

PLANET MARS IN 3-D

On June 2, 2003, the first European mission to another planet took off from the Baikonur cosmodrome in Kazakhstan: Mars Express. Since 25 December 2003, the probe of the European Space Agency (ESA) has been flying around Earth's outer neighbor on an elliptical orbit. On this orbit, the point of closest approximation to Mars is about 250 kilometers above the planet's surface. The mission is scheduled to last until the end of 2016.

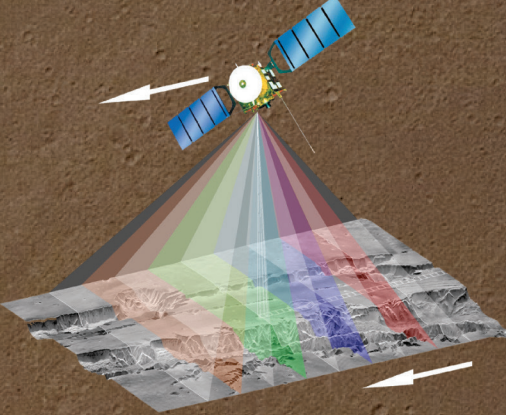
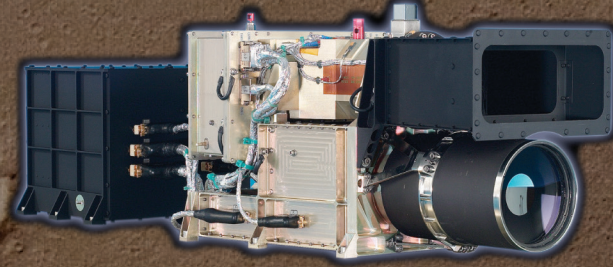
All seven scientific experiments on board are designed to help observe and explore the Red Planet closely, including the High Resolution Stereo Camera (HRSC) that was developed and built in Germany. It is the first camera system on an interplanetary mission to systematically deliver high-definition stereo image data in color.

The ultimate objective of the HRSC experiment is to generate a global topographical map of Mars with a resolution better than 40 meters per pixel, with major parts of Mars being mapped at a precision of 20 and even ten meters per pixel. By the end of the mission, a topographical model covering the surface of the entire planet should be available.

Three-dimensional images showing the terrain on the Martian surface are of great benefit to science. The elevation data contained in the high-resolution imagery will significantly improve our theories concerning the geological evolution of the planet in the course of its history of four-and-a-half billion years.

This highly precise 3-D mapping process became possible thanks to an imaging technique used for the first time in planetary research: the HRSC uses light-sensitive line sensor arrays arranged across track to scan the landscape as it passes beneath the probe. Thus, two sets of four channels – four of those eight channels are equipped with different color filters – view the ground simultaneously,

looking both ahead and astern in the direction of flight at various angles. Pointing vertically downward, the nadir array delivers the most highly defined images. The camera features an integrated telescope lens. This channel, called „Super Resolution Channel“ (SRC) delivers square images with a resolution of 2.5 meters per pixel along the track of the HRSC.

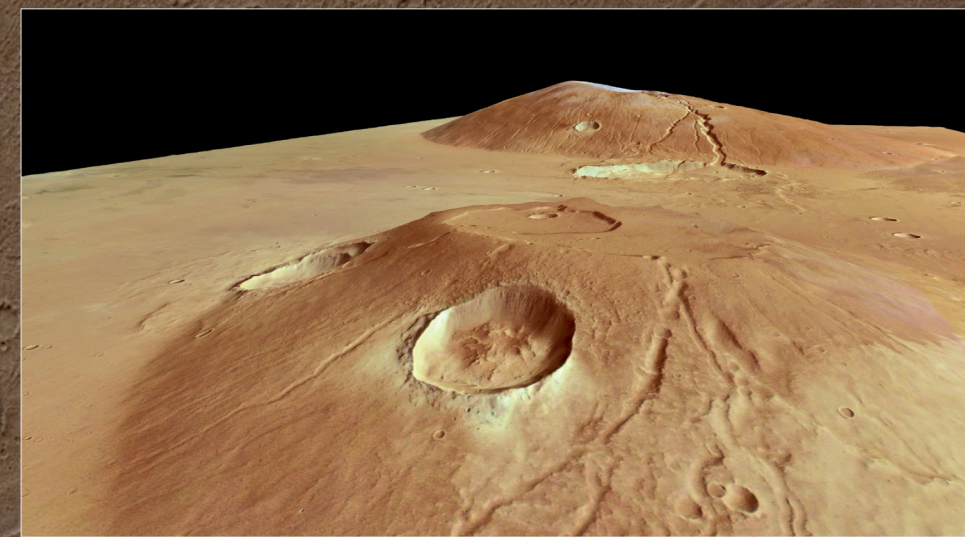


VOLCANOES

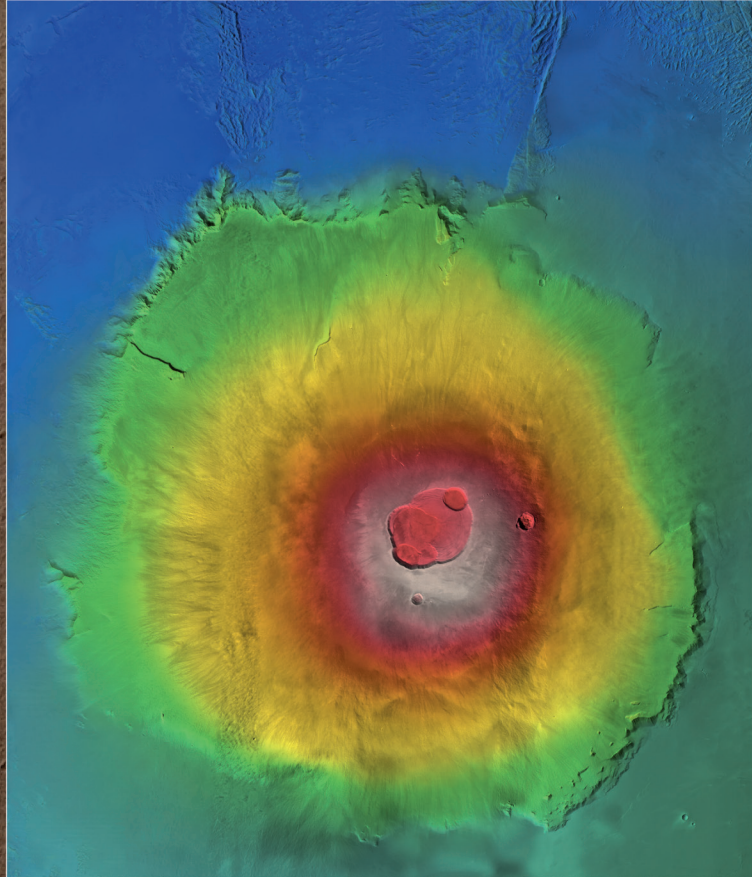
We have known of the existence of gigantic volcanoes on Mars ever since automated space probes radioed the first pictures back to Earth in the 1970s. Olympus Mons measures more than 500 kilometers in diameter and rears up to a height of 26 kilometers above its surroundings, which makes it the highest volcano in the solar system. Not far from it, there are another three volcanoes that peak at between 15 and 21 kilometers – Ascreaeus Mons, Arsia Mons, and Pavonis Mons on the Tharsis plateau. Measuring almost 1,600 kilometers in diameter, even the rather flat looking Alba Patera, which is 5 kilometers high, is a gigantic volcano.

Quite obviously, volcanism was extremely active on Mars in the early age of the planet, as witnessed not only by its volcanic cones and shields but also by large areas that are covered by flows of hardened lava that was once highly fluid.

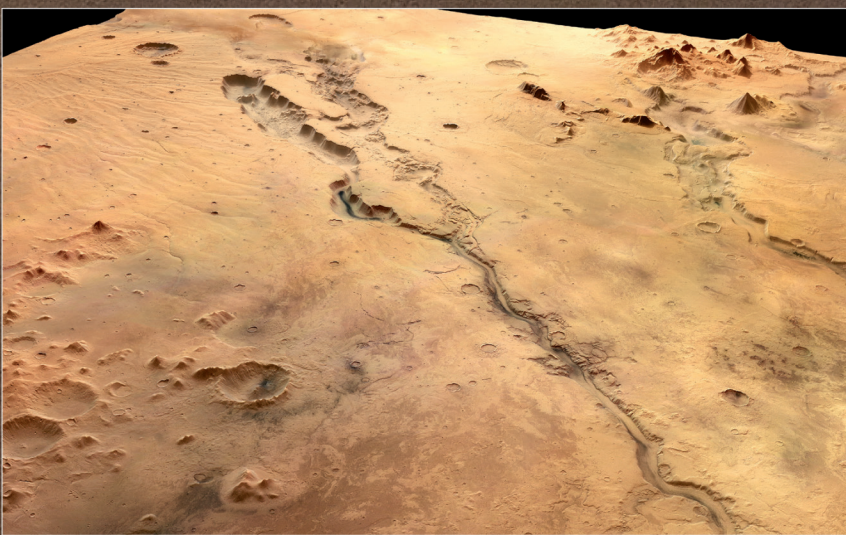
However, when the data of Mars Express were evaluated they showed that some of the large shield volcanoes in the big volcanic province of Tharsis were active until only a few million years ago – a mere instant in geological terms.



Above: Olympus Mons, color-coded elevation model  
Below: Uranus Tholus and Ceraunius Tholus (front)



WATER



The question that is most hotly discussed by Martian researchers is this: during what period did the planet have bodies of flowing water? And another: how much water was it, and where did it go?

There is no dispute that large quantities of water must have been flowing on the surface of Mars in the planet's early

days. What else could explain valleys many hundred kilometers in length, which closely resemble riverbeds on Earth? Next to ramified valley systems, numerous outflow channels stretch from the Martian highlands to the low-lying plains in the north. Minerals that can form only in an aqueous environment bear witness to the fact that water once flowed into craters and depressions, forming stagnant bodies of water at least for a certain period. Clay minerals formed first and mineral salts later on, indicating a dramatic climate change on Mars.

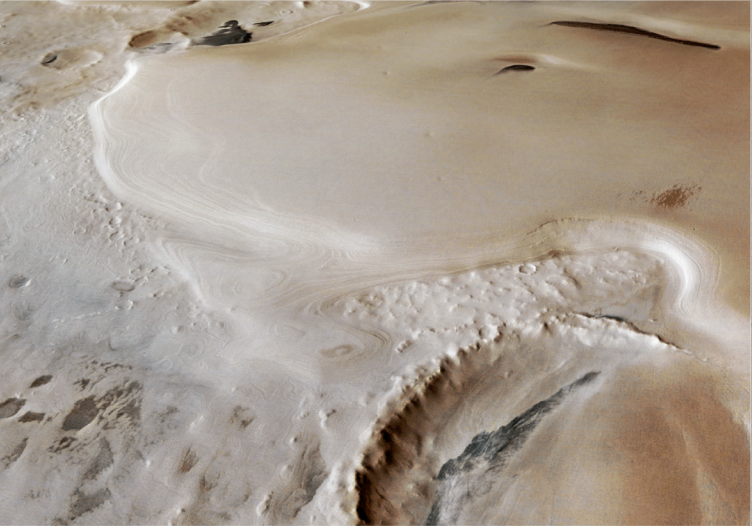
What we do not yet know is whether the water that eroded these outflow channels seeped into the soil of the northern lowlands, where it may still be present as ice in cavities below the surface, or escaped into space. After all, when we look for water, it is with one question at the back of our mind: might not this planet have harbored life at one time?



Above: Dao and Niger Valles  
Below: Ares Vallis source region

ICE

Temperatures on Mars are very much lower than on Earth. Any water would immediately solidify into ice. Astronomers discovered as early as in the 17th and 18th centuries that the poles of Mars are covered by ice. Space probes showed that in winter, when temperatures drop below minus 130 degrees Celsius, the ice caps on the north and south pole are enlarged considerably by carbon dioxide ice. Much of it evaporates again in the spring, leaving behind a shield of water ice at the north pole and a mixture of water and carbon dioxide ice at the south pole.



Radar measurements show that large volumes of ice are present under the surface in the northern plains of Mars. Its source might be water that once flowed from the highlands through the big valleys towards the north, where it seeped into the ground and froze.

Moreover, HRSC images show clear indications of the presence of ice in the temperate latitudes. Moving in a dense mixture of rock debris, sand, and dust, so-called rock glaciers slid down the slopes. We do not know how much ice still remains below the protective layer of dust spread by these rock glaciers. At the same time, the continually changing inclination of the polar axis had a considerable influence on where and when ice sheets formed on Mars.

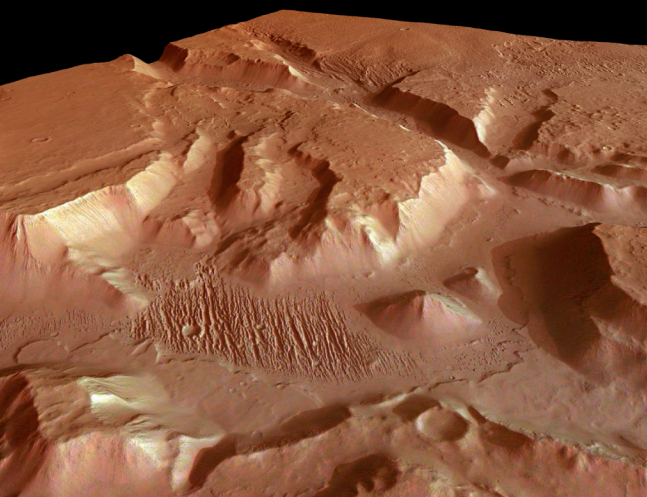
Above: Promethei Planum in the south pole region  
Below: Chasma Boreale near the north pole



10 YEARS HIGH RESOLUTION STEREO CAMERA ON MARS EXPRESS

TECTONICS

Disturbances on the surface of Mars indicate that there are processes going on in its interior. Tensions in the crust may be caused by a variety of forces. They might, for example, be caused by the movement of viscoelastic masses of rock within the mantle of Mars: when hot material slowly rises from the depths, exerting pressure from below on the outer rocky envelope (the so-

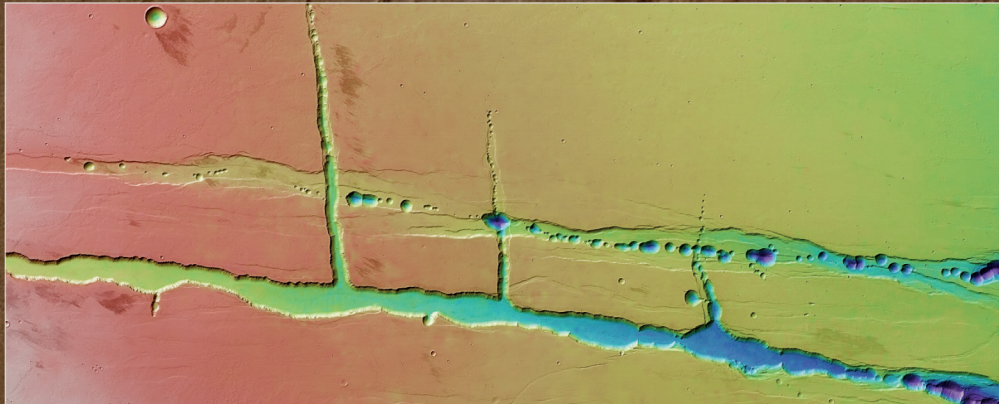


called lithosphere), this leads to the formation of large regional bulges. When tension rises beyond the limit of stress, rock may be destroyed by brittle fracture. If, however, the deformation is plastic, the rock will change shape without breaking up, leading to the formation of folds.

Studying these tectonic structures permits us to take an – albeit restricted –

look at the interior and the dynamics of Mars. To be sure, Mars has no plate tectonics like Earth, where the process moves entire rocky plates. Today, the lithosphere of Mars is cool enough to permit large-scale elastic deformation. While Earth's lithosphere consists of about a dozen individual plates, Mars has only a single global lithosphere plate. Along zones of high strain, patterns of rifts and clefts form that frequently feature volcanoes as well. In these rift zones, a landscape called 'horst and graben system' evolved, similar to what happened on Earth along the upper Rhine graben or the Rift Valley in eastern Africa.

Wherever there is compressive stress, which crushes the rock, so-called reverse- or thrust faults may occur as blocks of rock are pushed on top of one another. The Tharsis region is entirely surrounded by a concentric belt of structures like these.



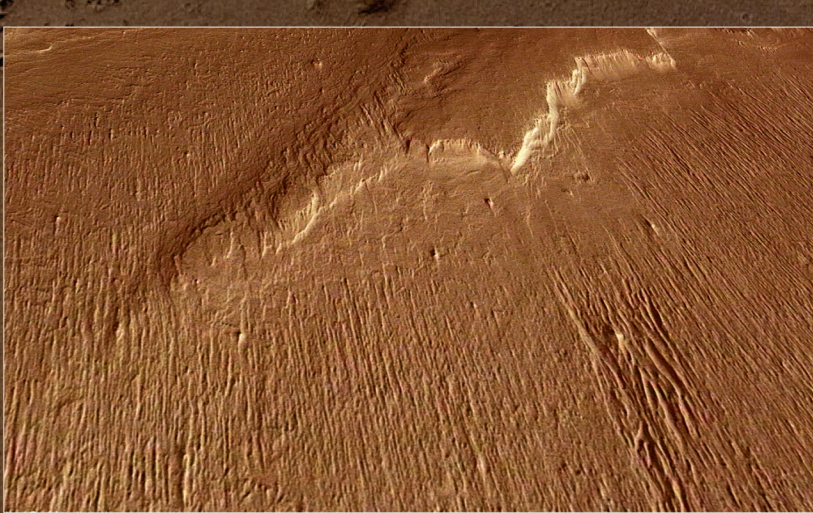
Above: Noctis Labyrinthus  
Below: Color-coded elevation model of Tractus Catena

ATMOSPHERE AND WIND

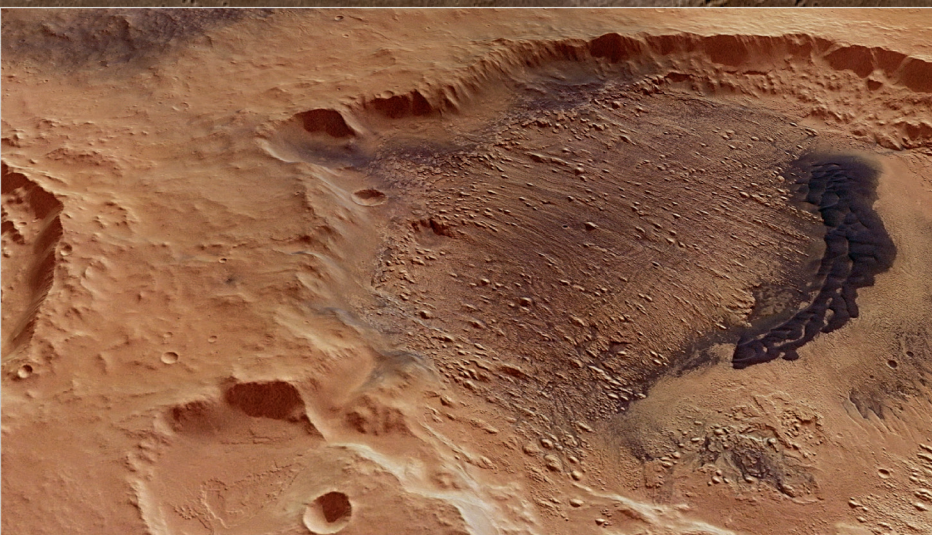
Like Earth, a gaseous envelope surrounds Mars.

However, the Martian atmosphere is very much thinner than that of Earth, and its composition is different, too: it consist of 95 per cent carbon dioxide, mixed with some nitrogen, argon, and traces of other gases. As, moreover, the spin axis of Mars is inclined relative to its orbit around the Sun, Mars has distinct seasons which, however, last twice as long as on Earth because of its two-year orbital period. The annual variation in solar irradiation at the equator, in the temperate latitudes, and at the poles causes an exchange of energy between the equatorial latitudes and the poles. The weather on Mars is therefore quite dynamic.

It is the weather that causes the surface of Mars to change slowly but steadily. Characteristic weather events include powerful, long-lasting storms, which pick up dust and tiny grains of sand from the ground, carry them around the entire globe, and deposit them elsewhere. One of the results of this process is the existence of dunes, a frequent phenomenon on the desert planet. Thus, for example, a broad belt of sand dunes several hundred kilometers wide encircles the north pole. Imperceptibly, over hundreds of millions of years, at a rate smaller than that on Earth by several orders of magnitude, boulders and stones are being ground down by the slight but persistent erosive force of the wind,



Above: Dunes in Danielson crater  
Below: Yardangs in Gordii Dorsum



SEARCH FOR LIFE

Mars is the planet that most closely resembles our Earth, the only one in the solar system on which life might conceivably exist. In the planet's early age, water flowed across its surface at least temporarily, forming stagnant pools here and there. Water is seen as an indispensable prerequisite for the existence of life. Moreover, we find on Mars and in its atmosphere certain chemical elements that are necessary for life, including carbon, hydrogen, oxygen, nitrogen, sulphur, and phosphorus. Lastly, it has both an external and an internal source of energy, one being the Sun, and the other being the heat stored in the interior of the planet, which feeds the volcanoes.

We have not yet found an answer to the question of whether life has ever existed on Mars or might even exist today. We do not know whether the periods in which water was present were long enough to allow life to evolve, and whether temperatures were higher then. To this day, neither fossil nor living samples of life have been discovered on Mars. Still, searching for life on Mars remains one of the most important tasks in planetary research.

MARTIAN MOONS

Phobos and Deimos, the two moons of Mars, were discovered in 1877. Meaning 'fear' and 'terror', their names were taken from the companions of the Greek god of war, Ares. Phobos (photo) is an irregularly shaped body measuring between 18.4 and 27.8 kilometers in diameter. It takes 7.65 hours to complete one orbit at an altitude of nearly 6,000 kilometers above the Martian equator. Deimos, whose diameter ranges between 10.4 and 15.0 kilometers, circles around Mars at the distance of about 20,000 kilometers, taking 1.26 terrestrial days to complete an orbit. The rotation of both moons is 'coupled' to that of Mars, meaning that they turn once around their axis in the time they need to orbit the planet. Consequently, they always turn the same face towards Mars.

What is unclear about the two moons is their origin. Their surface is darker than that of Mars, prompting the assumption that Phobos and Deimos are not 'children' of Mars but asteroids that were trapped by the planet's gravity.



MARS IN COMPARISON WITH EARTH

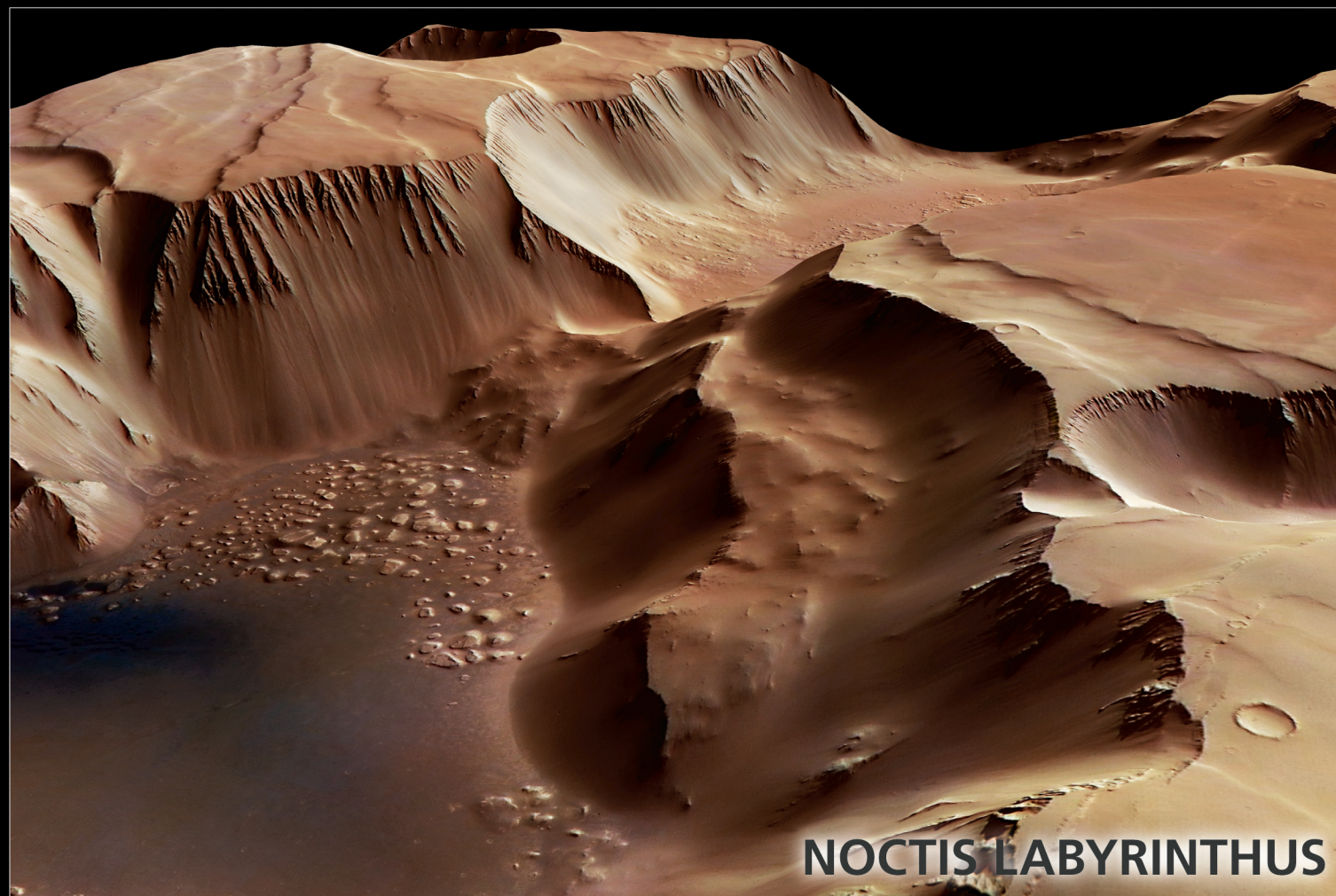
	MARS	EARTH
Diameter	6779 km	12,742 km
Surface	144 Mio. km²	510 Mio. km²
Mass	0.642 x 10 <sup>24</sup> kg	5.976 x 10 <sup>24</sup> kg
Gravitation	3.69 m/s²	9.78 m/s²
Orbit	227,900,000 km	149,600,000 km
Length of a Year	687 days	365.24 days
Length of a Day	26.62 hours	23.93 hours
Axial tilt	25.2°	23.4393°
Topography	-8000 m to 21,200 m	-11,000 m to 8850 m
Temperature	-60 °C (-133 °C to 27 °C)	15 °C (-88 °C to 58 °C)
Mean air pressure	6.35 mbar	1013 mbar
Atmosphere	95% CO <sub>2</sub> , 3% N <sub>2</sub> , 2% Ar	78% N <sub>2</sub> , 21% O <sub>2</sub> , 1% Ar

The German Aerospace Centre (DLR) presents a series of pictures from the ongoing Mars Express mission. The image material was taken by the HRSC, a high-resolution stereo camera that was developed and built at DLR. An experiment team headed by Professor Ralf Jaumann at the DLR Institute of Planetary Research is responsible for operating the High Resolution Stereo Camera. The images on display were created from the HRSC data record by the Institute of Geological Sciences at the Freie Universität Berlin in collaboration with the DLR Institute of Planetary Research. DLR scientists present six current themes of Martian research.

Links:	<a href="http://www.dlr.de/mars-express">www.dlr.de/mars-express</a> <a href="http://www.dlr.de/mex10">www.dlr.de/mex10</a> <a href="http://www.esa.int/marsexpress">www.esa.int/marsexpress</a> <a href="http://www.geoinf.fu-berlin.de/projekte/mars/">www.geoinf.fu-berlin.de/projekte/mars/</a>
Contact:	Regional Planetary Image Facility DLR Berlin Rutherfordstr. 2, 12489 Berlin, Germany E-Mail: <a href="mailto:rpif@dlr.de">rpif@dlr.de</a> <a href="http://www.dlr.de/rpif/">www.dlr.de/rpif/</a>
Design:	Susanne Pieth, Ulrich Köhler (DLR), HRSC-Experiment-Team, 2013
Image Credits:	all images Mars, Phobos: ESA/DLR/FU Berlin (G. Neukum) HRSC: EADS/Astrium graphic imaging technique HRSC: DLR



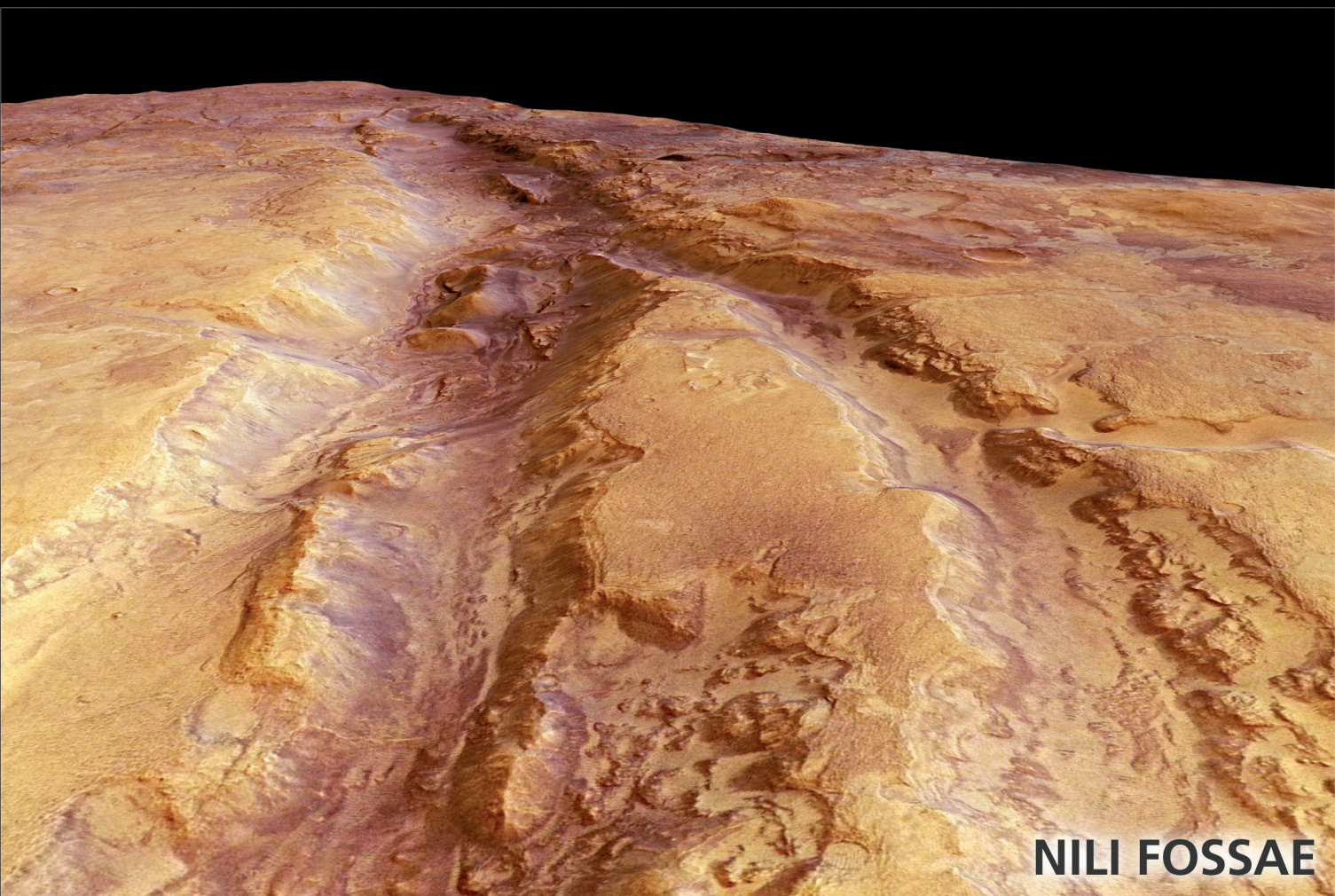




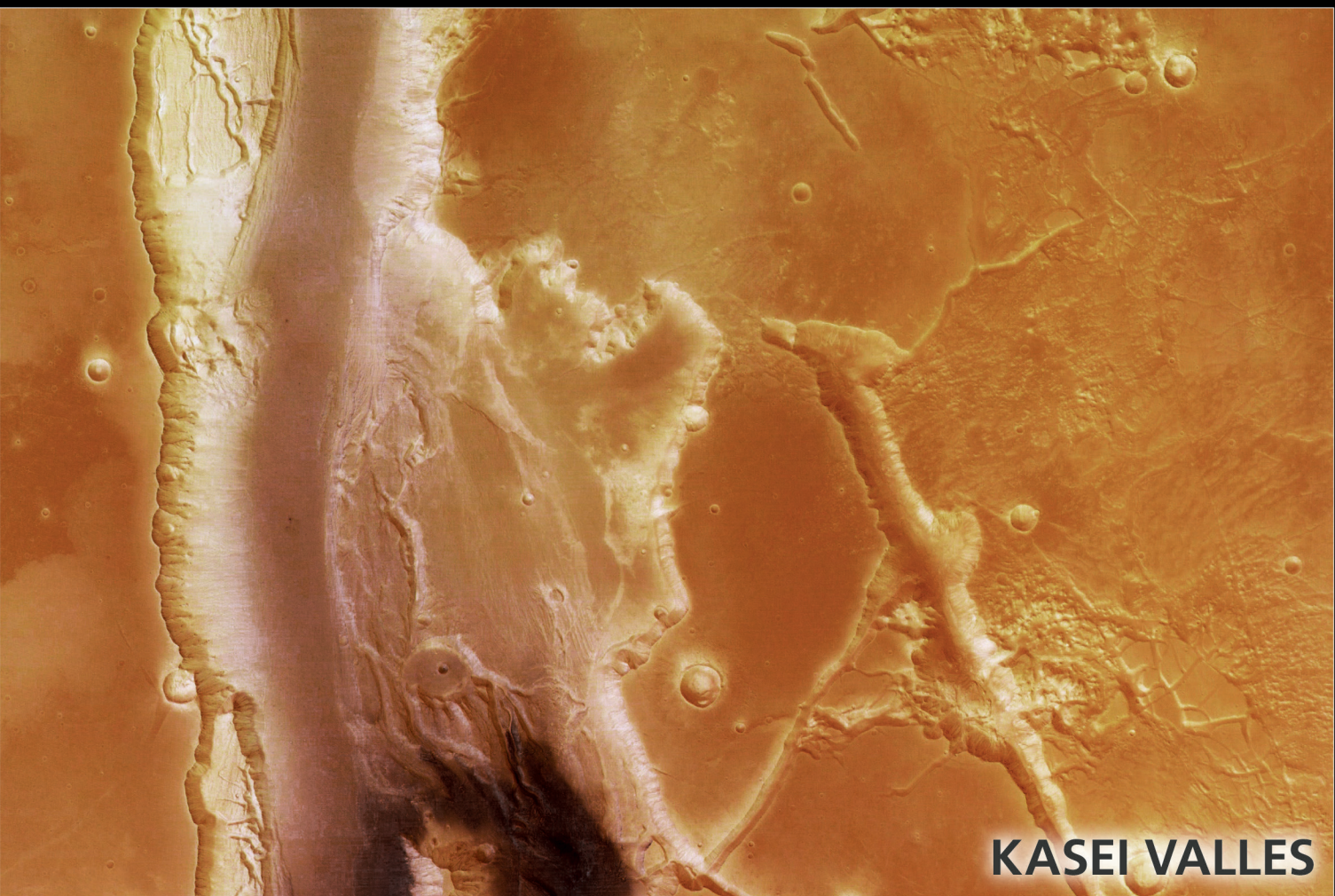
NOCTIS LABYRINTHUS



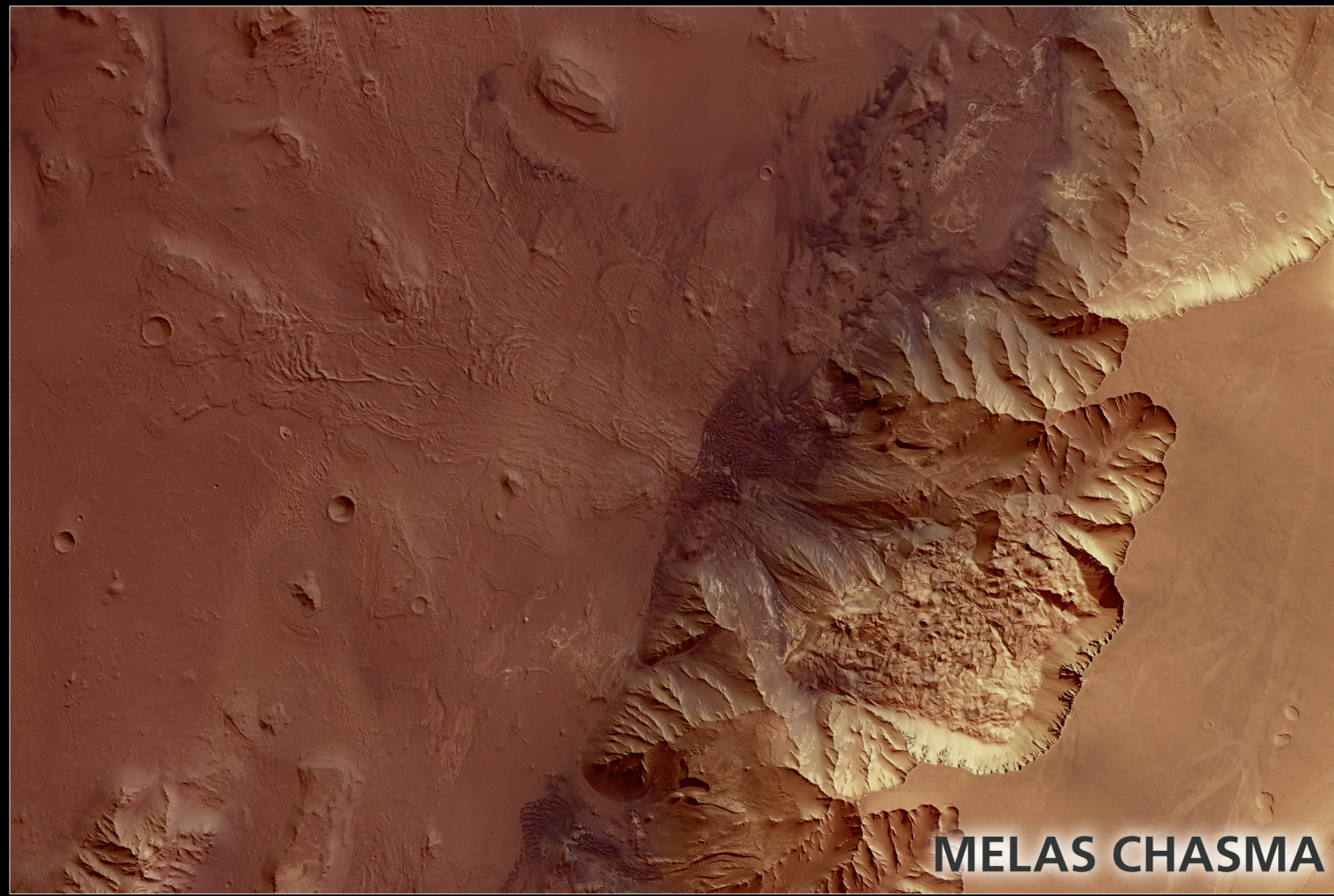
URANIUS & CERAUNIUS THOLUS



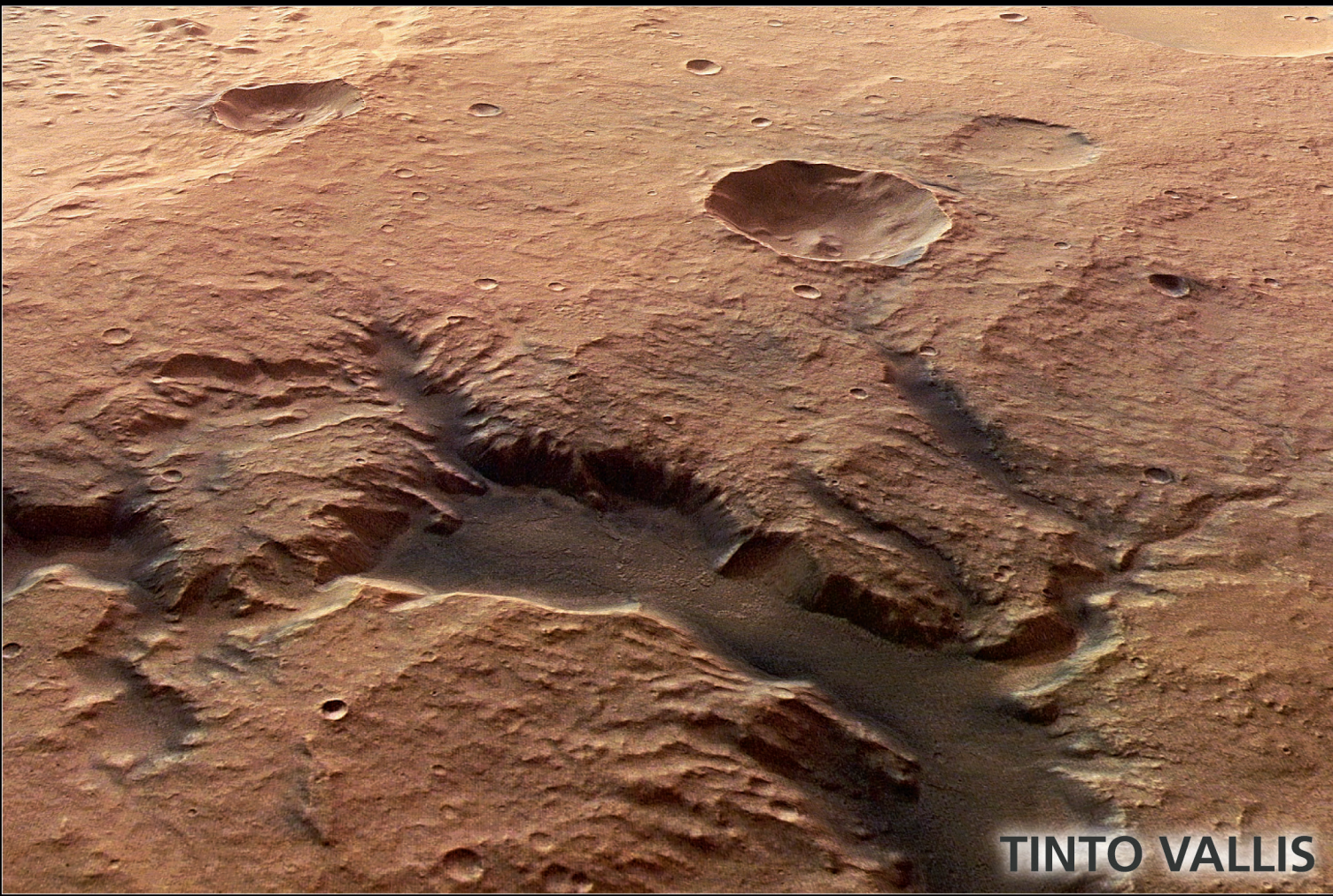
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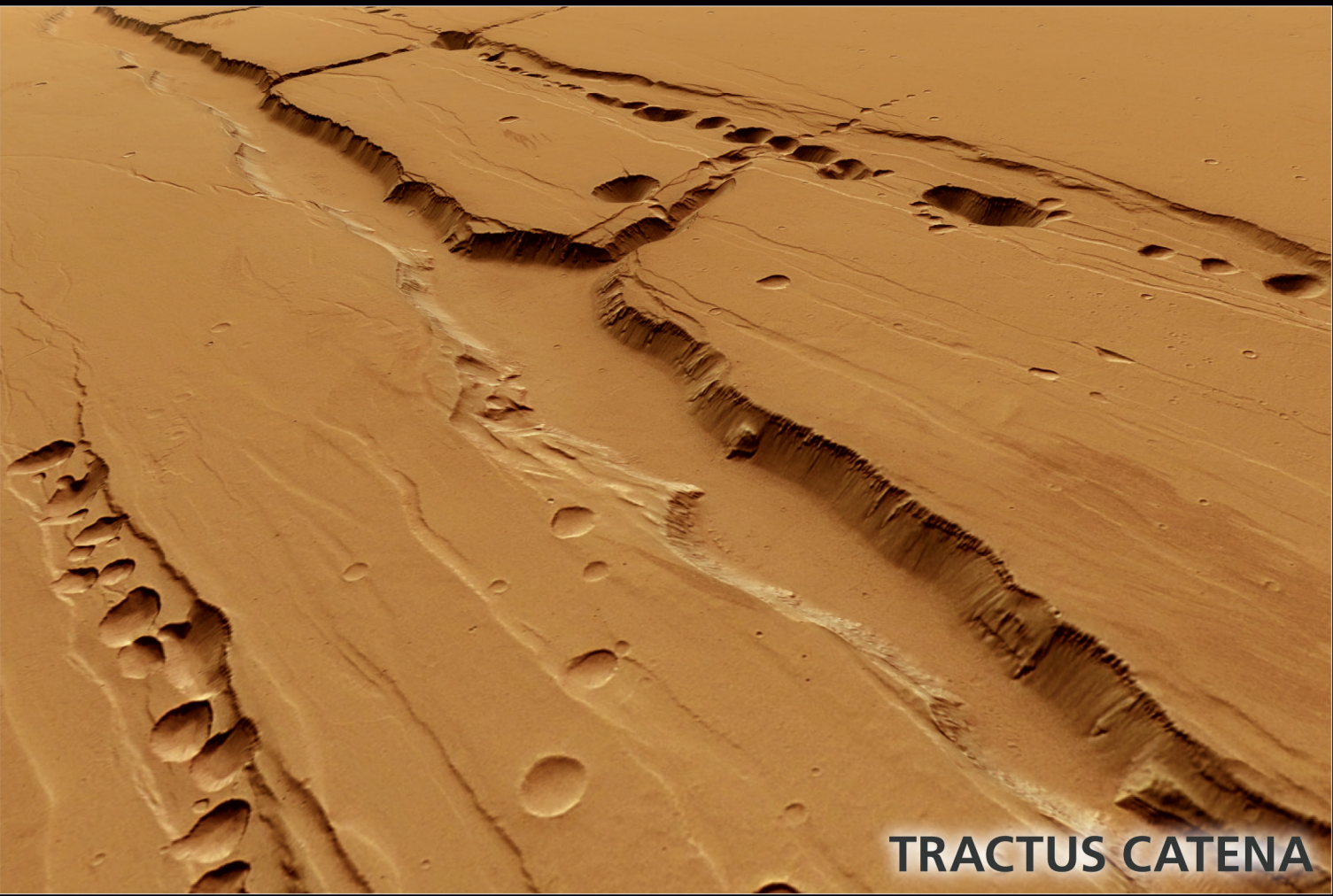


MELAS CHASMA



TINTO VALLIS

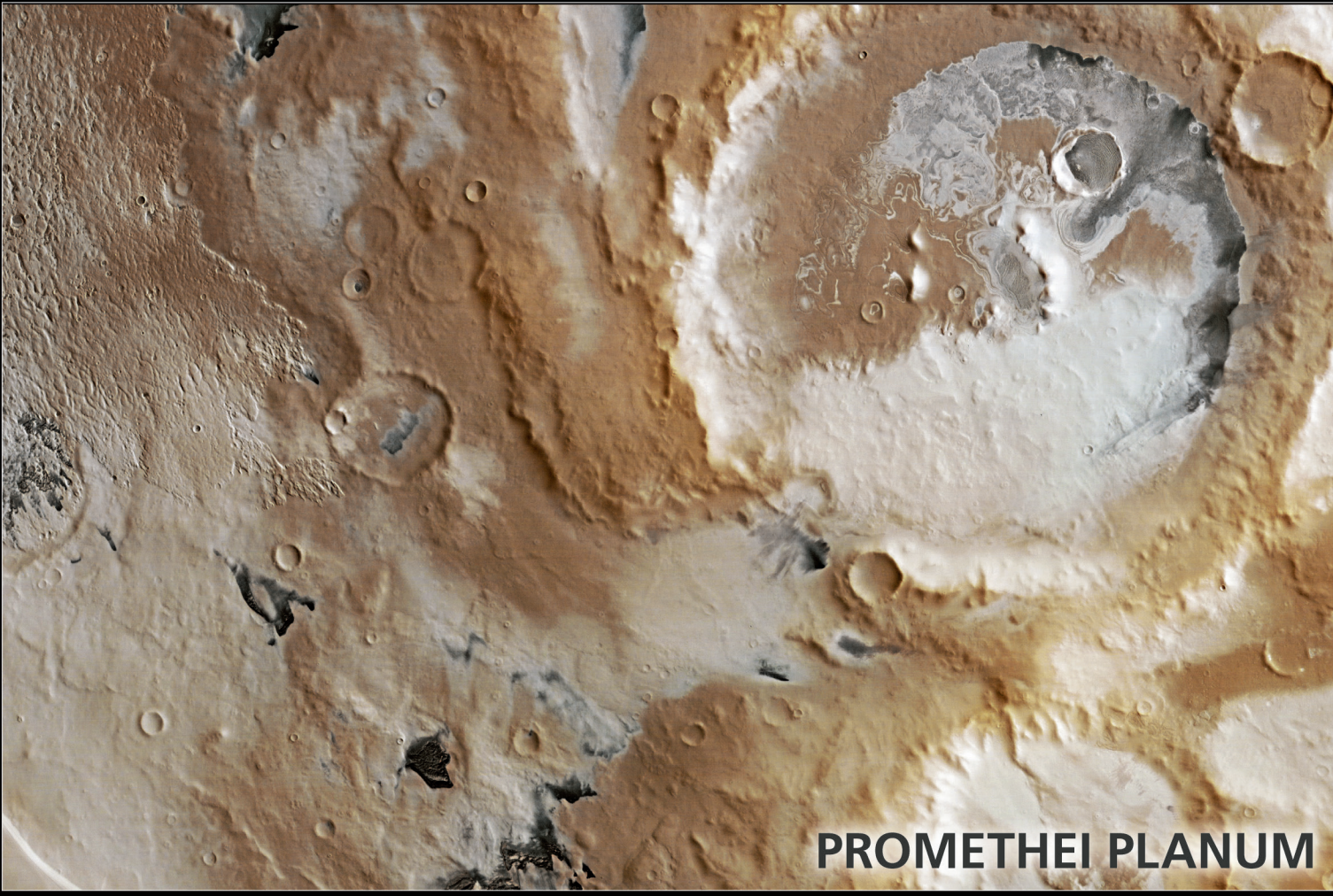
# 10 Years Mars Express with HRSC



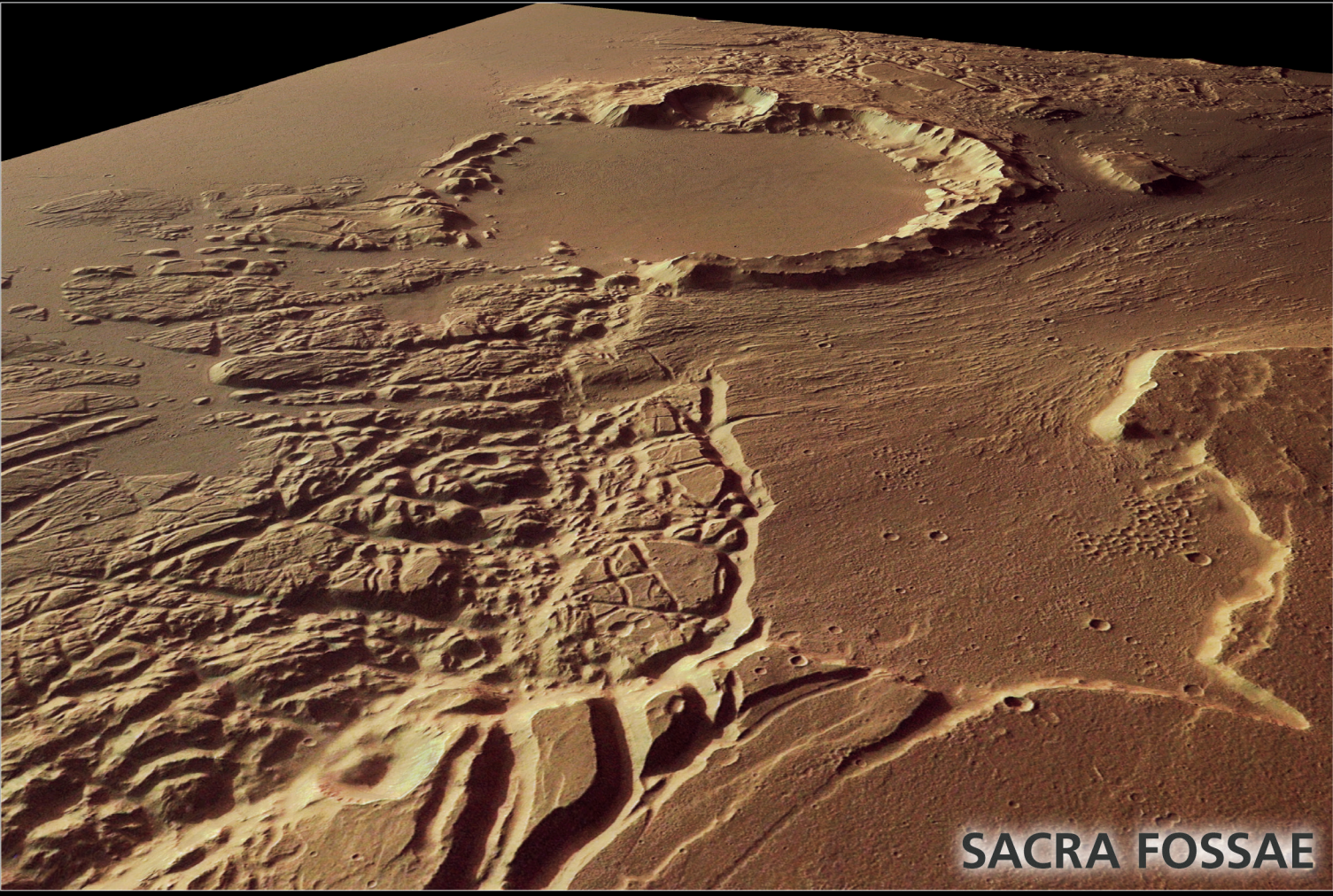
TRACTUS CATENA



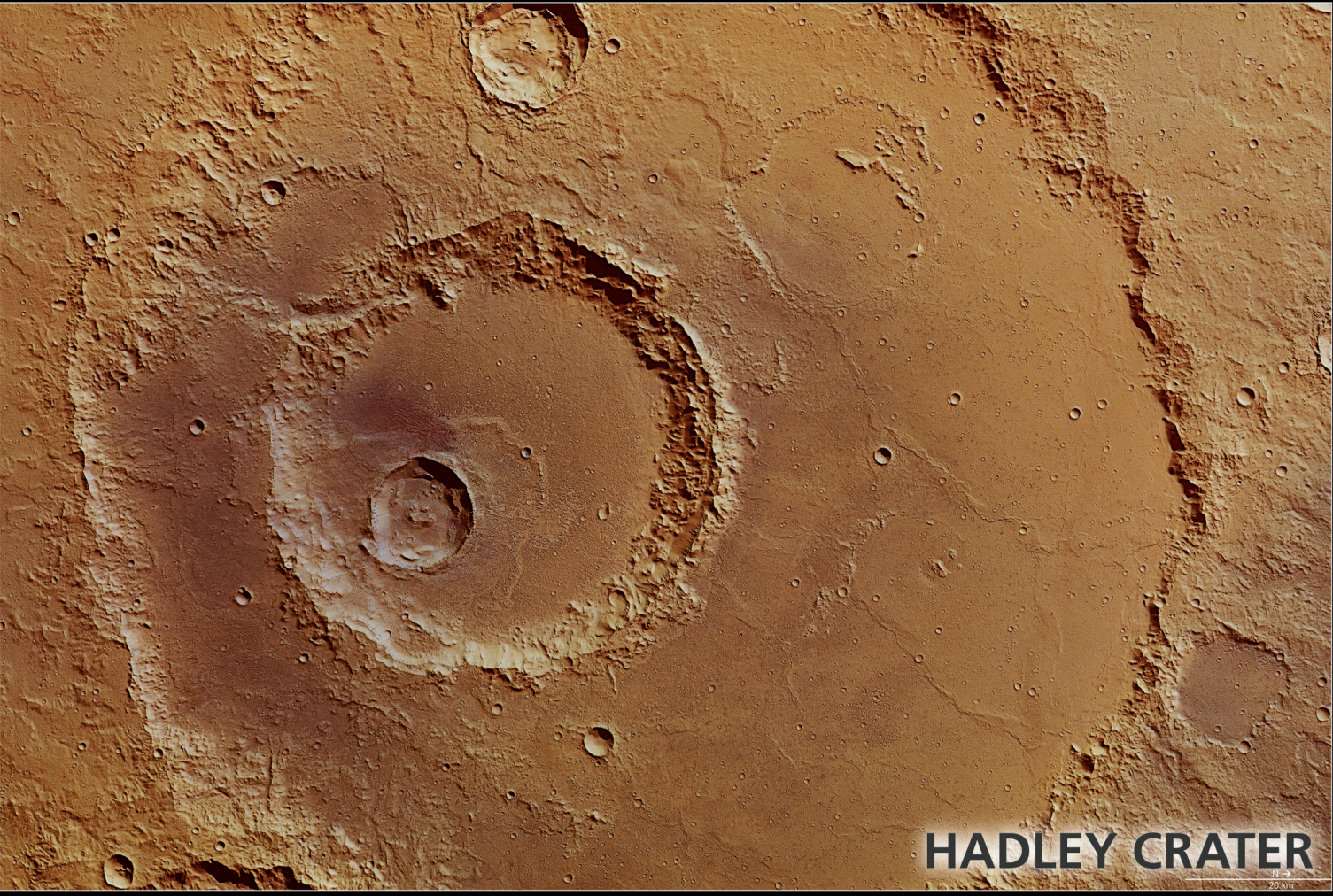
CANDOR & OPHIR CHASMA



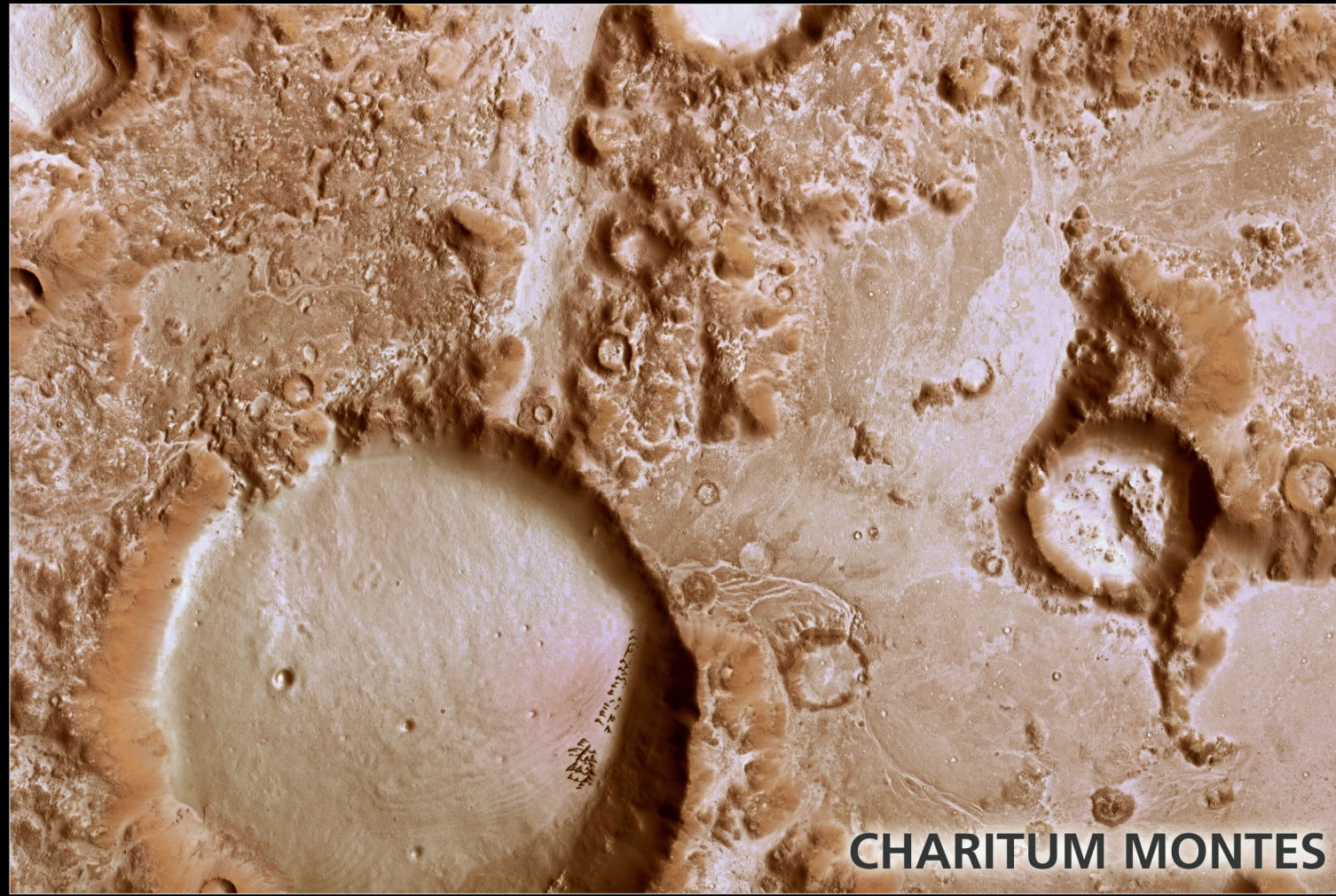
PROMETHEI PLANUM



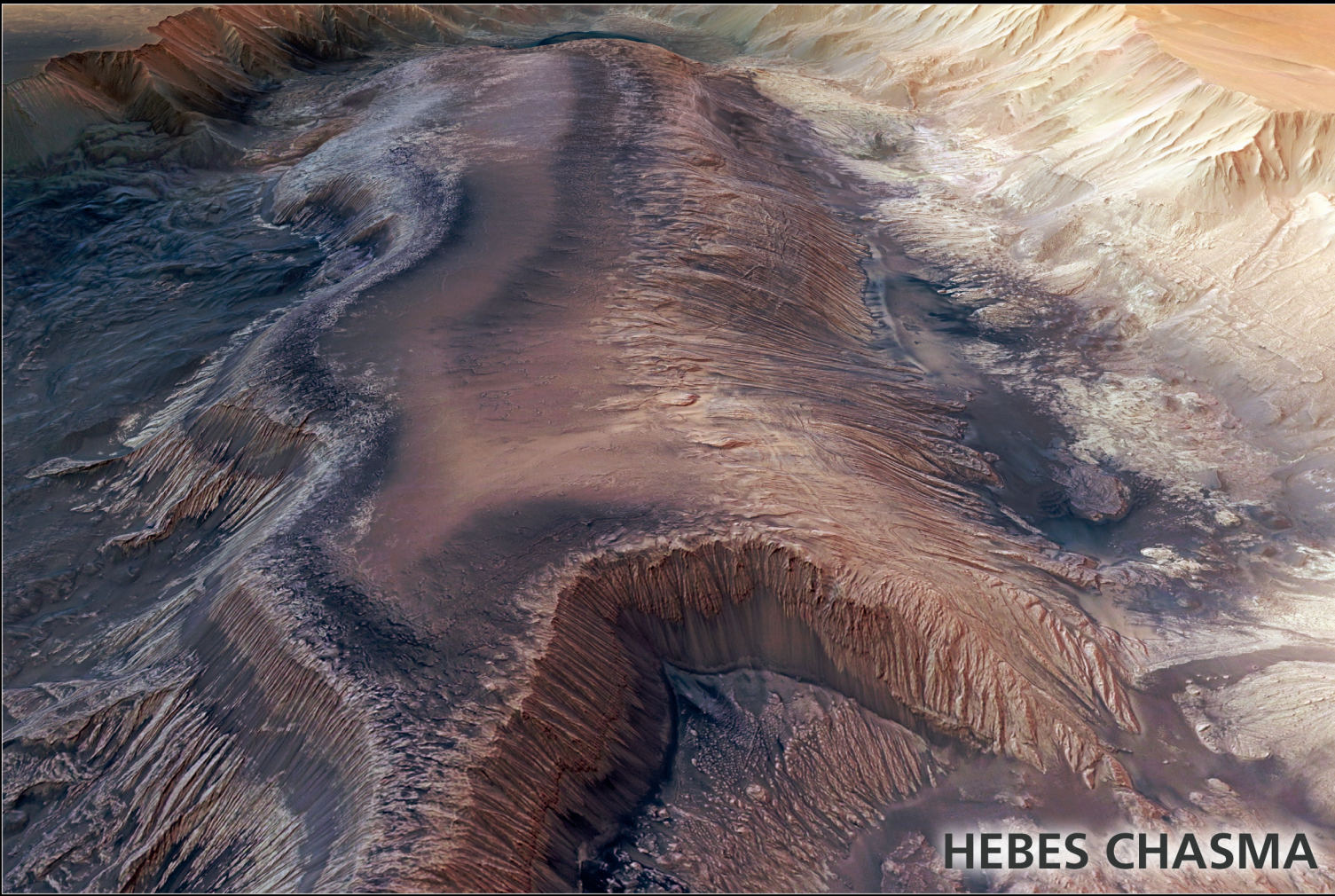
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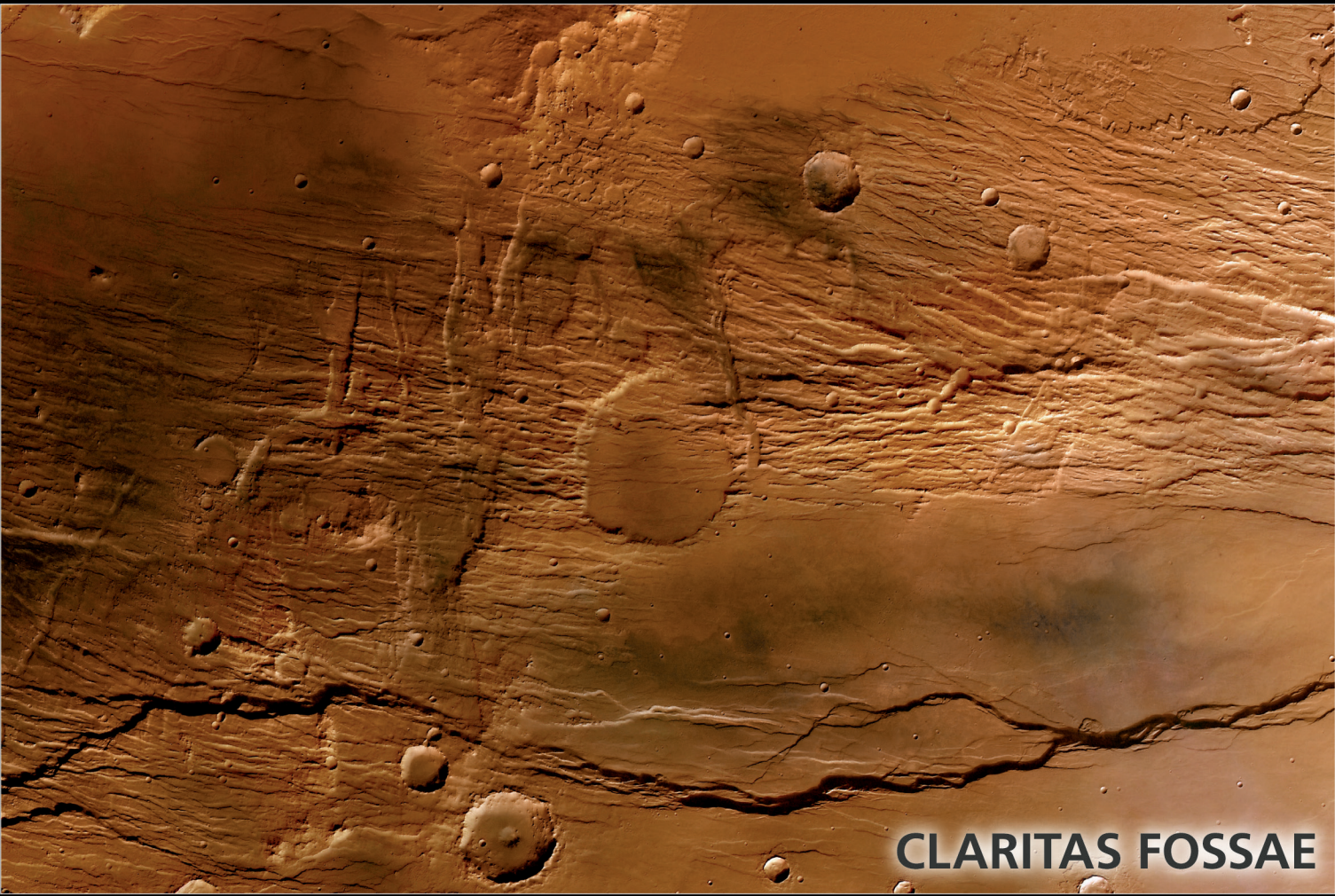
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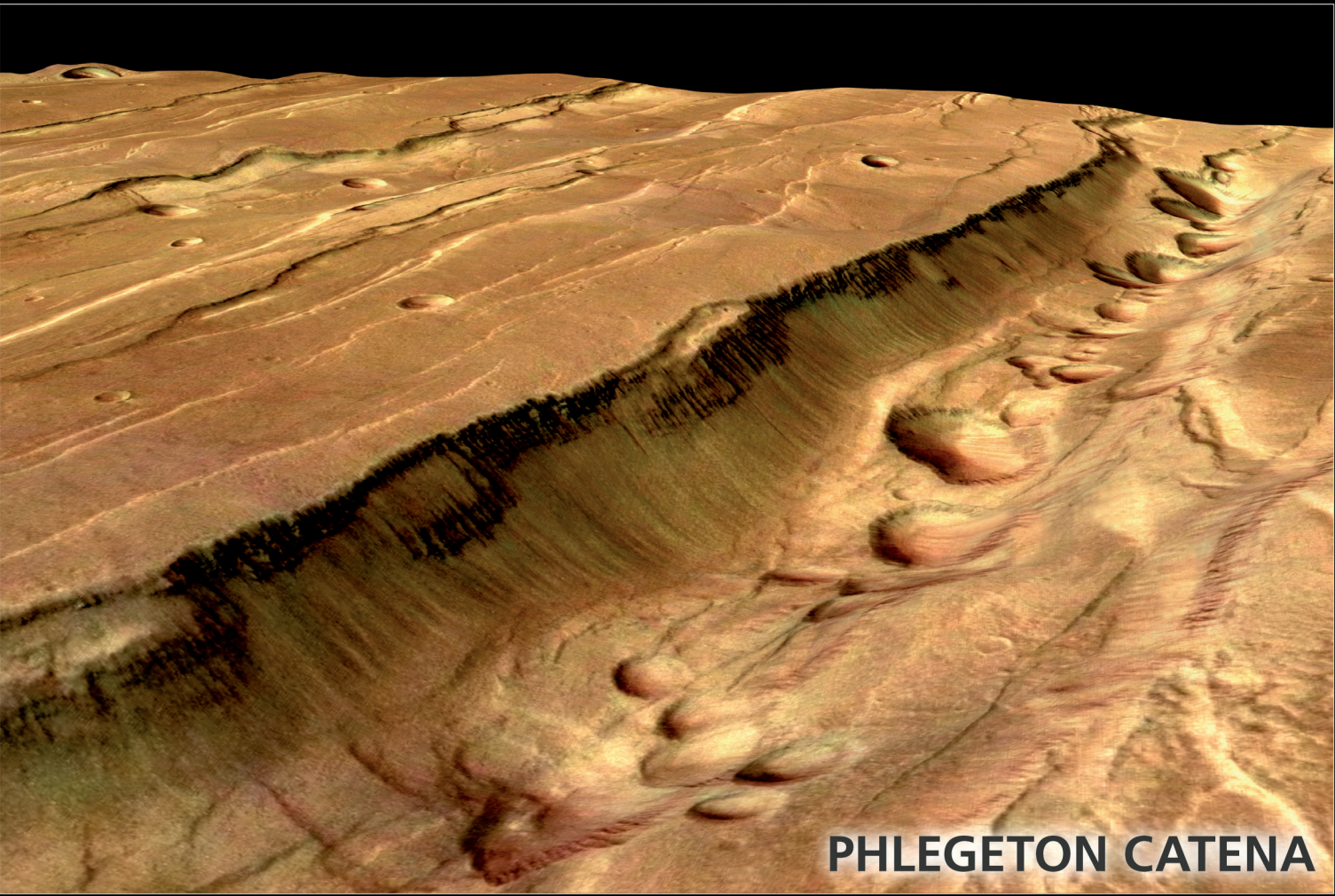
CHARITUM MONTES



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