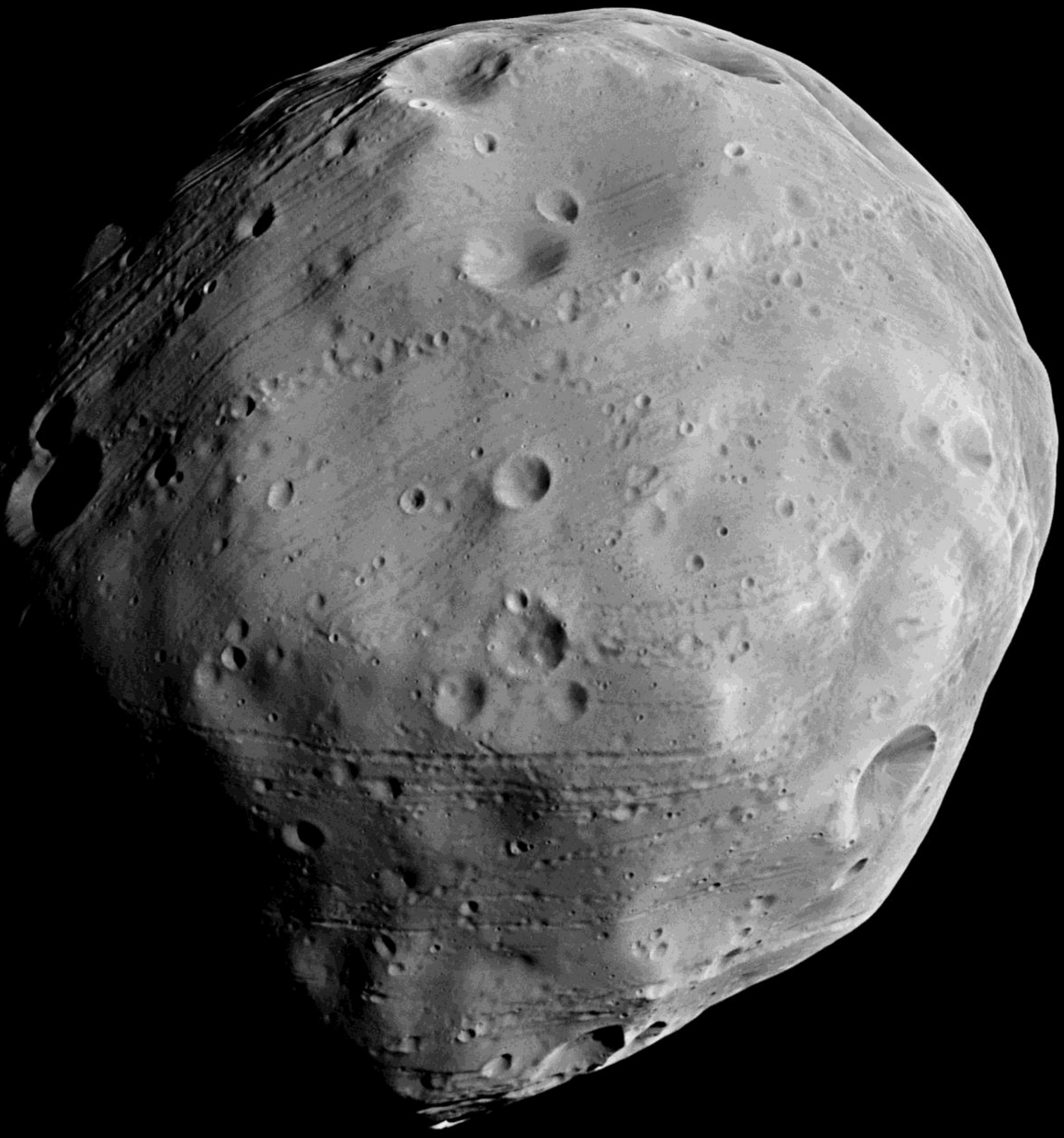
17 x 14 x 11 miles

Orbit: 8 hours

Spiraling toward Mars at 6 feet per hundred years (50 million years)

Stickney Crater

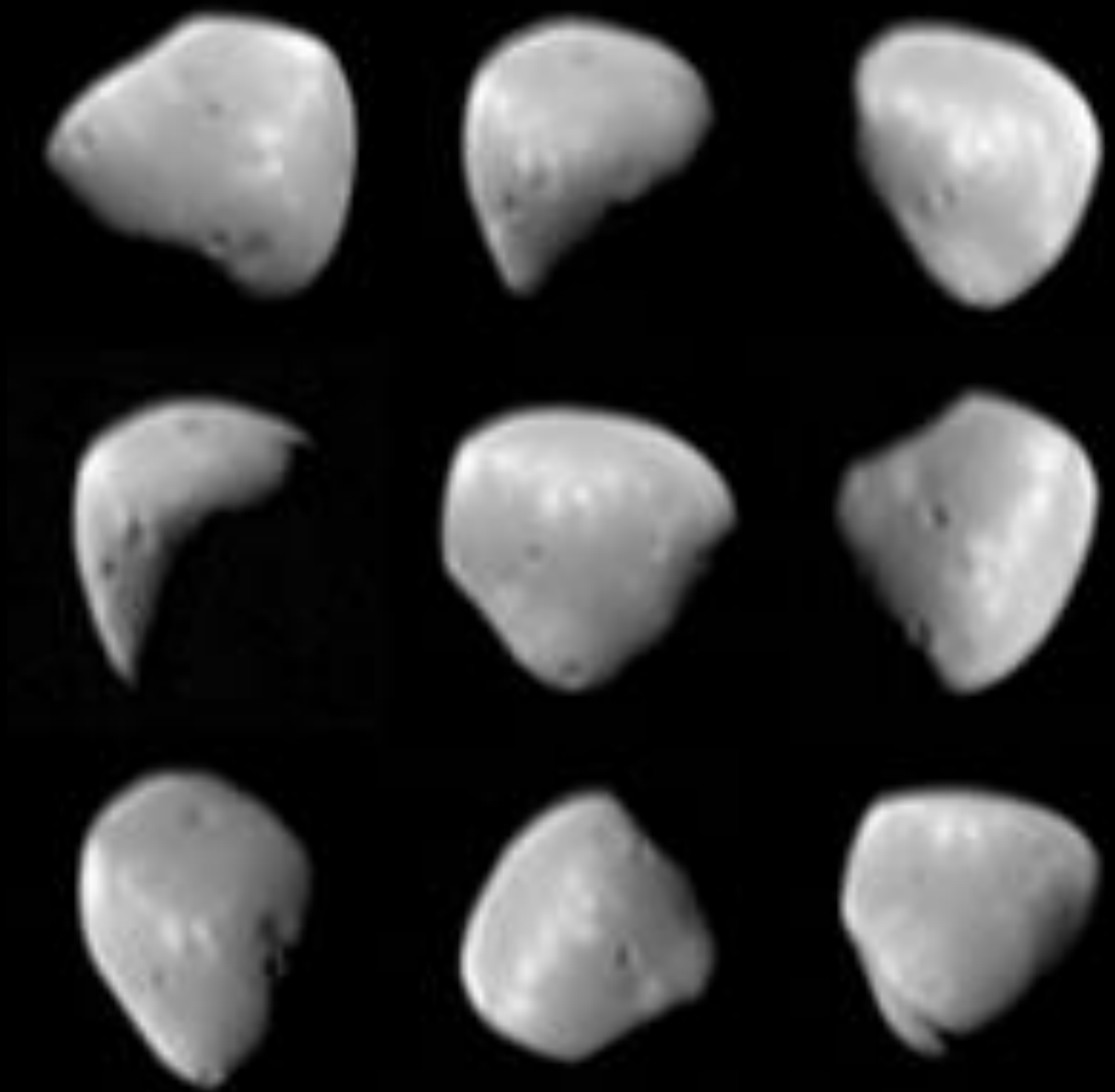
Phobos: far side

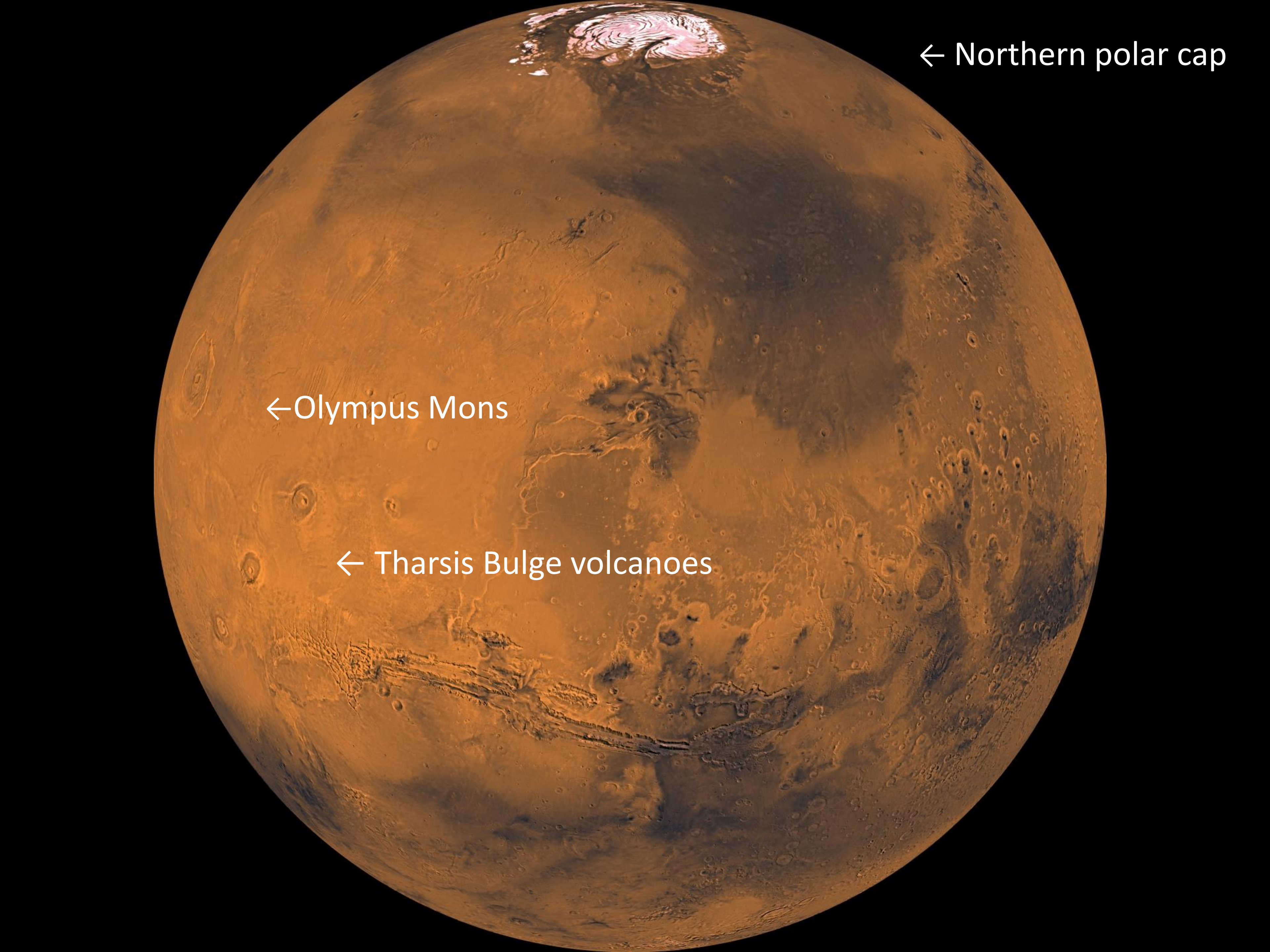


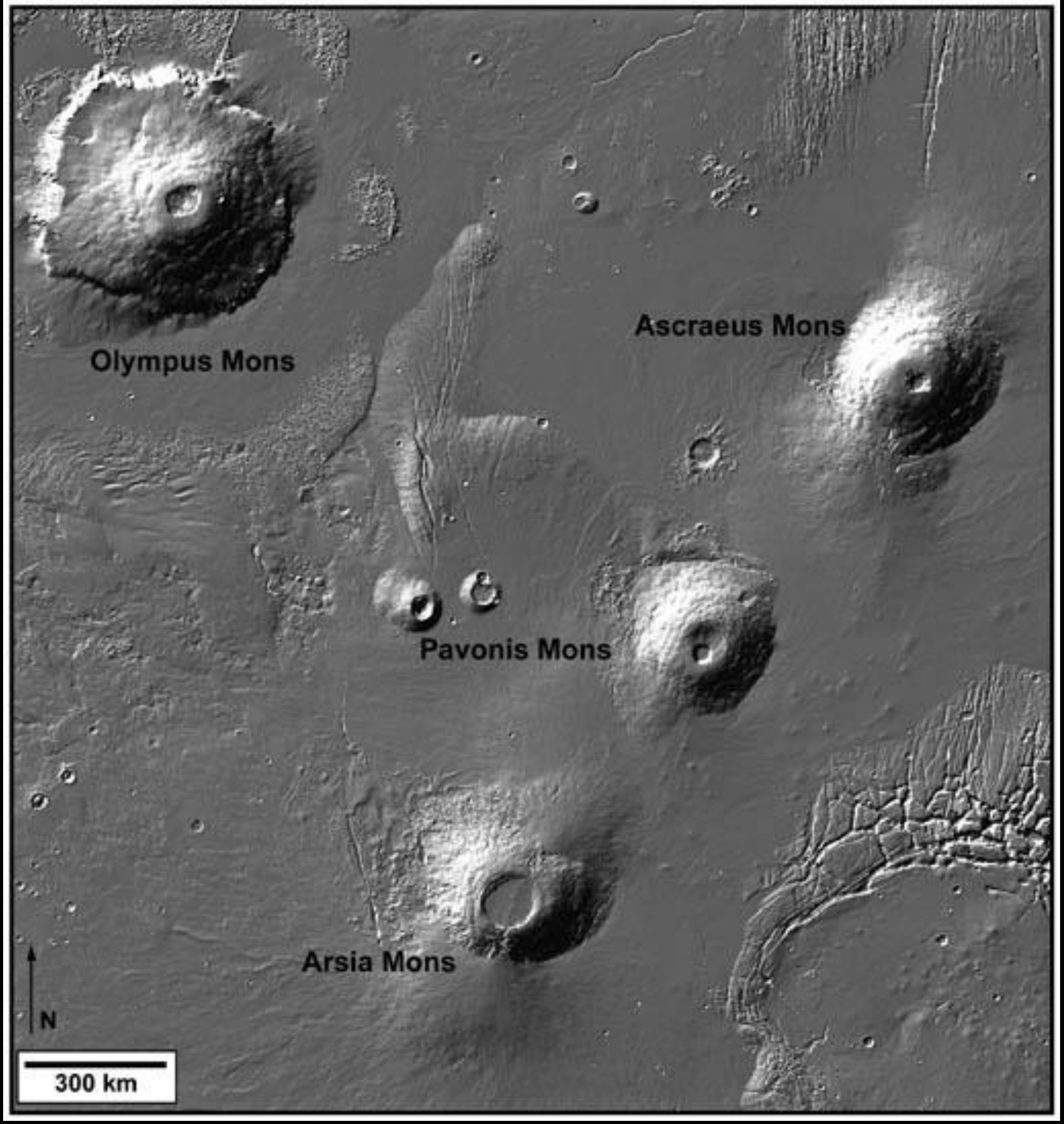
Deimos

4.7 x 3.8 x 3.2 miles

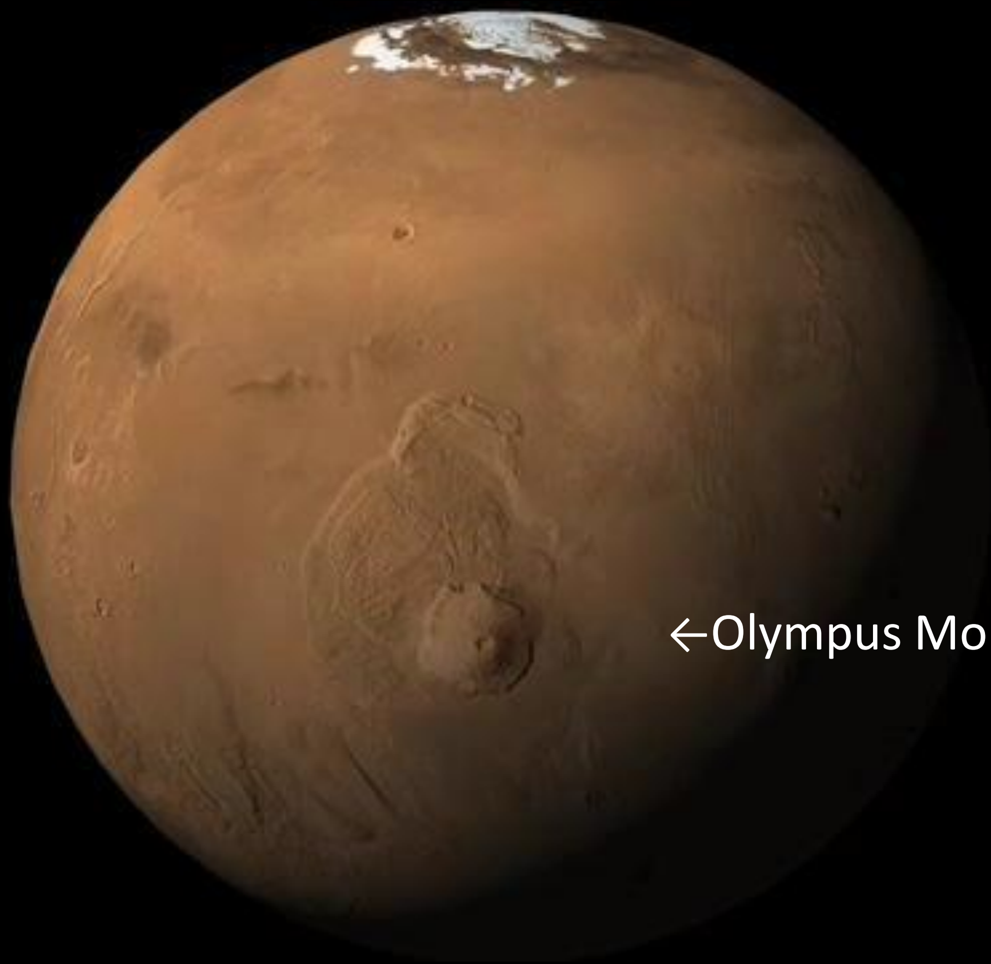
Orbit: 30 hours

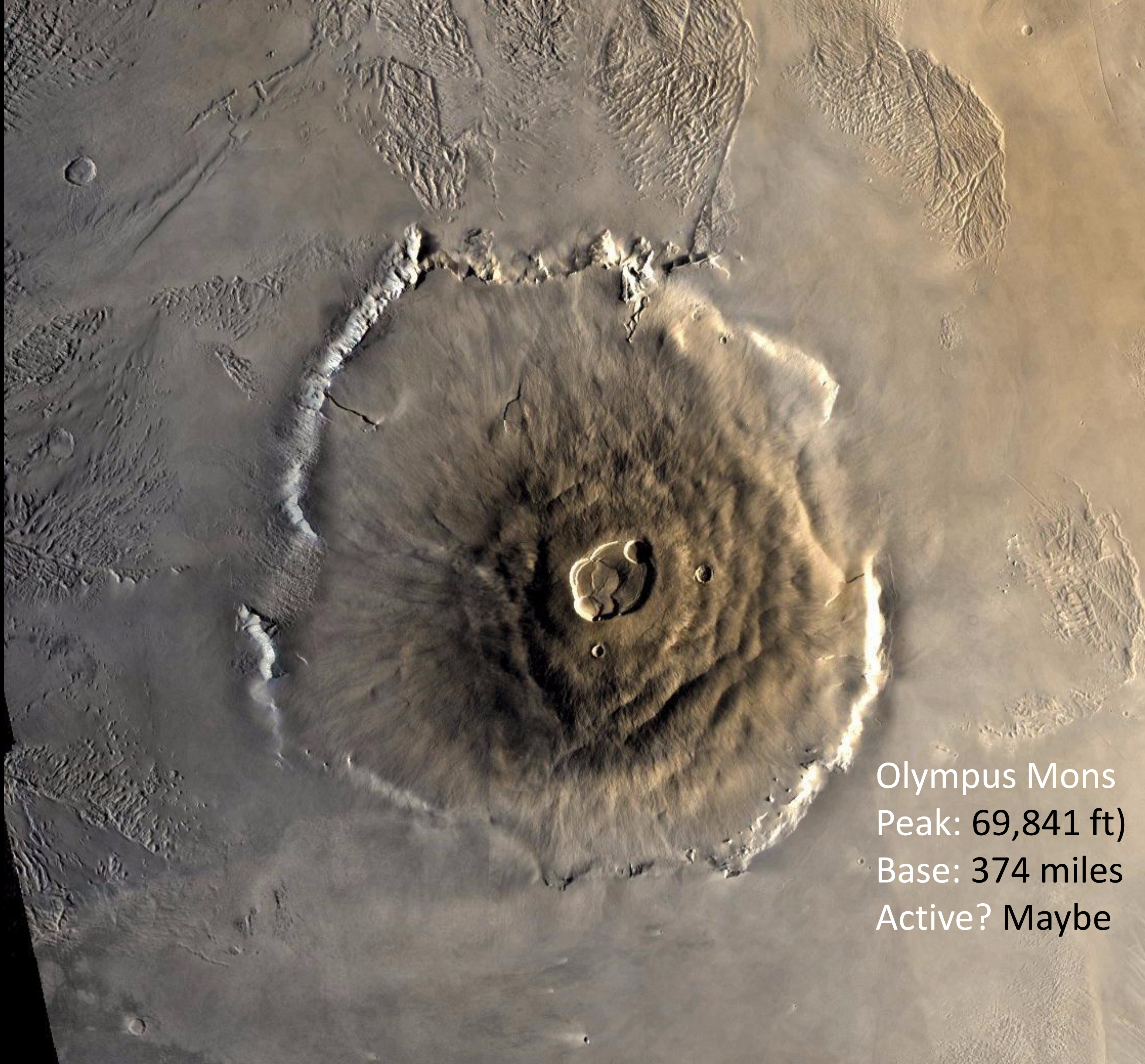



← Northern polar cap
←Olympus Mons
← Tharsis Bulge volcanoes



Olympus Mons
Ascraeus Mons
Pavonis Mons
Arsia Mons
N
300 km

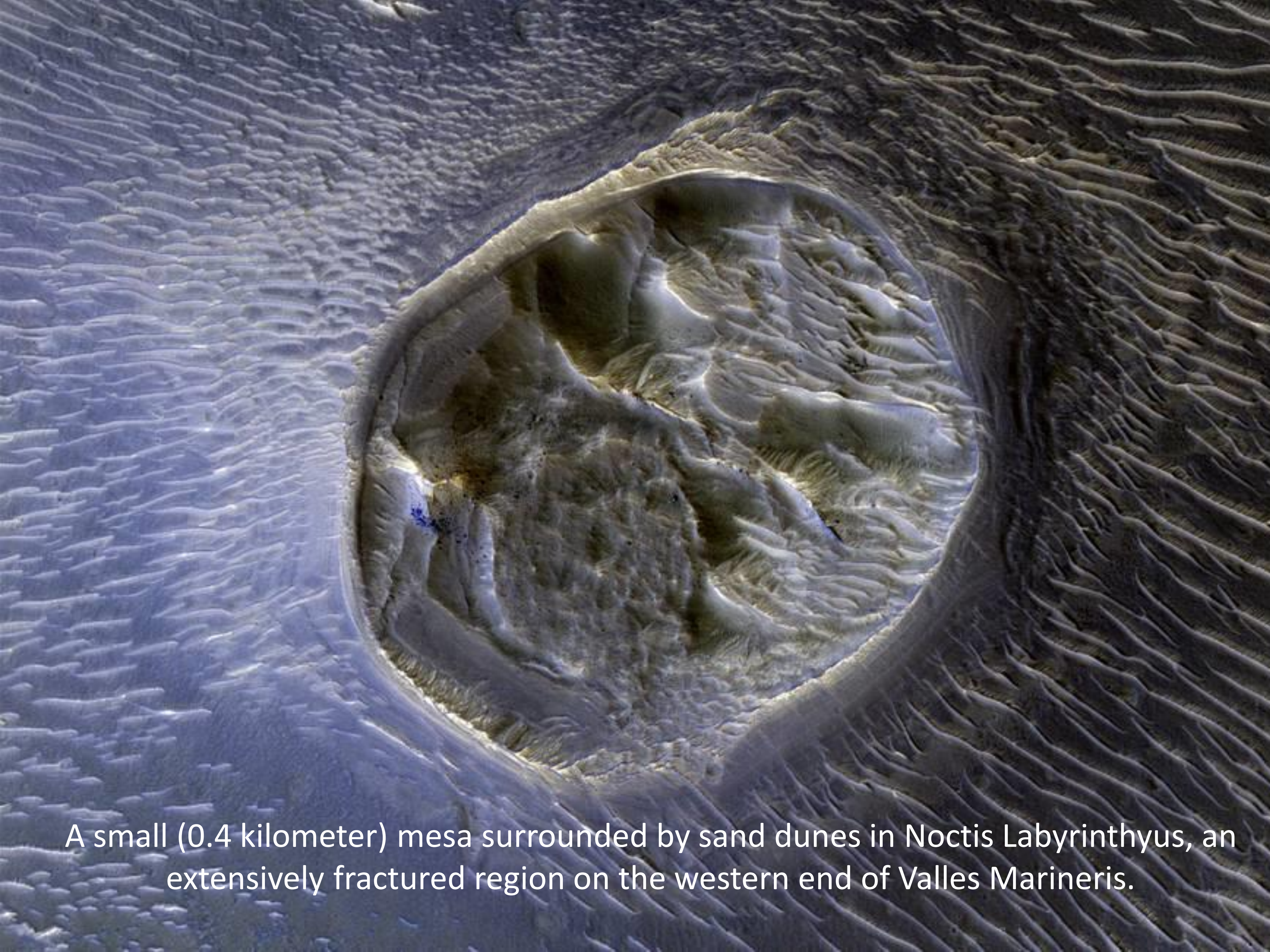

←Olympus Mons


Olympus Mons
Peak: 69,841 ft)
Base: 374 miles
Active? Maybe

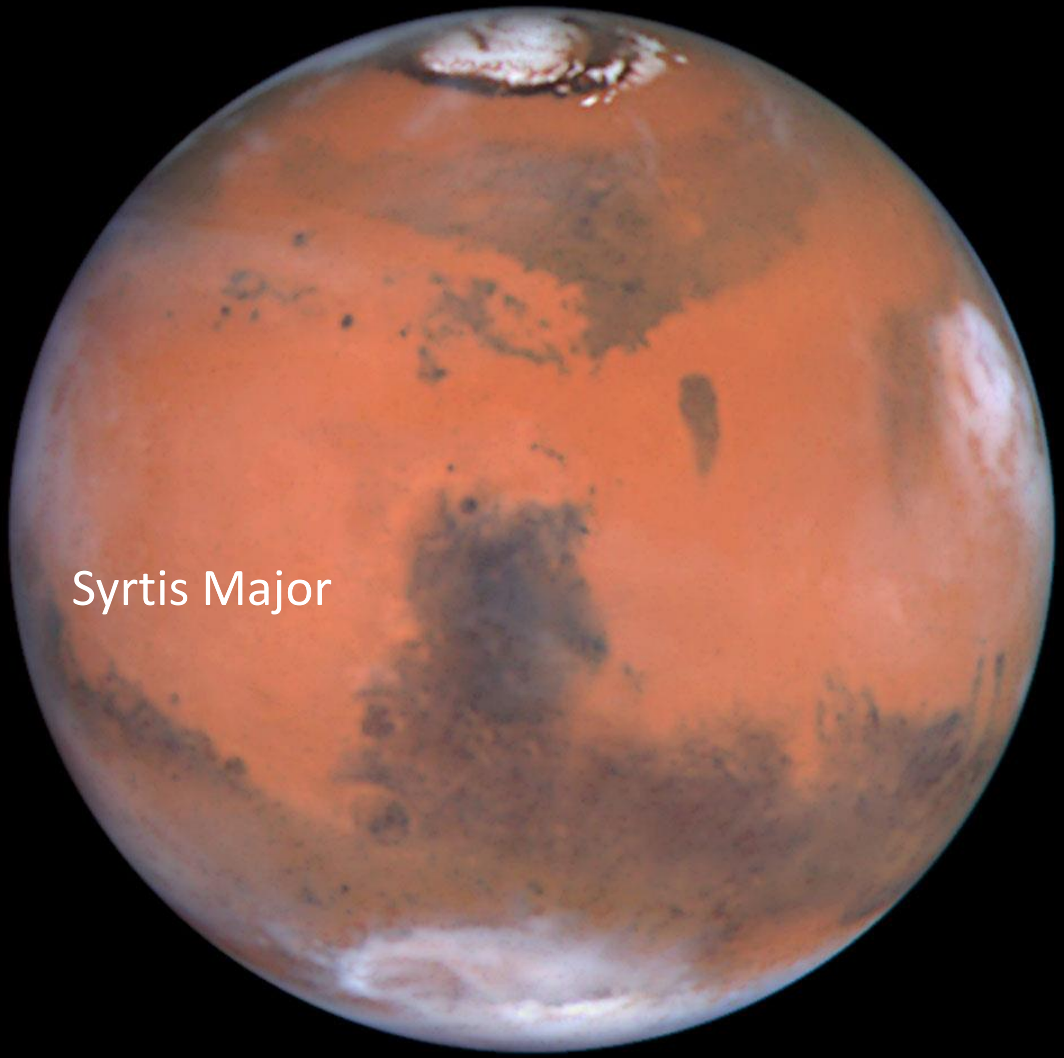

← Valles Marineris

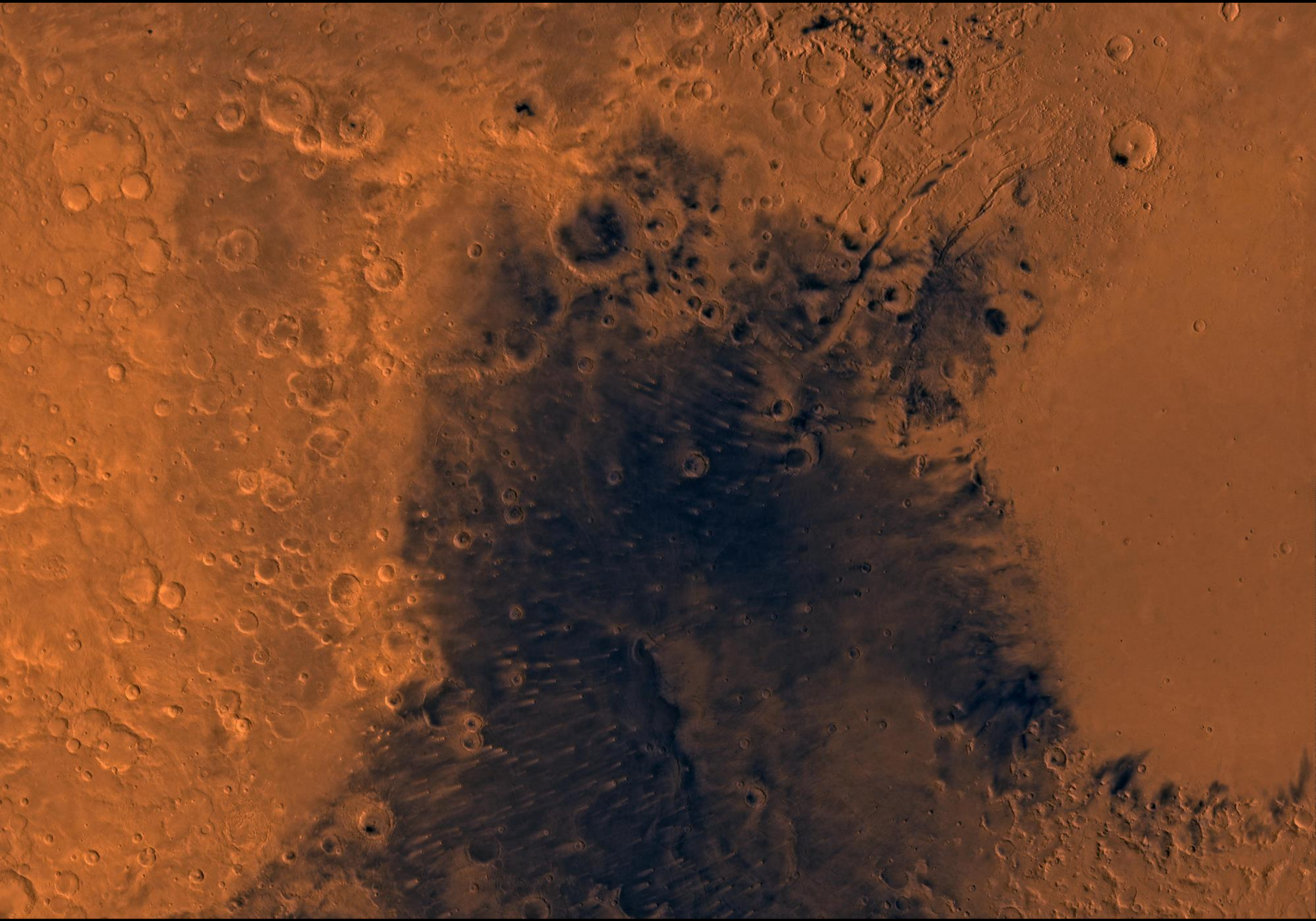
Valles Marineris

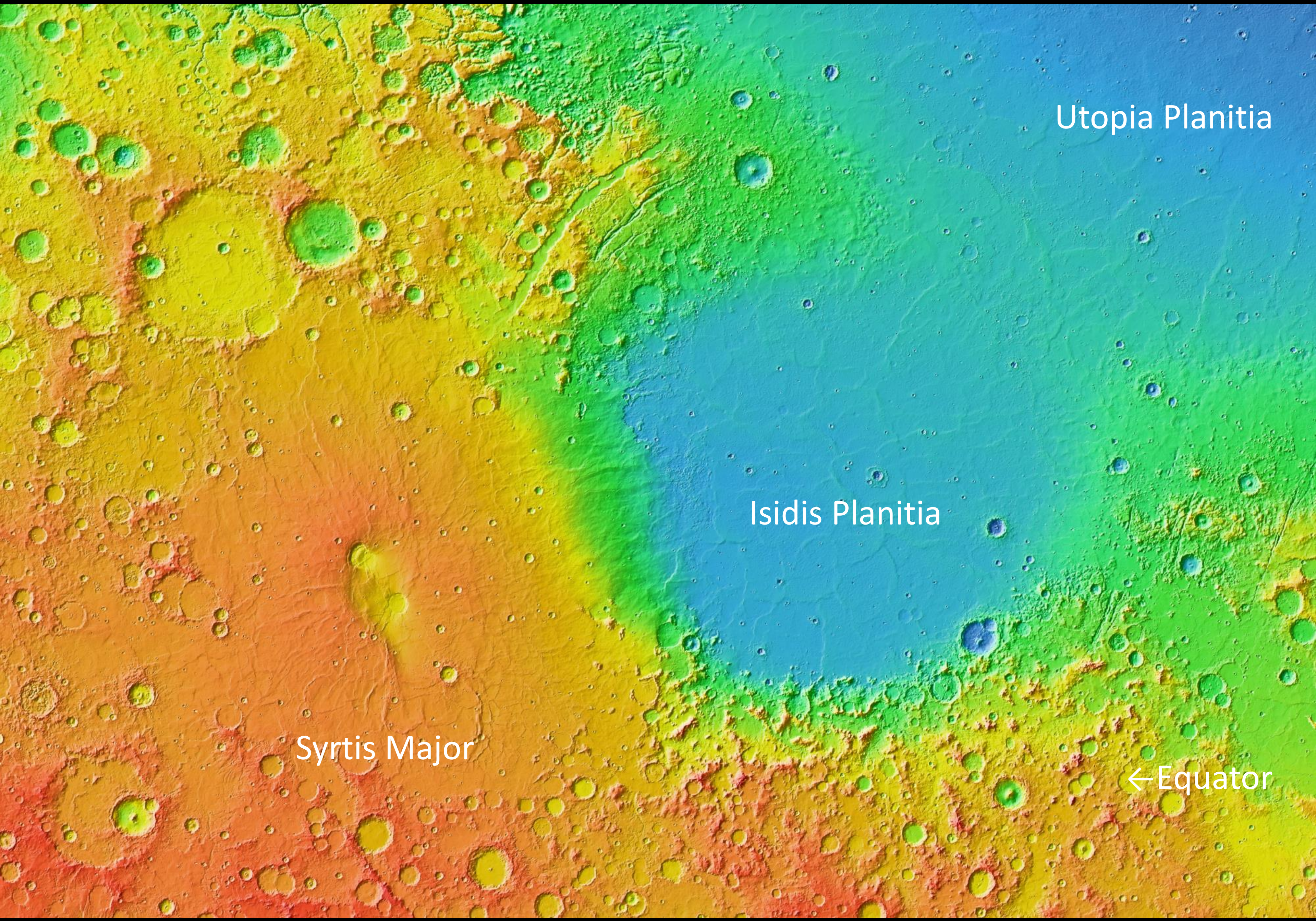
Length: 2000 miles (1/6 of circumference of planet)
Average depth: 5 miles



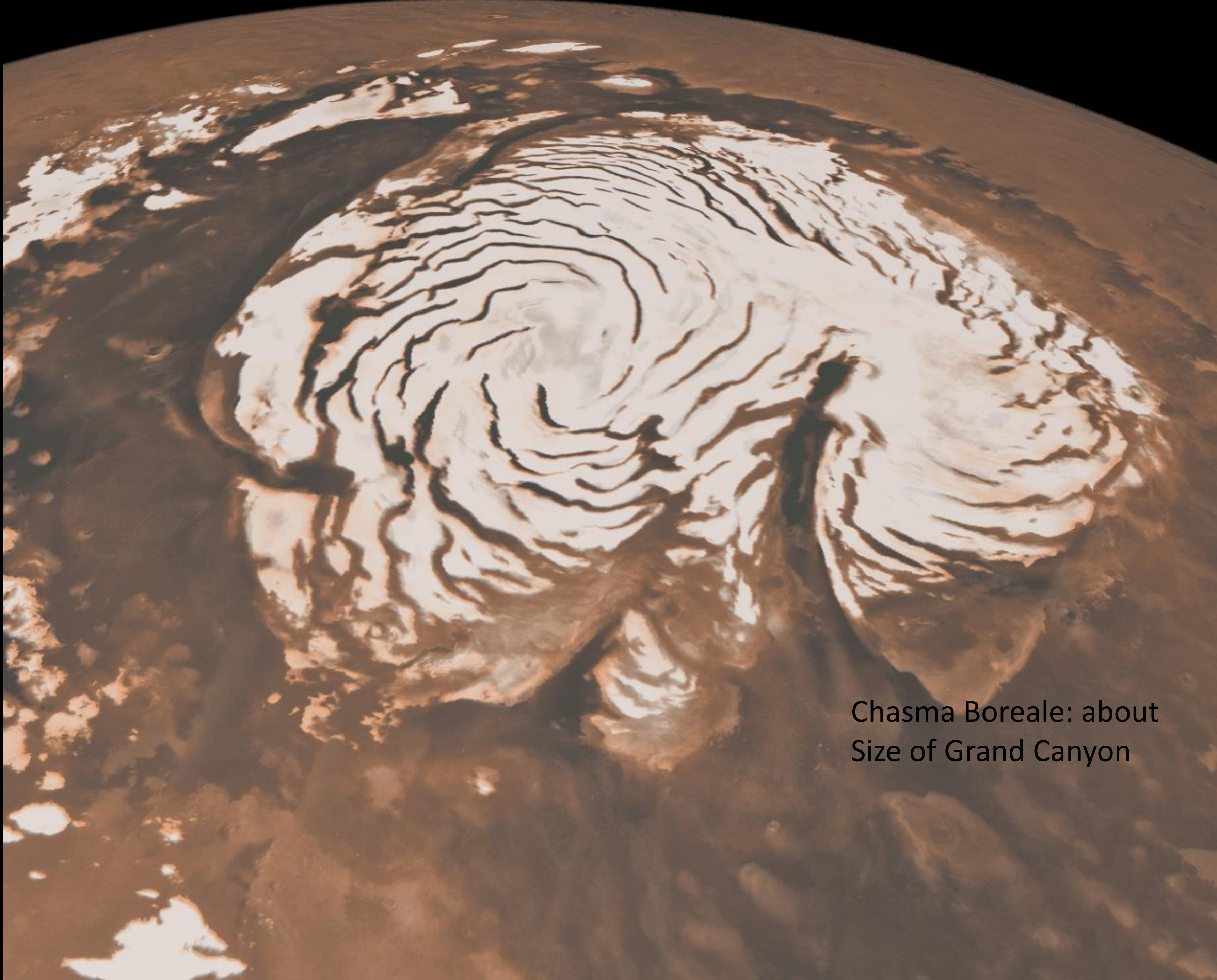
A small (0.4 kilometer) mesa surrounded by sand dunes in Noctis Labyrinthyus, an extensively fractured region on the western end of Valles Marineris.

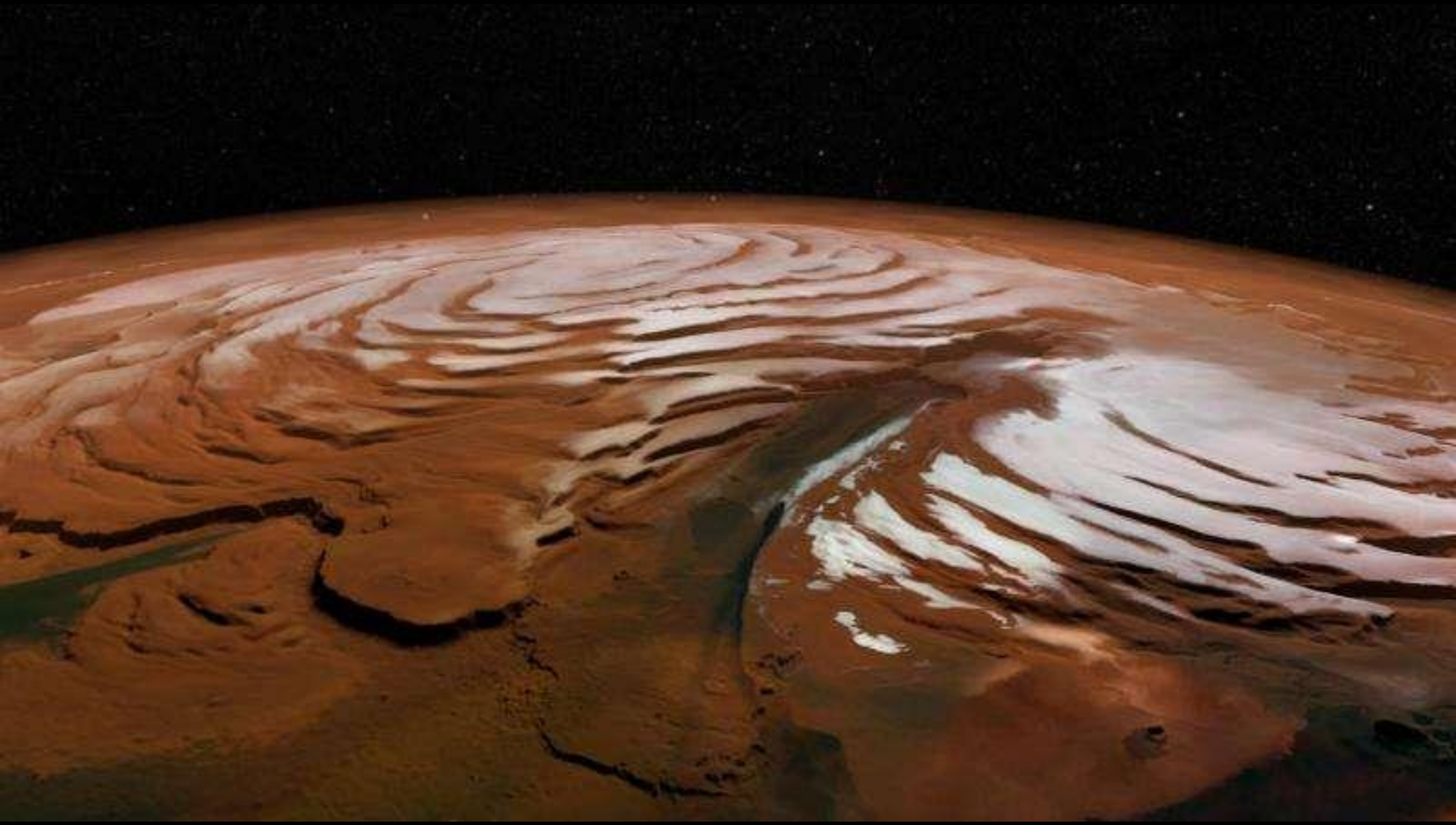

Syrtis Major



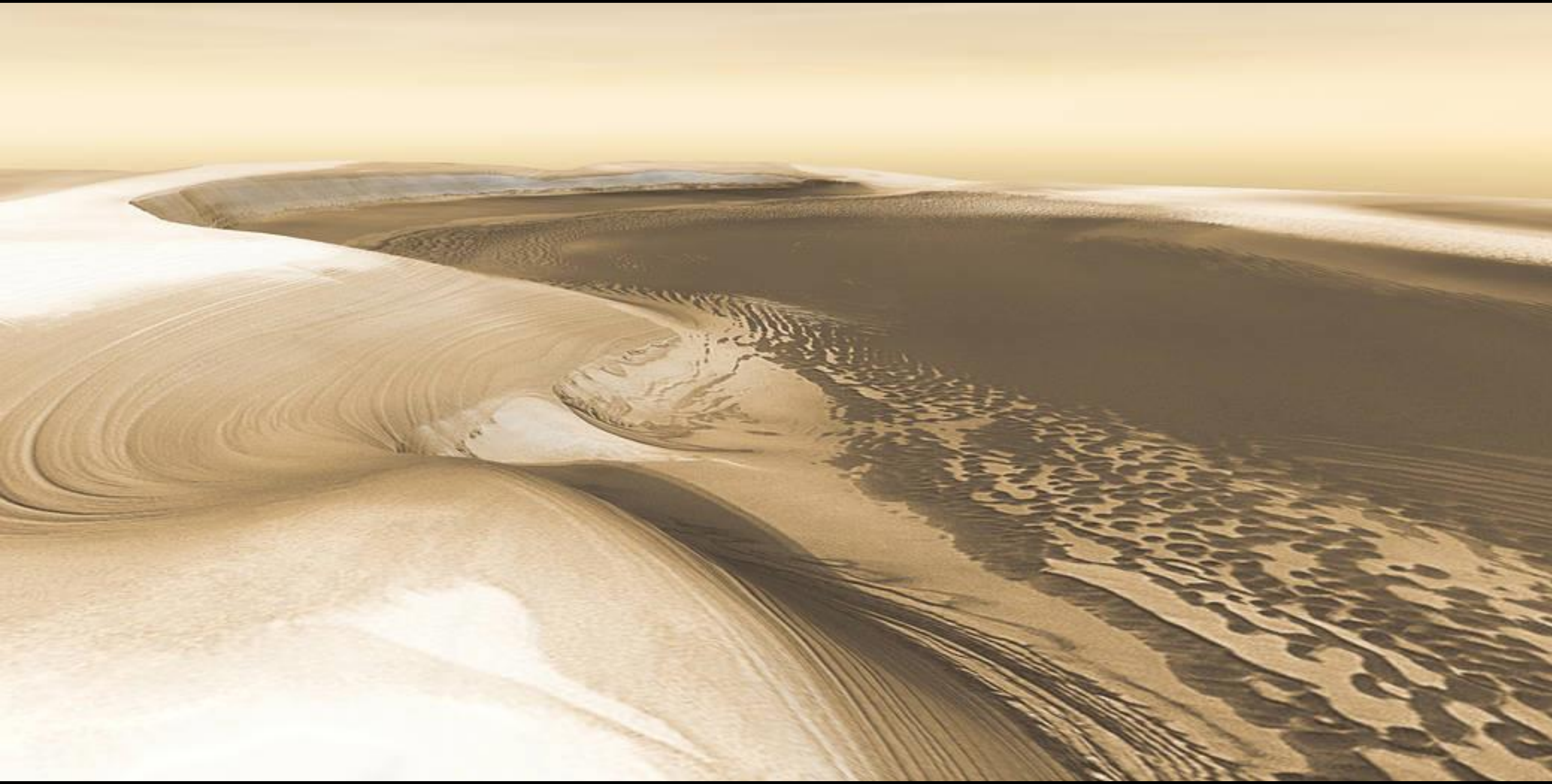

Utopia Planitia
Isidis Planitia
Syrtis Major
←Equator

North polar ice cap: 700 miles across


Chasma Boreale: about
Size of Grand Canyon

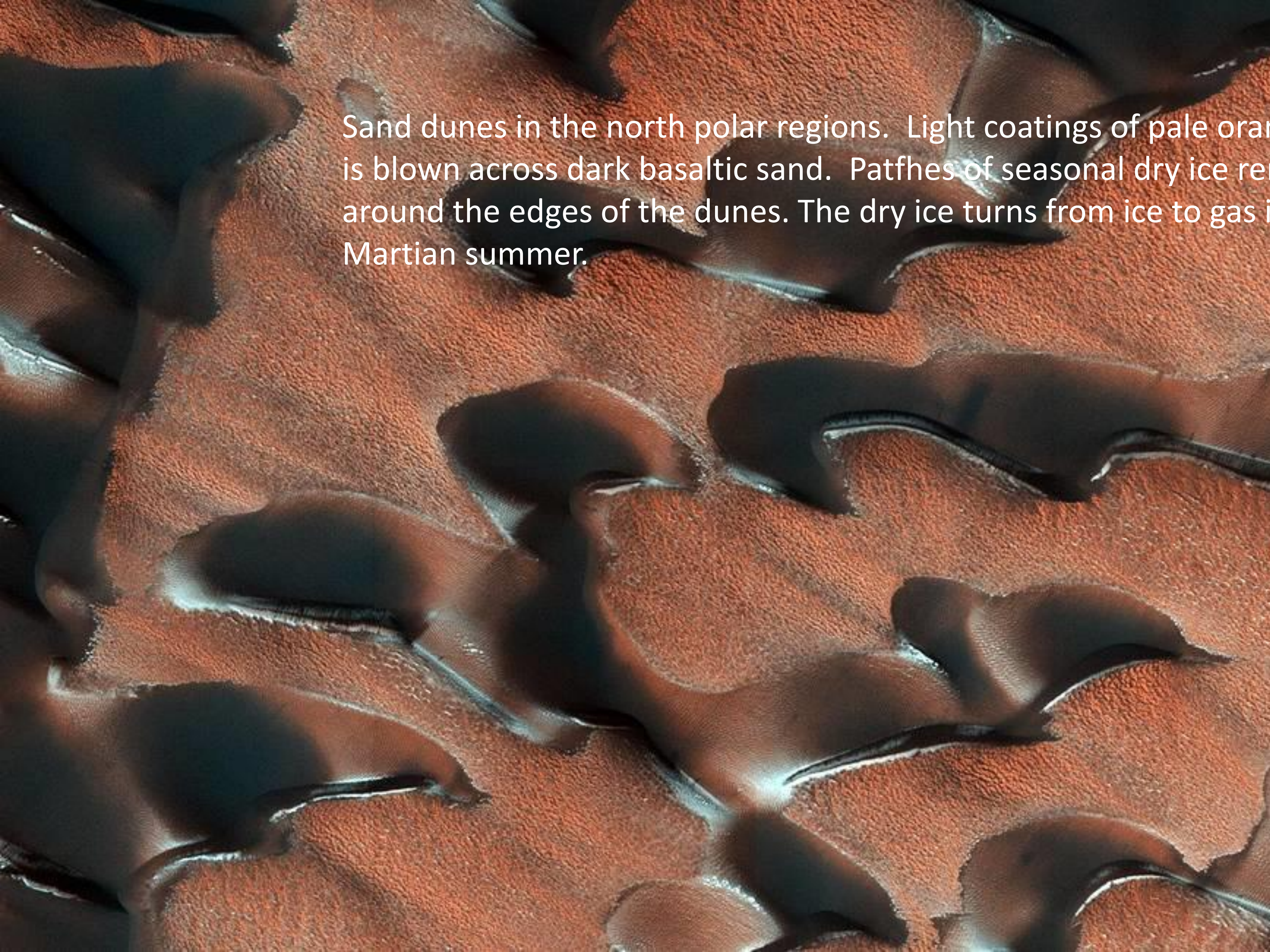


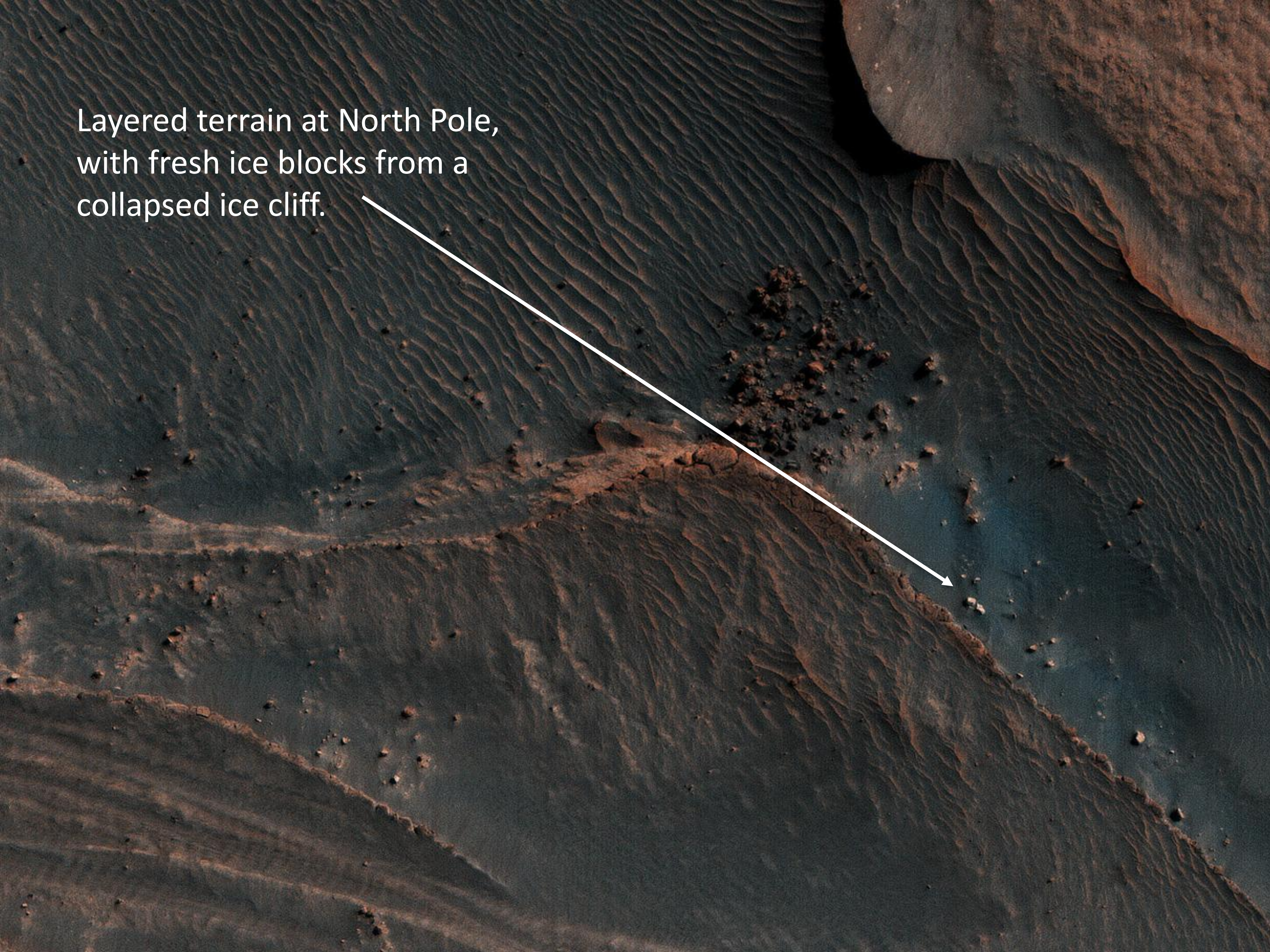
Perspective view of Chasma Boreale

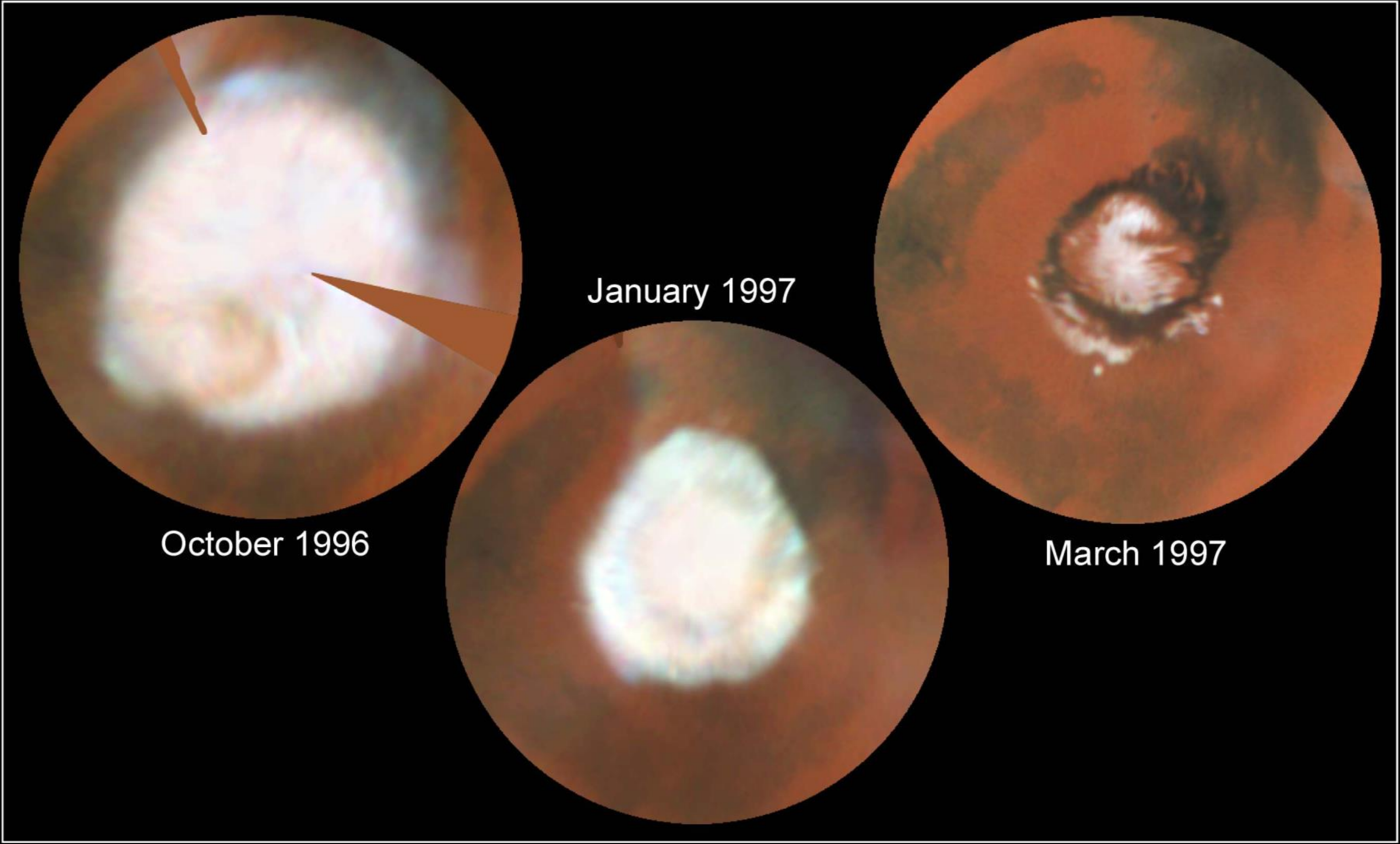


North polar ice cap

Sand dunes in the north polar regions. Light coatings of pale oran
is blown across dark basaltic sand. Patfhes of seasonal dry ice re
around the edges of the dunes. The dry ice turns from ice to gas i
Martian summer.



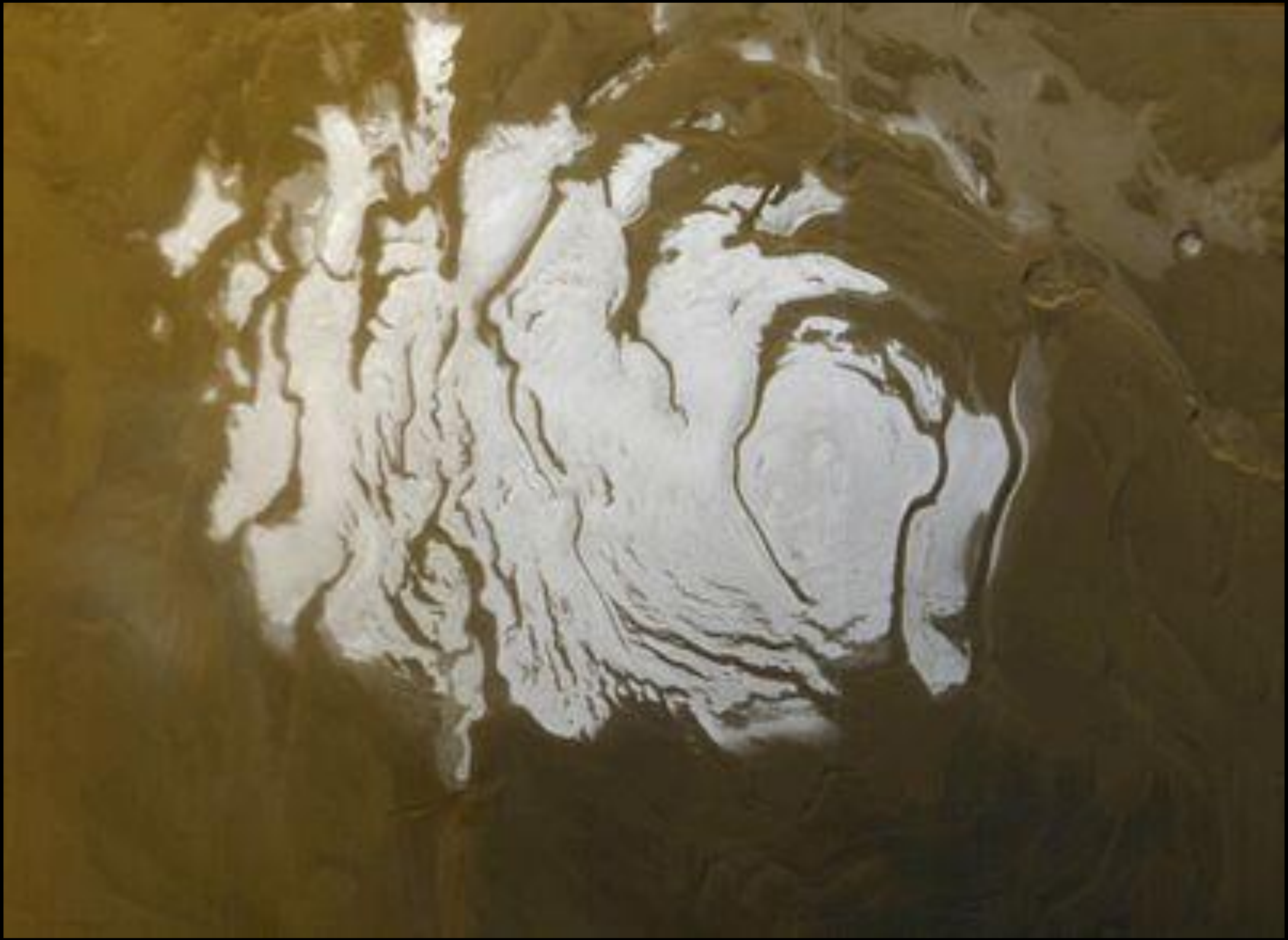

Layered terrain at North Pole,
with fresh ice blocks from a
collapsed ice cliff.



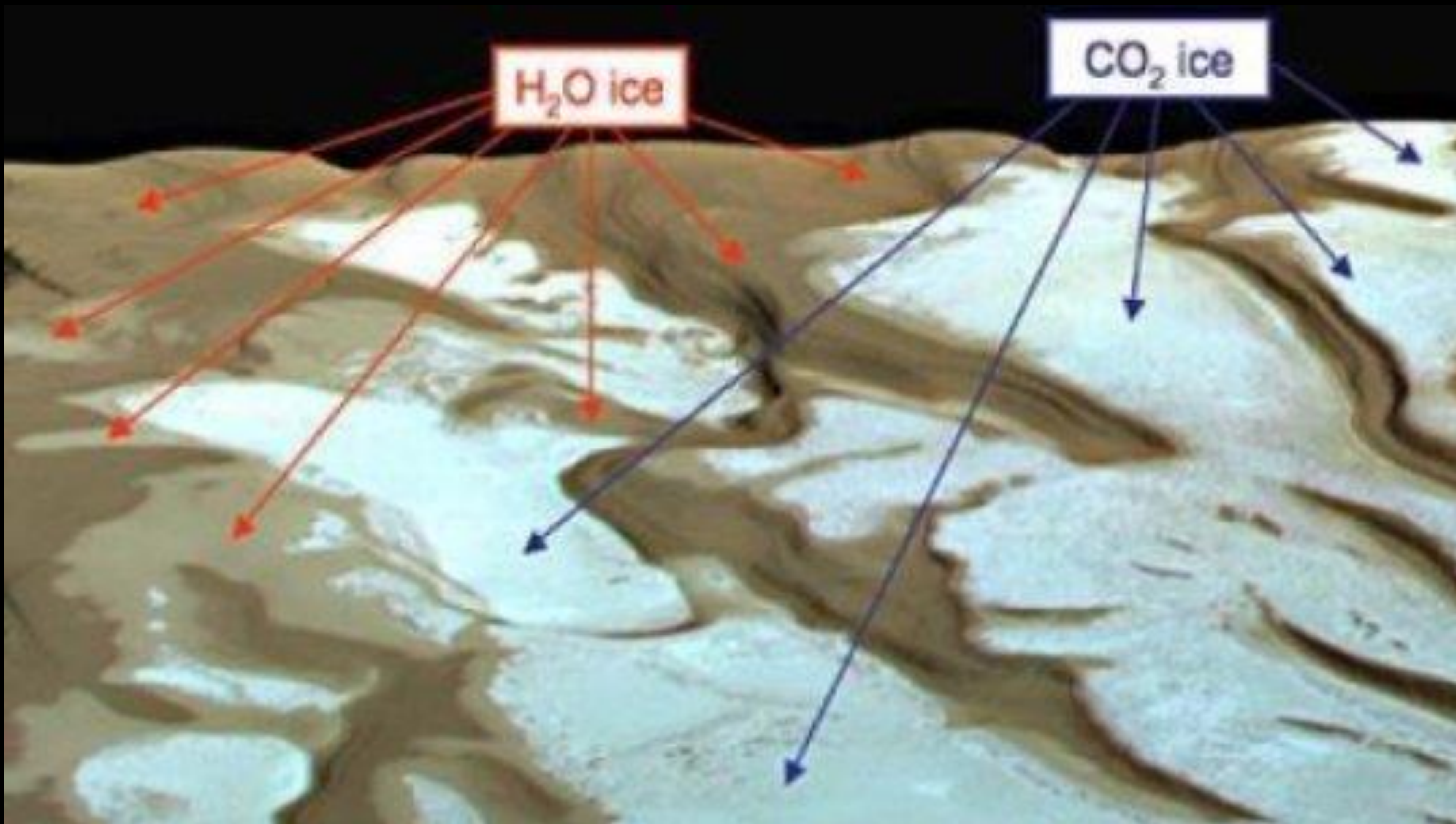
Mars • North Polar Cap

Hubble Space Telescope • WFPC2

PRC97-15b • ST ScI OPO • May 20, 1997 • P. James (Univ. Toledo), T. Clancy (Space Science Institute), S. Lee (Univ. Colorado) and NASA

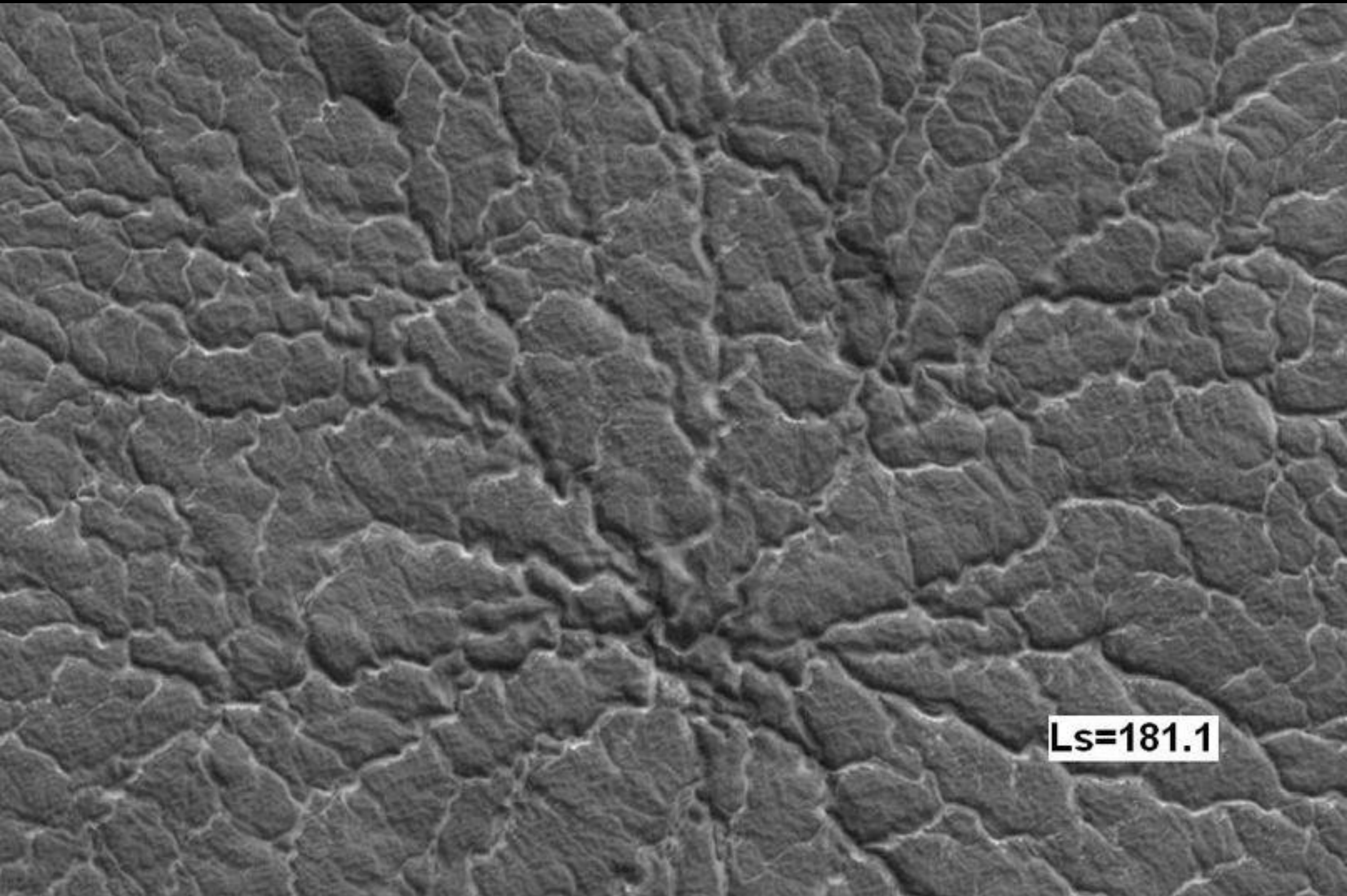


Southern polar cap: 280 miles across



Different ices in South Polar Cap
CO_2 on top of H_2O
CO_2 disappears in Martian summer


ow pits (dark) in carbon
de (dry ice) layer at south
r region (called ‘swiss cheese
in’). Top right shows a pit
er (collapse) or impact crater.



Erosion (by CO gas) spiders in southern polar cap: 500 meters wide, 1 meter deep

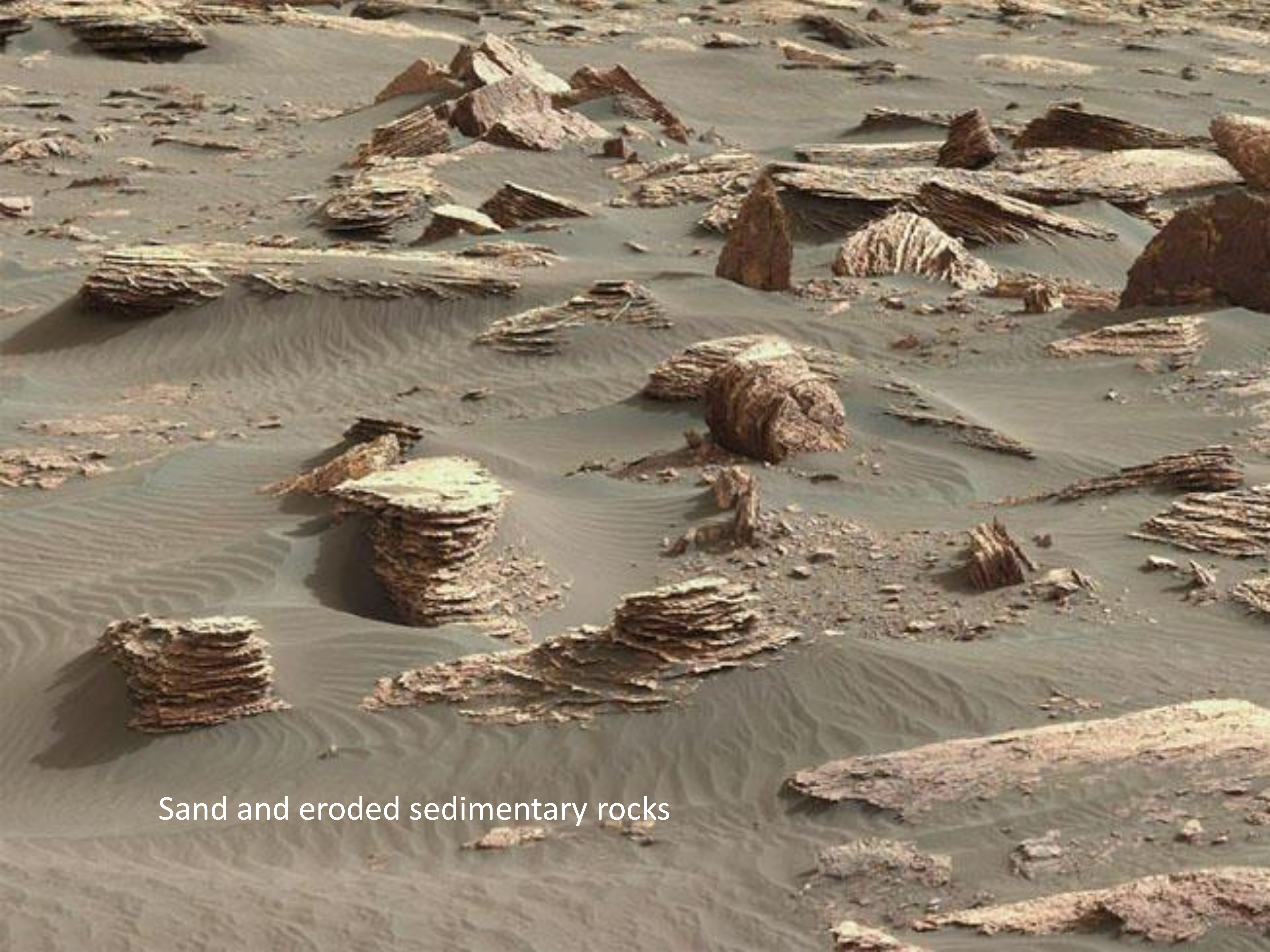
Odd-shaped pits in dry ice layer at south pole.

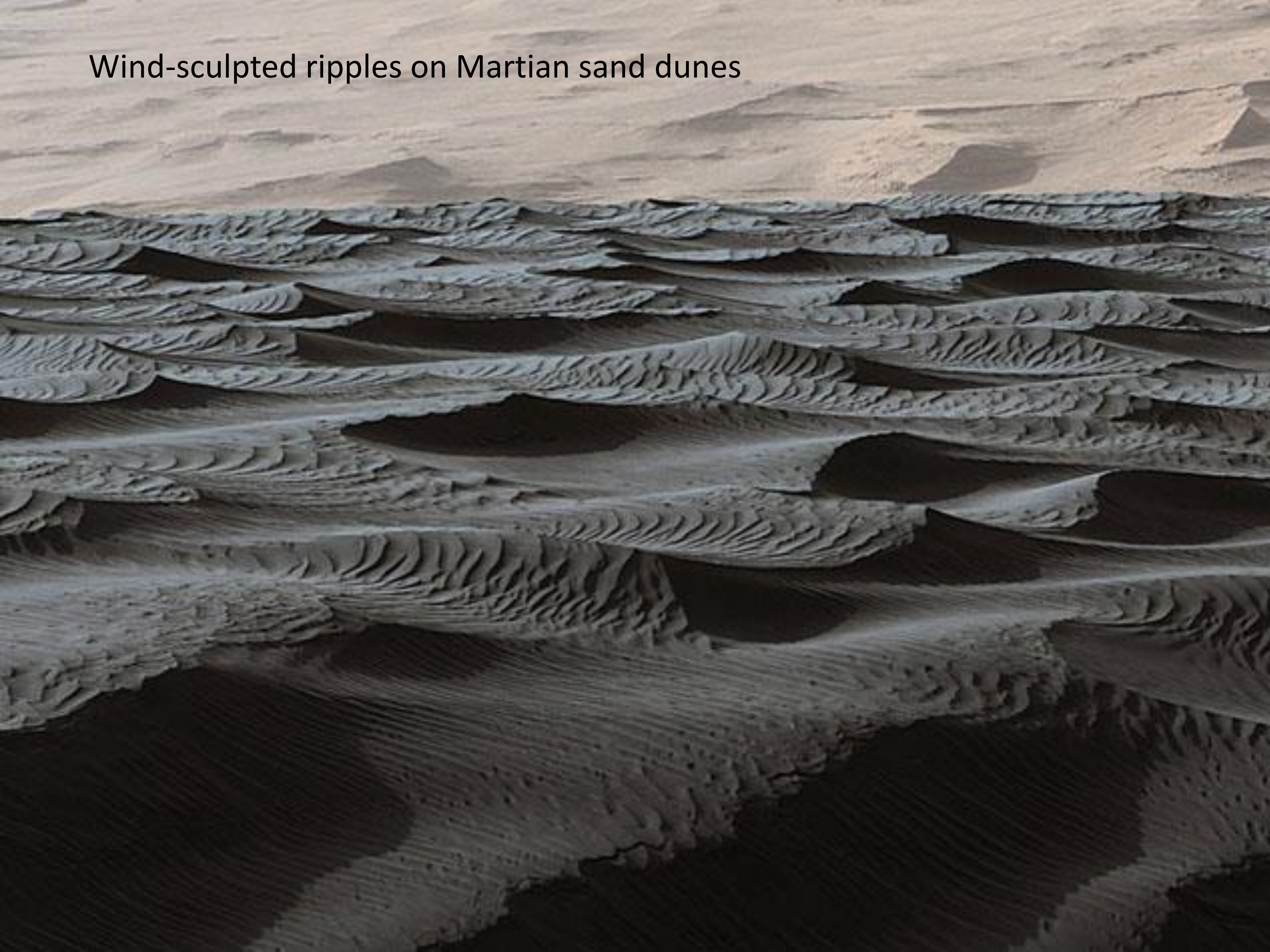
Sunset on Mars, seen from Curiosity’s location in Gale Crater.


MOUNT SHARP
NASA'S Mars Curiousity Rover looks uphill
at Mount Sharp


View from Curiosity toward Vera Rubin Ridge

View from Curiosity toward higher regions of Mount Sharp.
Long ridge in foreground is mostly hematite (iron oxide).
Just beyond is an undulating plane rich in clay minerals.
Rounded buttes in middle distance are rich in sulfate minerals.
All three involve exposure to water, billions of years ago.
Light-toned, wind-eroded cliffs further back formed in drier times.


Sand and eroded sedimentary rocks



Wind-sculpted ripples on Martian sand dunes

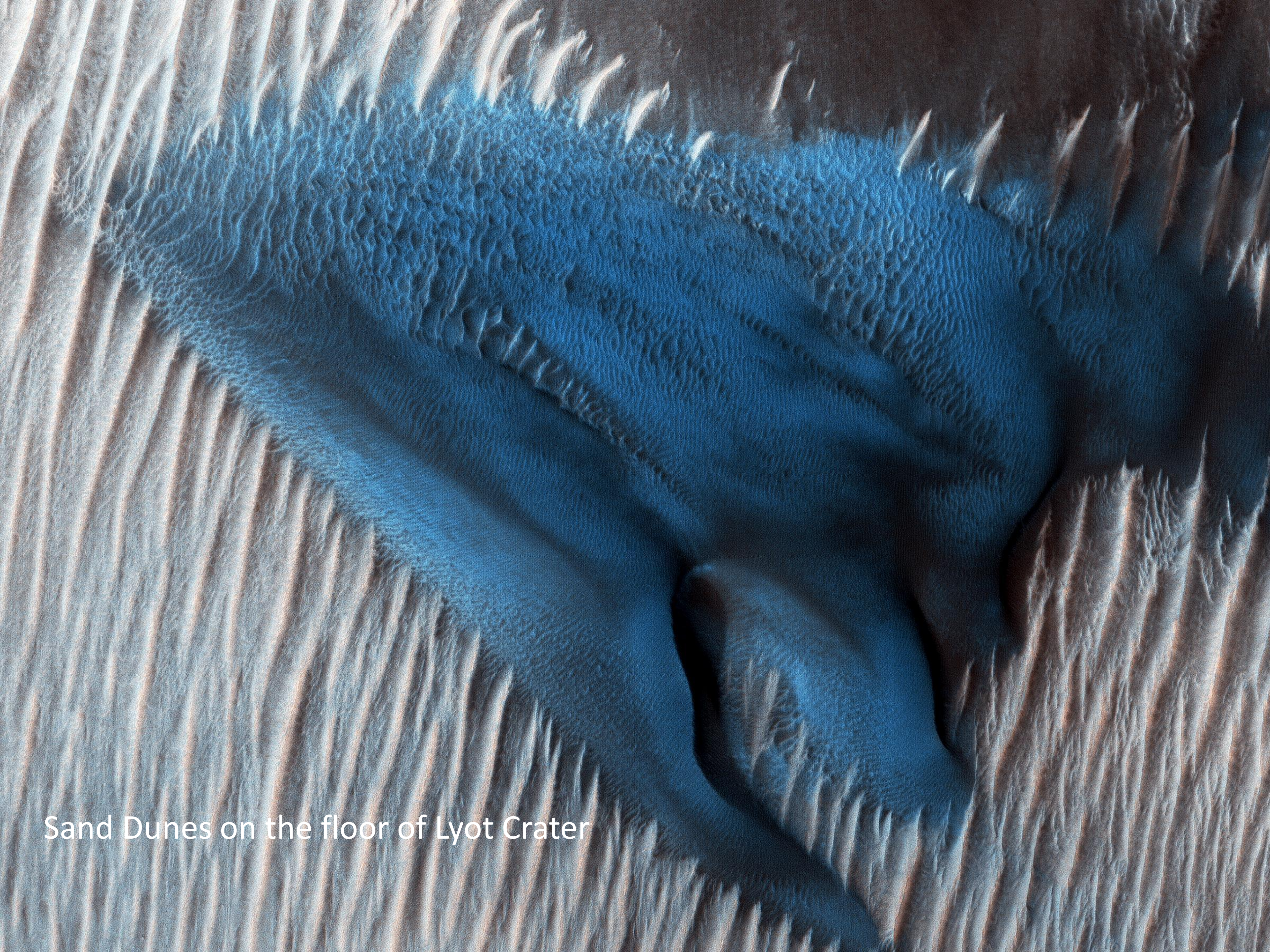

A golf-ball sized iron-nickel meteorite


Dime-sized hole drilled by Curiosity.

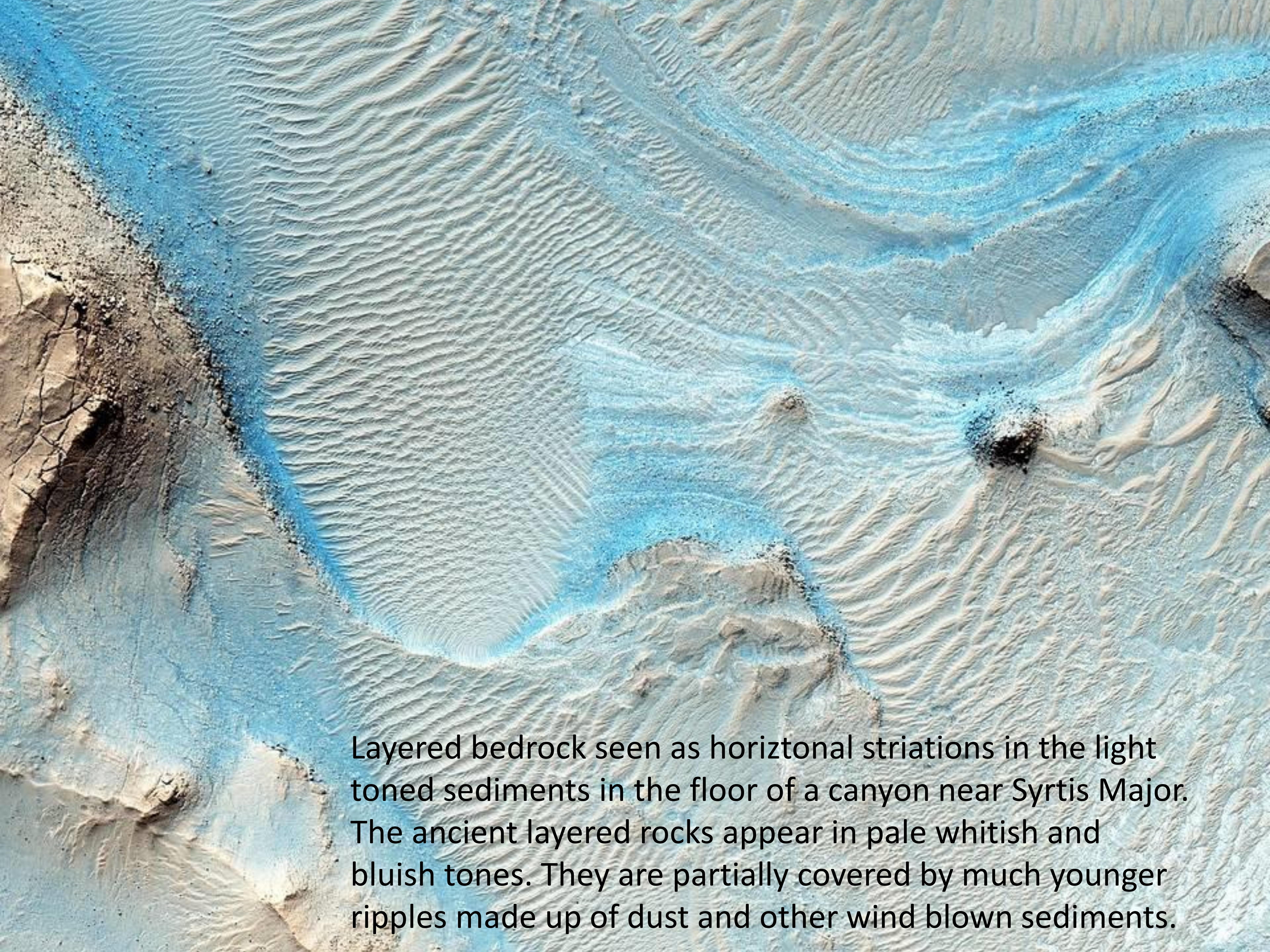

16-foot tall hill that rises above redder outcrop layer

LAYERS AND SAND DUNES

Much of Mars' surface is covered by fine-grained materials that hide the bedrock, but elsewhere, such as in this scene, the bedrock is well exposed

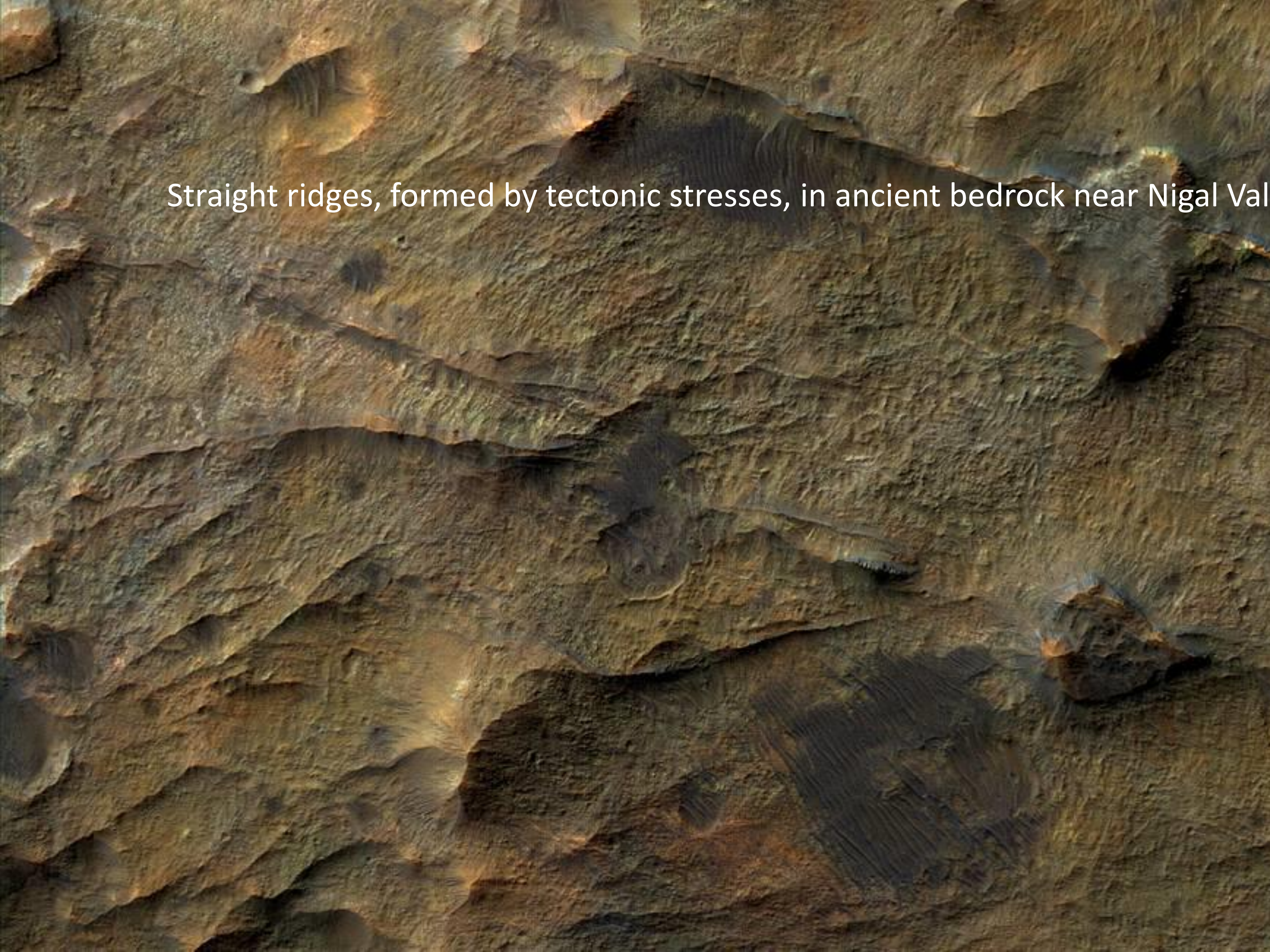


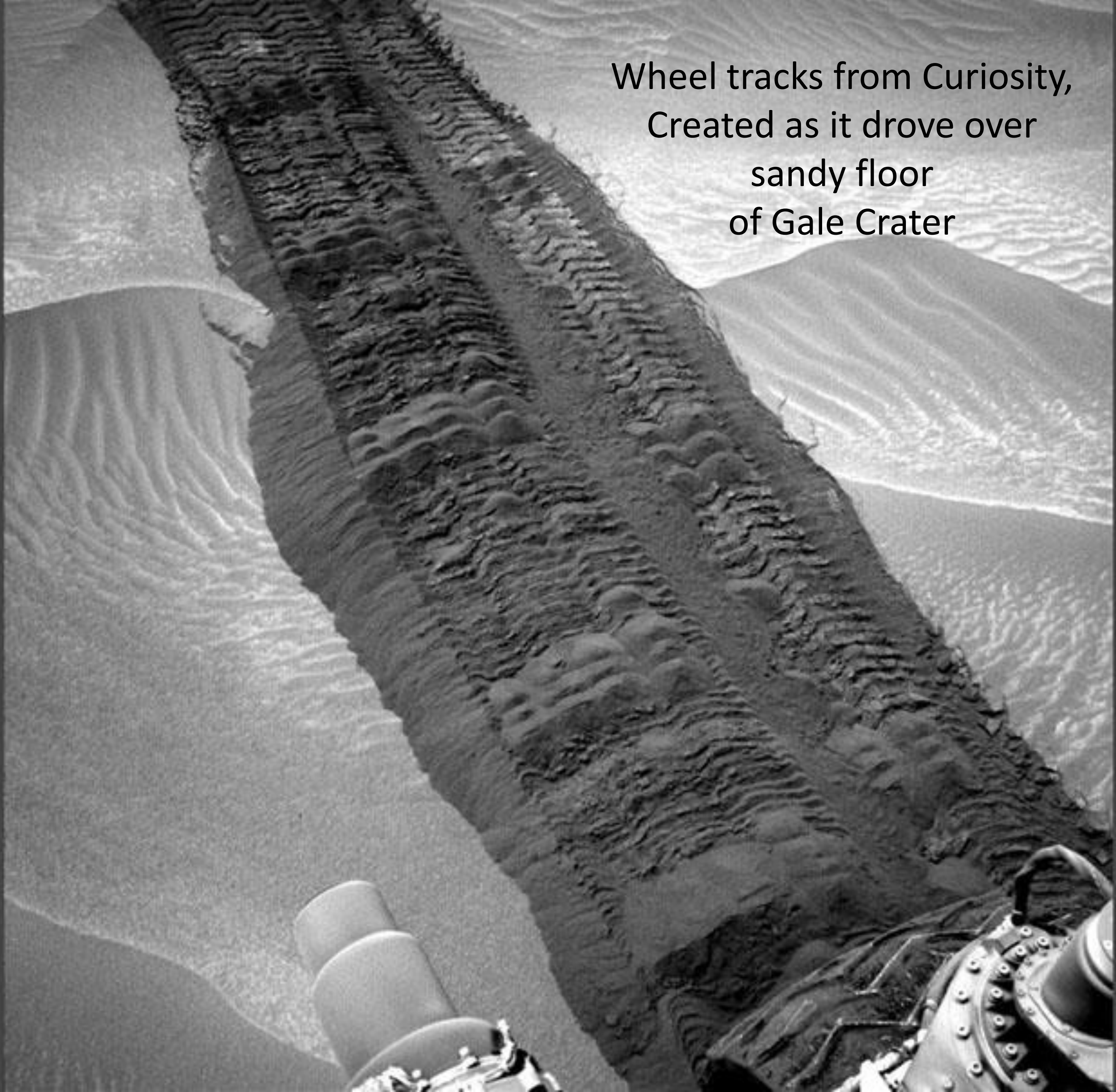
Sand Dunes on the floor of Lyot Crater



Layered bedrock seen as horiztonal striations in the light toned sediments in the floor of a canyon near Syrtis Major. The ancient layered rocks appear in pale whitish and bluish tones. They are partially covered by much younger ripples made up of dust and other wind blown sediments.


MOVING SANDS OF LOBO VALLIS
Bright ripple lines formed in ancient rivers and streams, when the climate on Mars was very different that it is today.


Straight ridges, formed by tectonic stresses, in ancient bedrock near Nigal Val

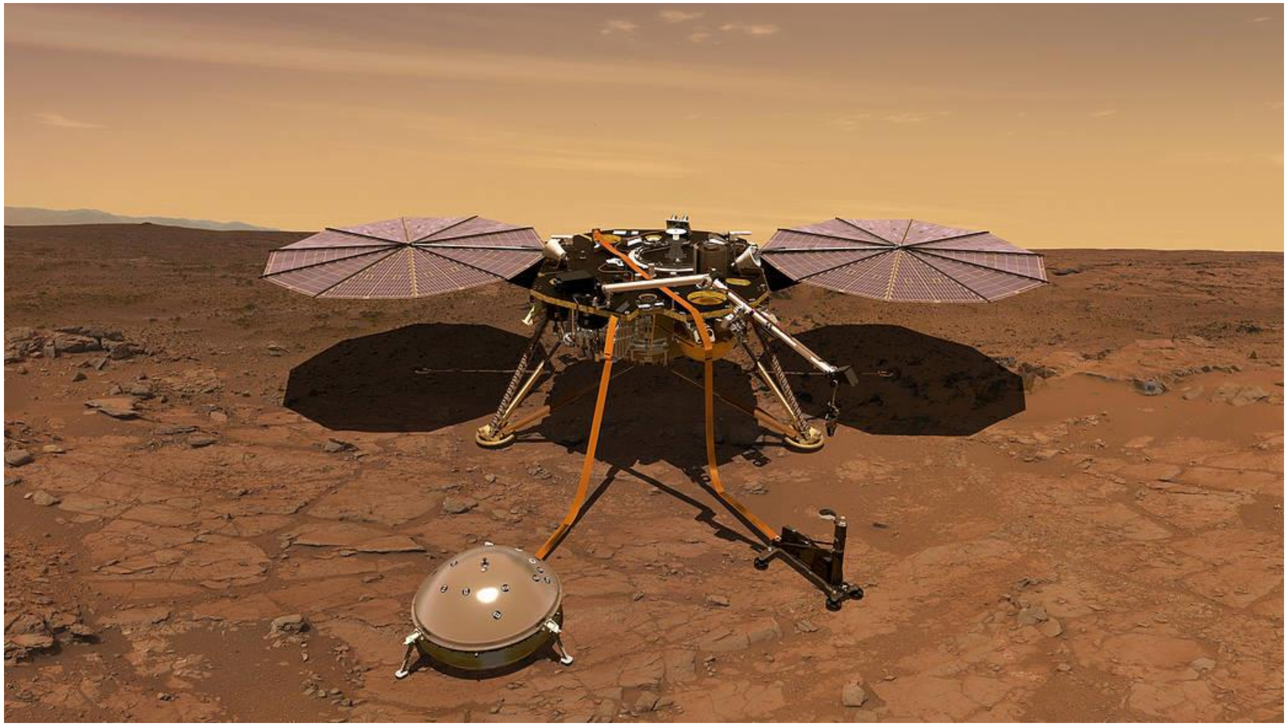

Wheel tracks from Curiosity,
Created as it drove over
sandy floor
of Gale Crater

A tadpole crater:
Valley (tadpole tail) carved by outflow of water that once filled the impact crater.

Ladon Basin: large impact crat
filled with sediment deposited b
major ancient river (Ladon Valle
Wet sediments are now layers
clay minerals, which would be
favorable to ancient Martian li

INSIGHT Mission (NASA)

- launched May 5, 2018
- landing scheduled for November 26, 2018

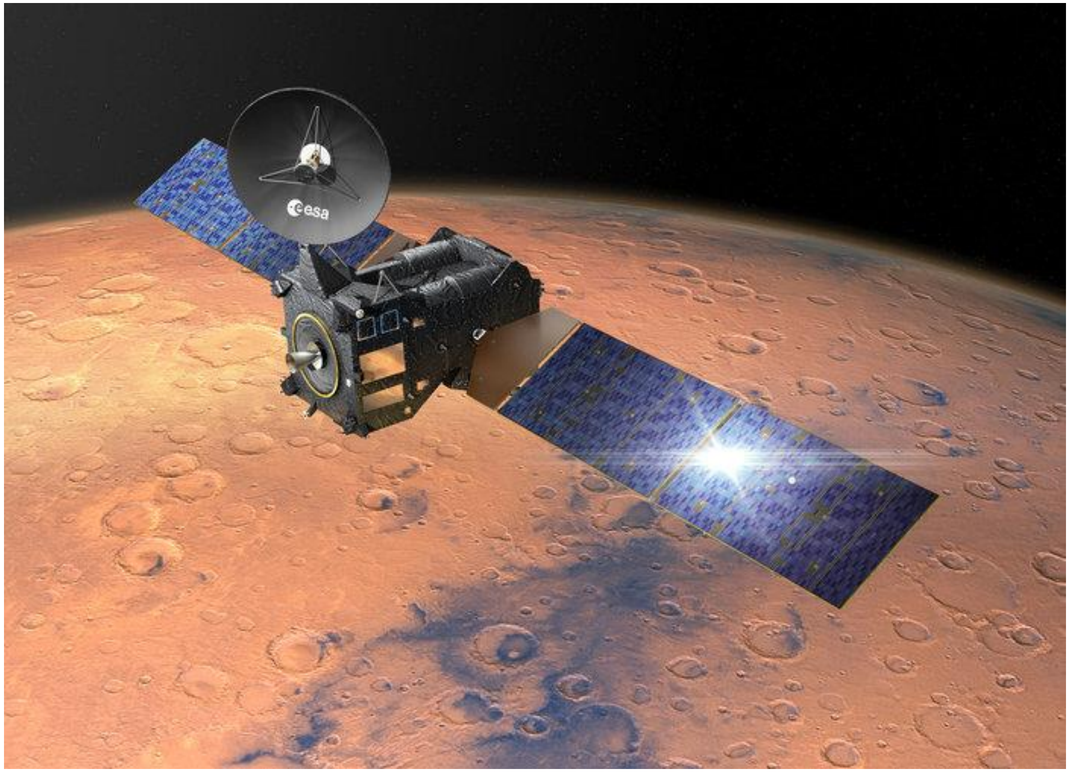


InSight (Interior Exploration using Seismic Investigations, Geodesy and Heat Transport) is a Mars lander full of geophysical instruments. Using a seismometer, heat flow probe, and precision tracking it seeks to explore the deep interior of Mars and improve our understanding of the formation of terrestrial planets.

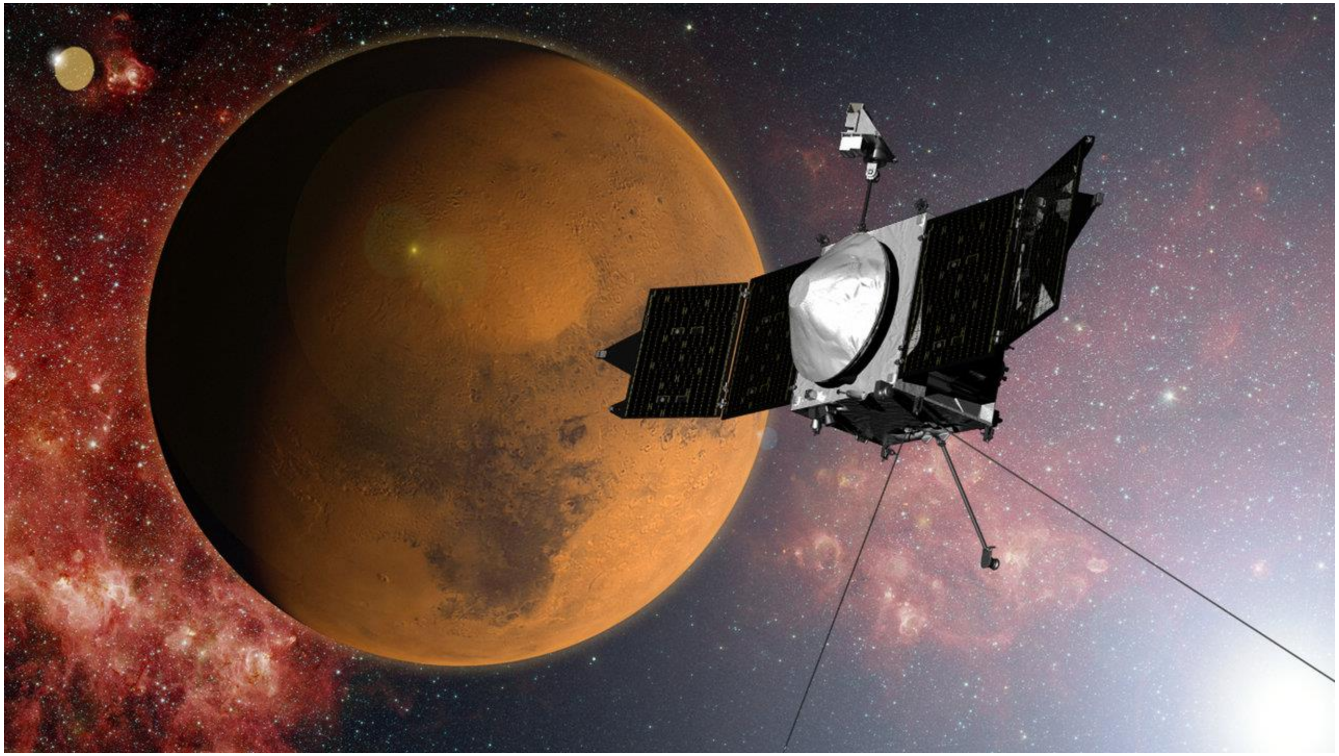
ExoMars Trace Gas Orbiter
Mars orbiter and lander (ESA)

Launch: March 14, 2016
Mars orbit insertion: October 19, 2016

This first mission of ESA's ExoMars program consists of a Trace Gas Orbiter plus an Entry, descent and landing Demonstrator Module, known as Schiaparelli (which transmitted data during its descent before crash landing on the martian surface). The main objectives of this mission are to search for evidence of methane and other trace atmospheric gases that could be signatures of active biological or geological processes and to test key technologies in preparation for ESA's contribution to subsequent missions to Mars.*



From www.planetary.org



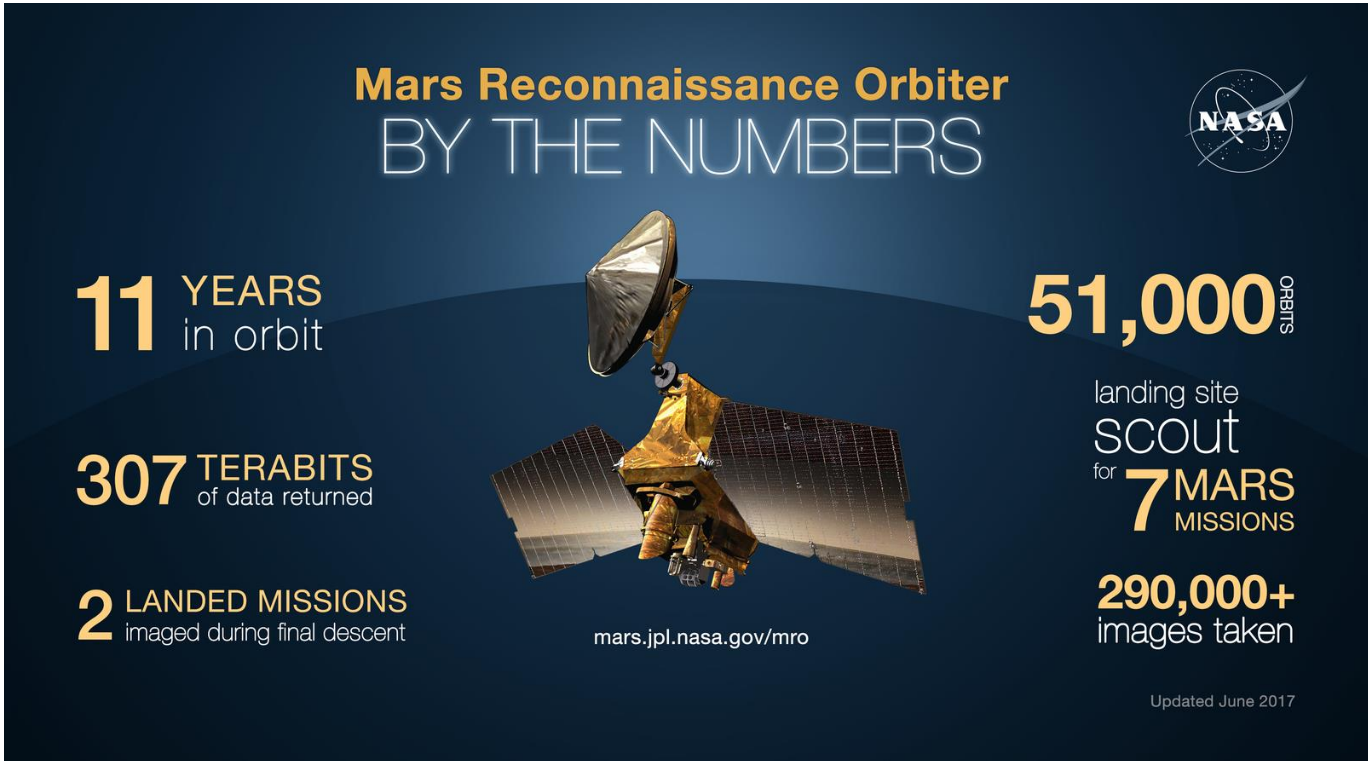
MAVEN
Mars orbiter (NASA)
Launch: November 18, 2013
Mars orbit insertion: September 22, 2014
MAVEN, which stands for Mars Atmosphere and Volatile Evolution mission, has provided first-of-its-kind measurements to address key questions about Mars climate and habitability and improve understanding of dynamic processes in the upper Martian atmosphere and ionosphere.*

From www.planetary.org

Mars Orbiter Mission (MOM)
Mars orbiter (ISRO)
Launch: November 5, 2013
Mars orbit insertion: September 24, 2014
Sometimes referred to by the nickname "Mangalyaan," the Mars Orbiter Mission is India's first interplanetary spacecraft. It is primarily a technology demonstration mission that carries a small, 15-kilogram payload of 5 science instruments. It entered orbit at Mars in September 2014, just two days after the arrival of NASA's MAVEN mission. The orbit is highly elliptical, from 387 to 80,000 kilometers.*

Curiosity (Mars Science Laboratory) (MSL)
Mars rover (NASA)
Launch: November 26, 2011
Landing: August 6, 2012
Curiosity is the next generation of rover, building on the successes of Spirit and Opportunity. It landed in Gale Crater, the location of a 5+ km tall mound of layered sedimentary material, which Curiosity has found was at least partially deposited in a lake setting. The rover has also made key discoveries such as the detection of organic material. After a 2-(Earth)-year trek from its landing site, it is now entering the foothills of the mound, dubbed "Mount Sharp" (or Aeolis Mons), where it will then start its ascent up the mound. *

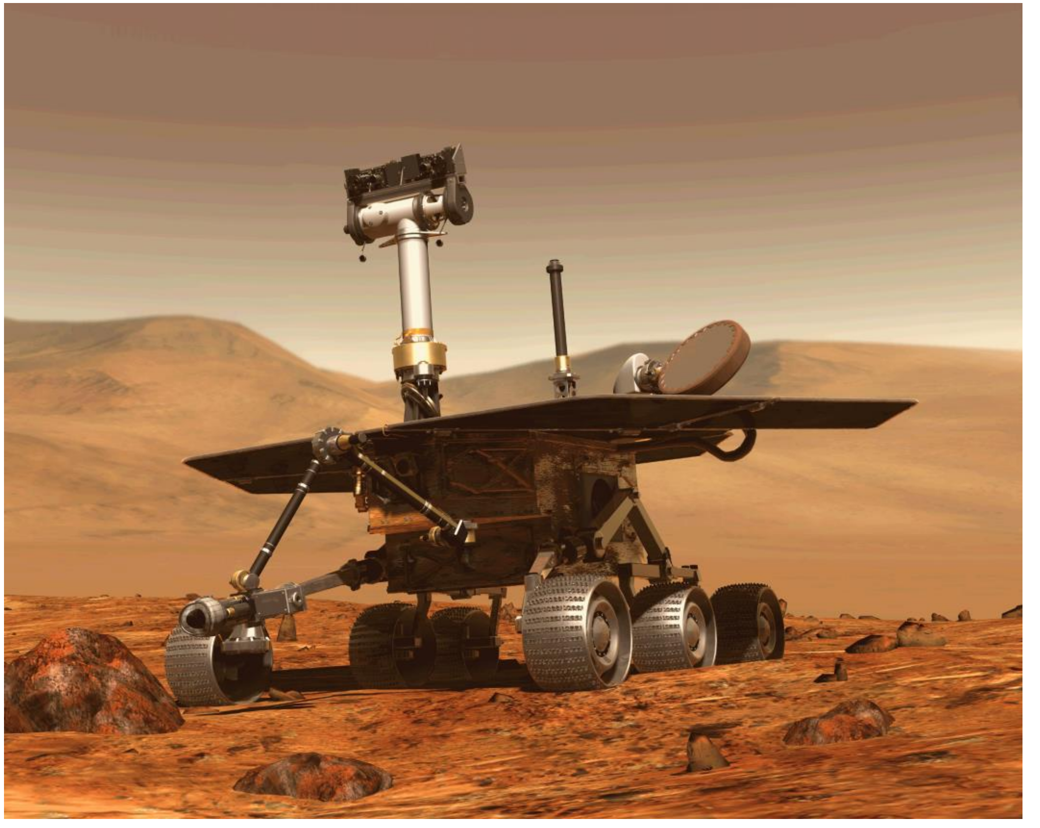
From www.planetary.org



As of June 2017

Mars Reconnaissance Orbiter
In orbit at Mars (NASA)
Launch: August 12, 2005
Mars arrival: March 10, 2006
The Mars Reconnaissance Orbiter is searching for evidence of past water on Mars, using the most powerful camera and spectrometer ever sent to Mars. Its cameras are also helping in the search for landing sites for future Mars rovers and landers, and to monitor martian weather on a day-to-day basis.*

From www.planetary.org



Mars Exploration Rover Opportunity
Currently roving across Mars (NASA)
Launch: July 7, 2003
Landing: January 24, 2004
Opportunity landed in Meridiani Planum at 354.4742°E, 1.9483°S, immediately finding the hematite mineral that had been seen from space by Mars Global Surveyor. After roving more than 33 kilometers, Opportunity arrived at the 22-kilometer-diameter crater Endeavour, a target it is currently exploring.*

Note: currently unresponsive after losing power in latest dust storm

From www.planetary.org

Mars Express
Currently in orbit at Mars (ESA)
Launch: June 2, 2003
Mars arrival: December 26, 2003
Mars Express successfully entered orbit on December 26 and immediately began returning stunning, 3D, color images. Mars Express has detected surprising concentrations of methane and evidence for recent volcanism on Mars. Its radar sounder, MARSIS, was deployed late in the mission due to spacecraft safety concerns, but is functioning well.

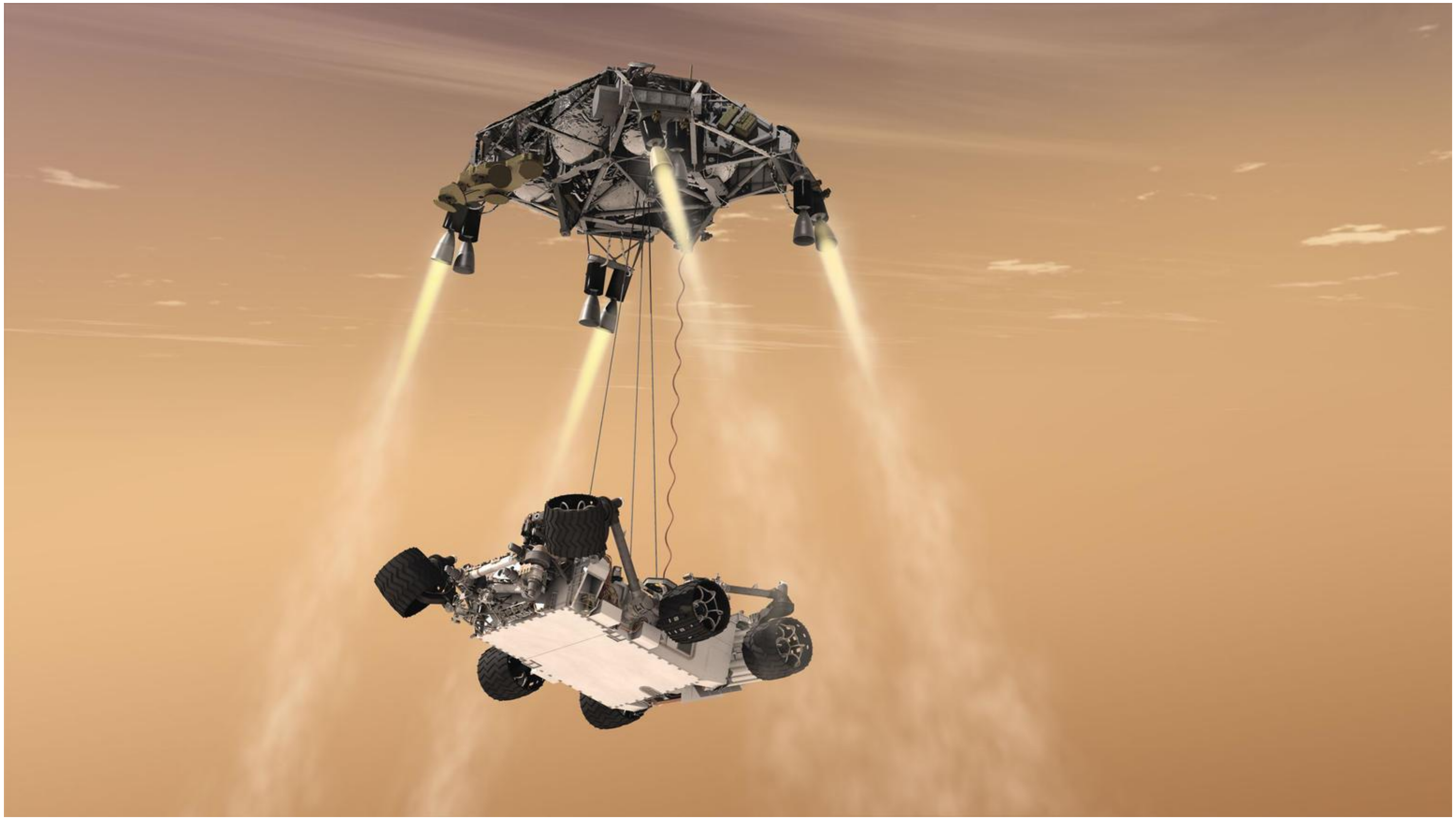
From www.planetary.org

2001 Mars Odyssey
Currently in orbit at Mars (NASA)
Launch: April 7, 2001
Mars arrival: October 24, 2001
Mars Odyssey is capturing images of the Martian surface at resolutions between those of Viking and Mars Global Surveyor, and is making both daytime and nighttime observations of the surface in thermal infrared wavelengths at resolutions higher than ever before. It has detected massive deposits of water lying below Mars' surface in near-polar regions and widespread deposits of olivine across the planet, indicating a dry past for Mars. The MARIE instrument measured the radiation environment at Mars to determine its potential impact on human explorers, and found them to be 2 to 3 times higher than expected. Odyssey also serves as a communications relay for the Opportunity and Curiosity rovers.*

From www.planetary.org

FUTURE MISSION
2020 ExoMars Rover (ESA)

The ExoMars rover will travel across the Martian surface to search for signs of life. It will collect samples with a drill and analyse them with next-generation instruments. ExoMars will be the first mission to combine the capability to move across the surface and to study Mars at depth.



FUTURE MISSION
2020 Mars 2020 Rover (NASA)
Launch: July/August

The mission takes the next step by not only seeking signs of habitable conditions on Mars in the ancient past, but also searching for signs of past microbial life itself. The Mars 2020 rover introduces a drill that can collect core samples of the most promising rocks and soils and set them aside in a "cache" on the surface of Mars. A future mission could potentially return these samples to Earth.

Elon Musk

SpaceX

May 5: Dragon resupply (of International Space Station) mission

May 22: launch of five Iridium NEXT satellites and two GRACE-FO satellites from Vandenberg Air Force Base, California.

August 7: launch of Falcon 9 from Cape Canaveral with satellite for PT Telkom Indonesia

September 10: deployment launch of Telstar Vantage satellite

October 7: launch of SAOCOM 1A satellite from Space Launch Complex 4E (SLC-4E) at Vandenberg Air Force Base in California.

FALCON HEAVY

Falcon Heavy is the most powerful operational rocket in the world by a factor of two. With the ability to lift into orbit nearly 64 metric tons (141,000 lb)---a mass greater than a 737 jetliner loaded with passengers, crew, luggage and fuel--Falcon Heavy can lift more than twice the payload of the next closest operational vehicle, the Delta IV Heavy, at one-third the cost. Falcon Heavy draws upon the proven heritage and reliability of Falcon 9.

First launch: March 10, 2018

BFR: Big Falcon Rocket

On September 17, 2018, SpaceX announced fashion innovator and globally recognized art curator Yusaku Maezawa will be the company’s first private passenger flight around the Moon for 2023. This first private lunar passenger flight, featuring a fly-by of the Moon as part of a weeklong mission, will help fund development of the BFR vehicle, an important step in enabling access for everyday people who dream of flying to space.

Jeff Bezos

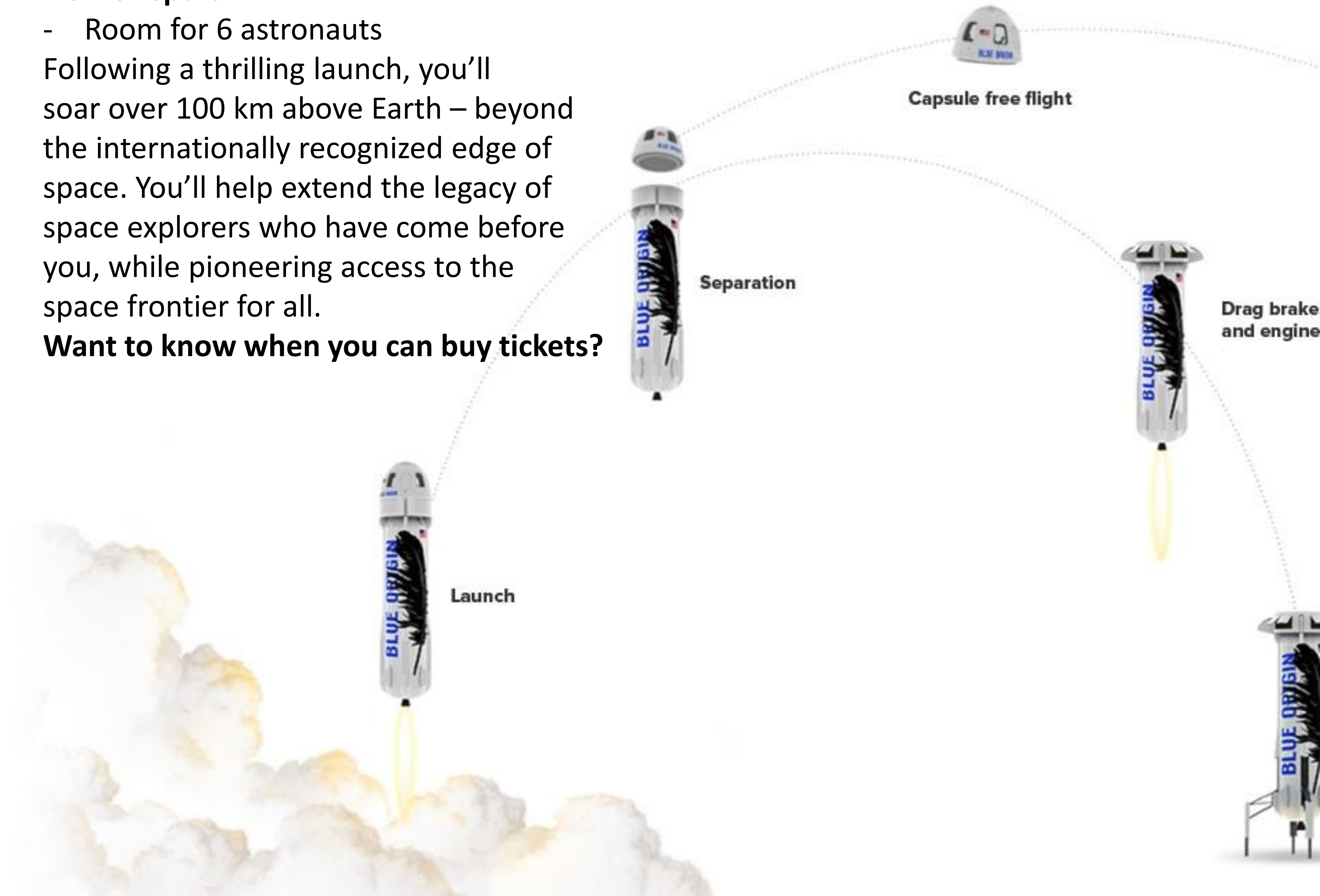
Blue Origin

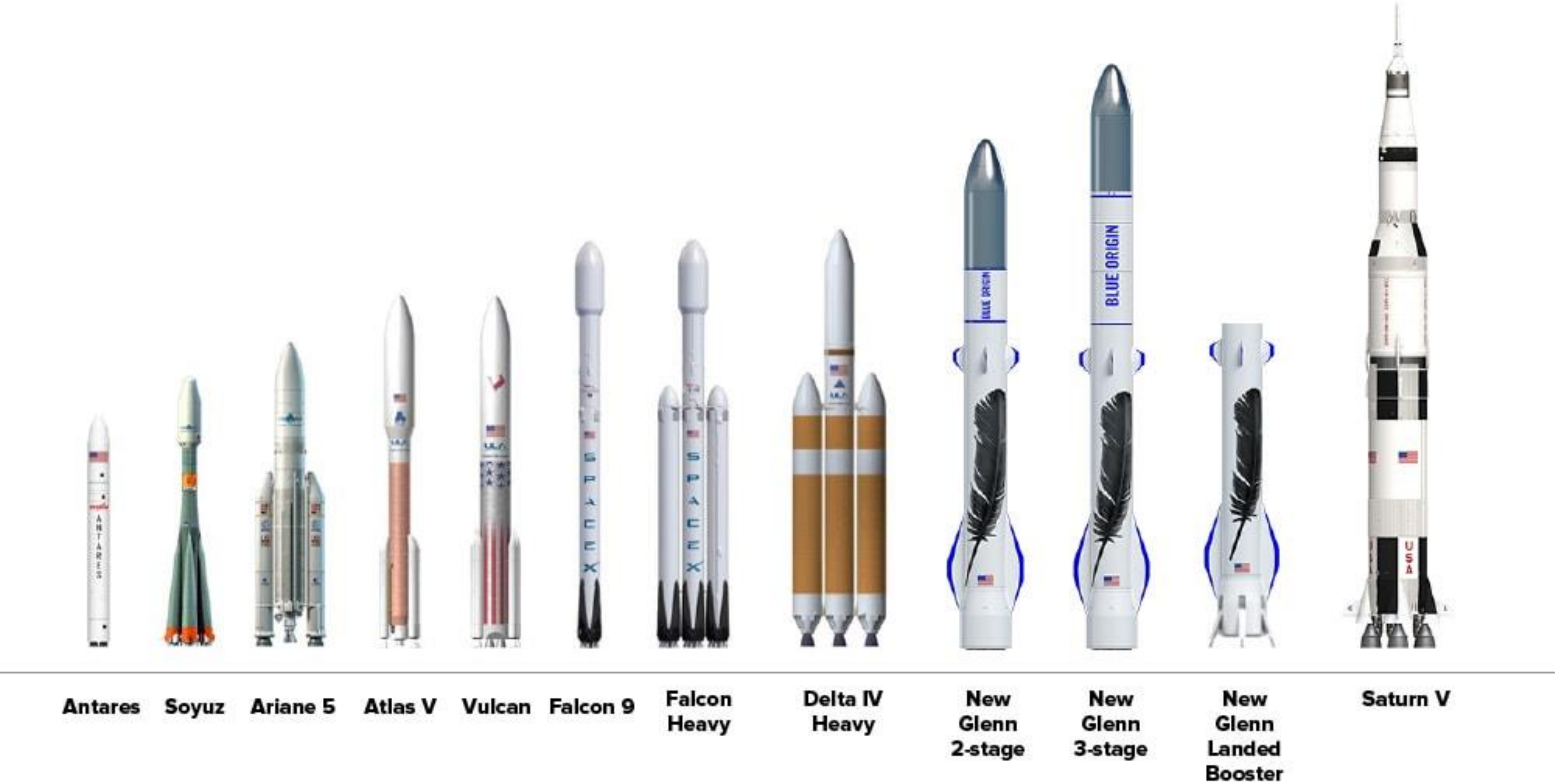
New Shepard

- Room for 6 astronauts

Following a thrilling launch, you'll soar over 100 km above Earth – beyond the internationally recognized edge of space. You'll help extend the legacy of space explorers who have come before you, while pioneering access to the space frontier for all.

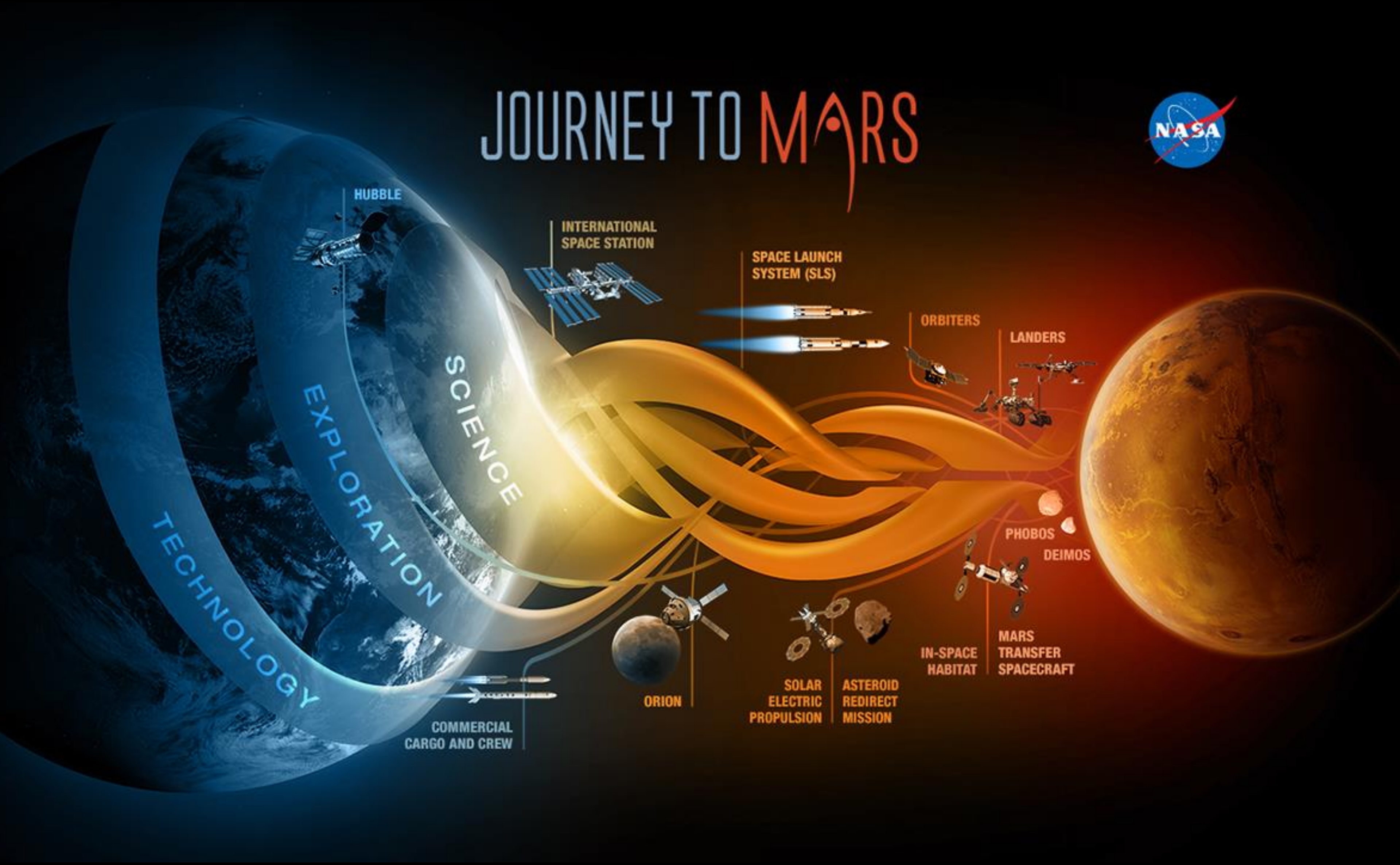
Want to know when you can buy tickets?





New Glenn

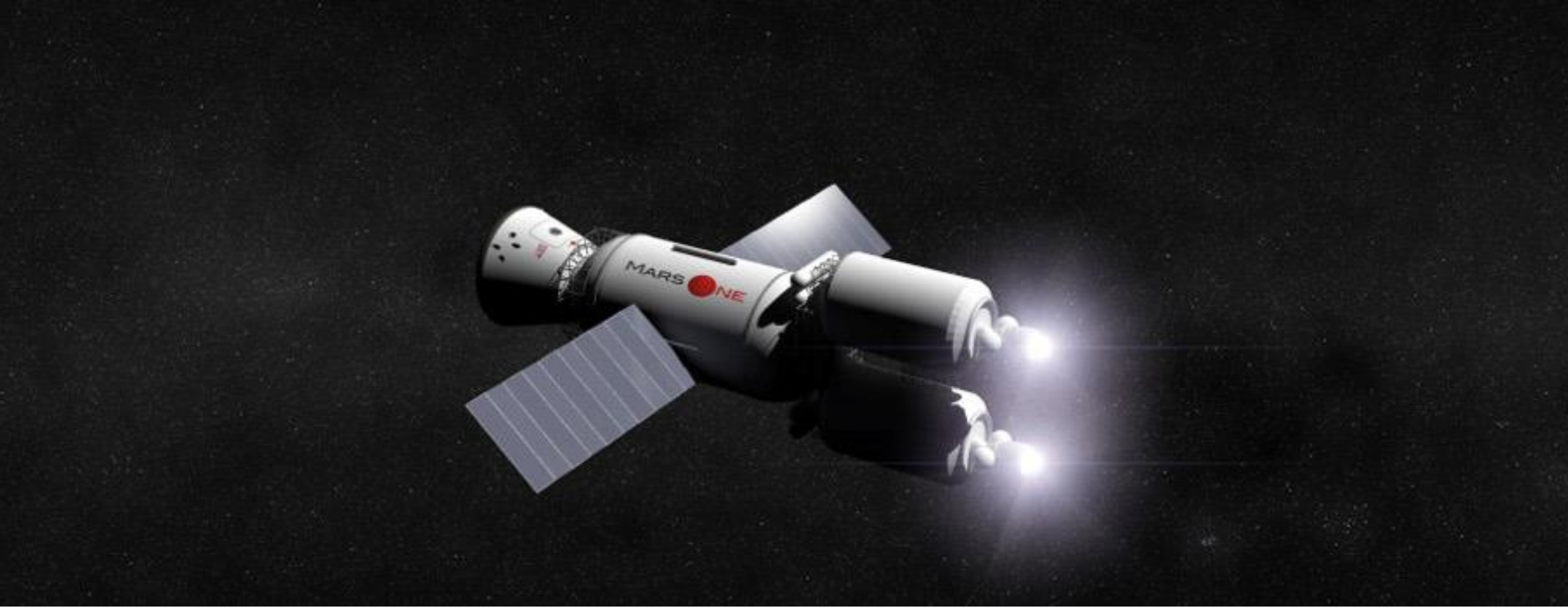
Introducing *New Glenn*, a major step toward achieving our vision of millions of people living and working in space. Featuring a fully reusable first stage, *New Glenn* will carry people and payloads routinely to Earth orbit.

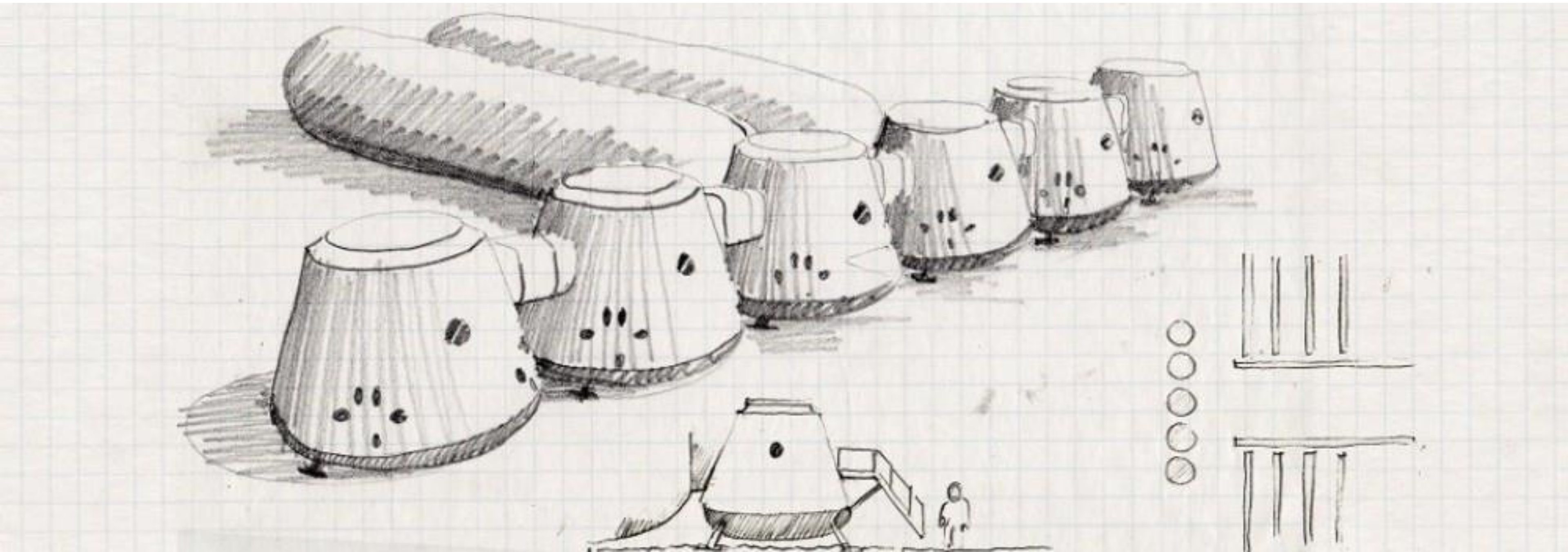


JOURNEY TO MARS
NASA
HUBBLE
INTERNATIONAL SPACE STATION
SPACE LAUNCH SYSTEM (SLS)
ORBITERS
LANDERS
SCIENCE
EXPLORATION
TECHNOLOGY
PHOBOS
DEIMOS
IN-SPACE HABITAT
MARS TRANSFER SPACECRAFT
SOLAR ELECTRIC PROPULSION
ASTEROID REDIRECT MISSION
ORION
COMMERCIAL CARGO AND CREW

United Arab Emirates

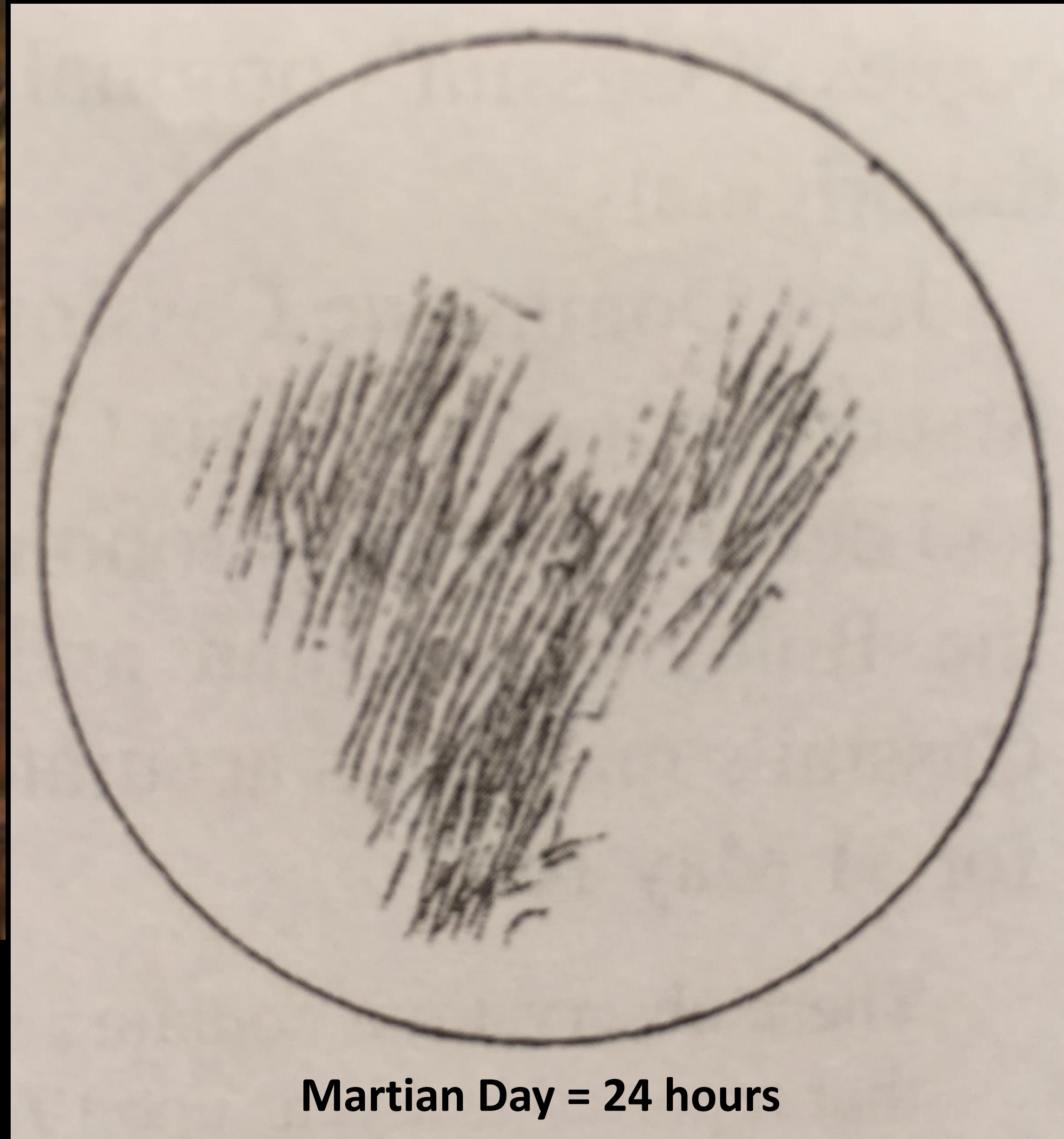
Mars 2117


MARS ONE



Mars


Saturn, with Titan
Mars
M22



Christiaan Huygens: 1659