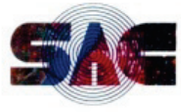
Mars Orbiter Mission (MOM)

Mars Atlas

Space Applications Centre
Indian Space Research Organisation

Mars Orbiter Mission (MOM) Mars Atlas



Space Applications Centre
Indian Space Research Organisation
Ahmedabad-380015
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Mars Orbiter Mission (MOM) Mars Atlas

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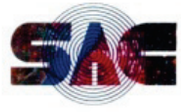

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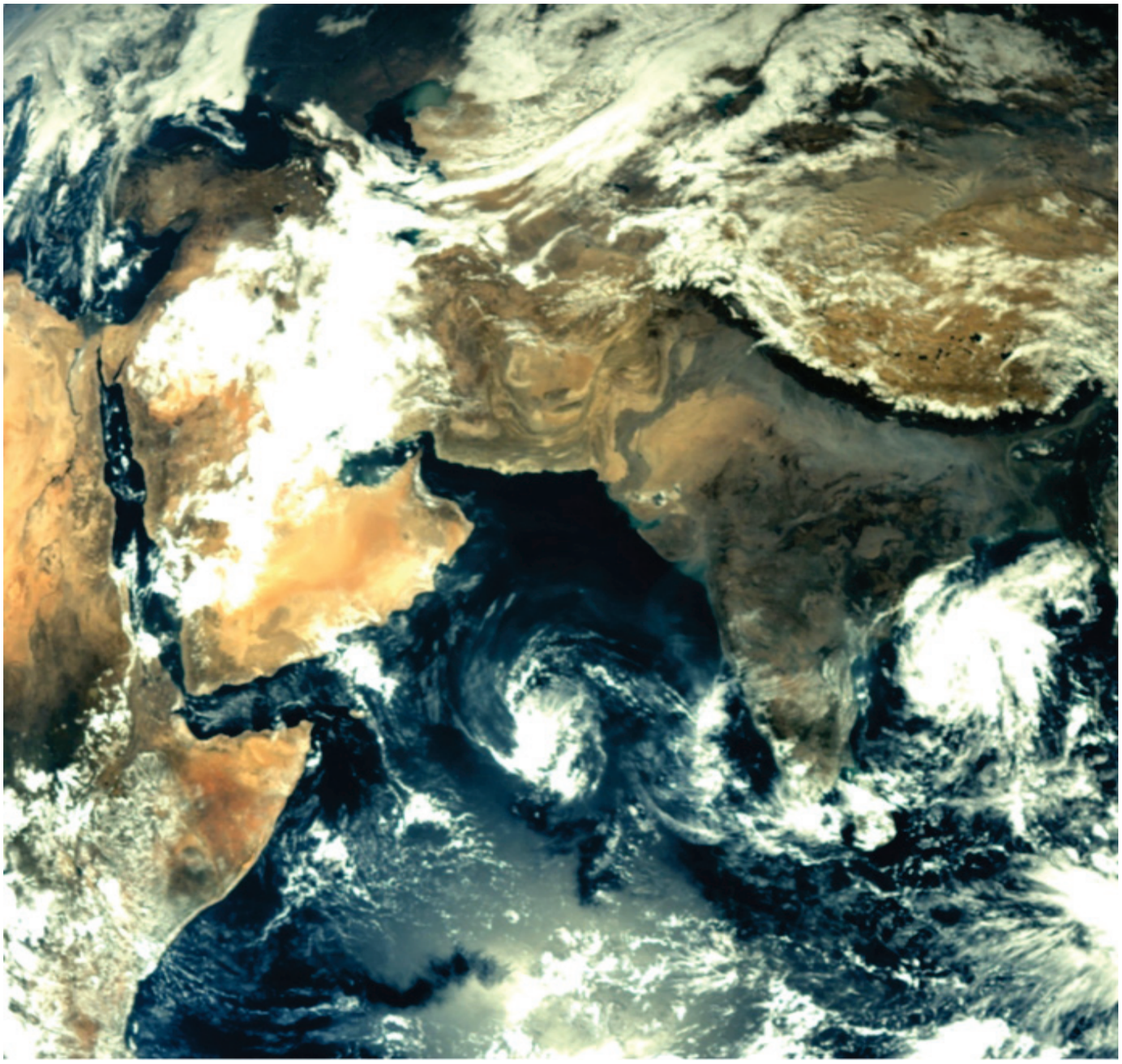

India as seen by Mars Colour Camera (MCC) during the Mars Orbiter Mission (MOM) journey towards Mars.

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आ. सी. किरण कुमार / A. S. Kiran Kumar
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FOREWORD

The exploration of Mars was an important objective of early interplanetary missions launched by various space agencies. A large number of unmanned orbiters, landers and rovers have been launched to reach Mars since early 1960s. These missions had provided large amount of scientific data, analysis of which enabled the scientific community to have a better insight about various features and composition of the planet. By successfully sending its first Mars exploration mission viz., Mars Orbiter Mission (MOM), India has joined the group of space-faring nations venturing into Mars exploration. The MOM spacecraft was designed, built and launched in a period of less than two years. It carried five science instruments onboard collecting data on surface geology, morphology, atmospheric processes, surface temperature and atmospheric escape process. MOM has evoked a lot of interest about planetary exploration among the researchers, students as well as the general public. Popular social media platforms have been extensively used to disseminate information about the mission.

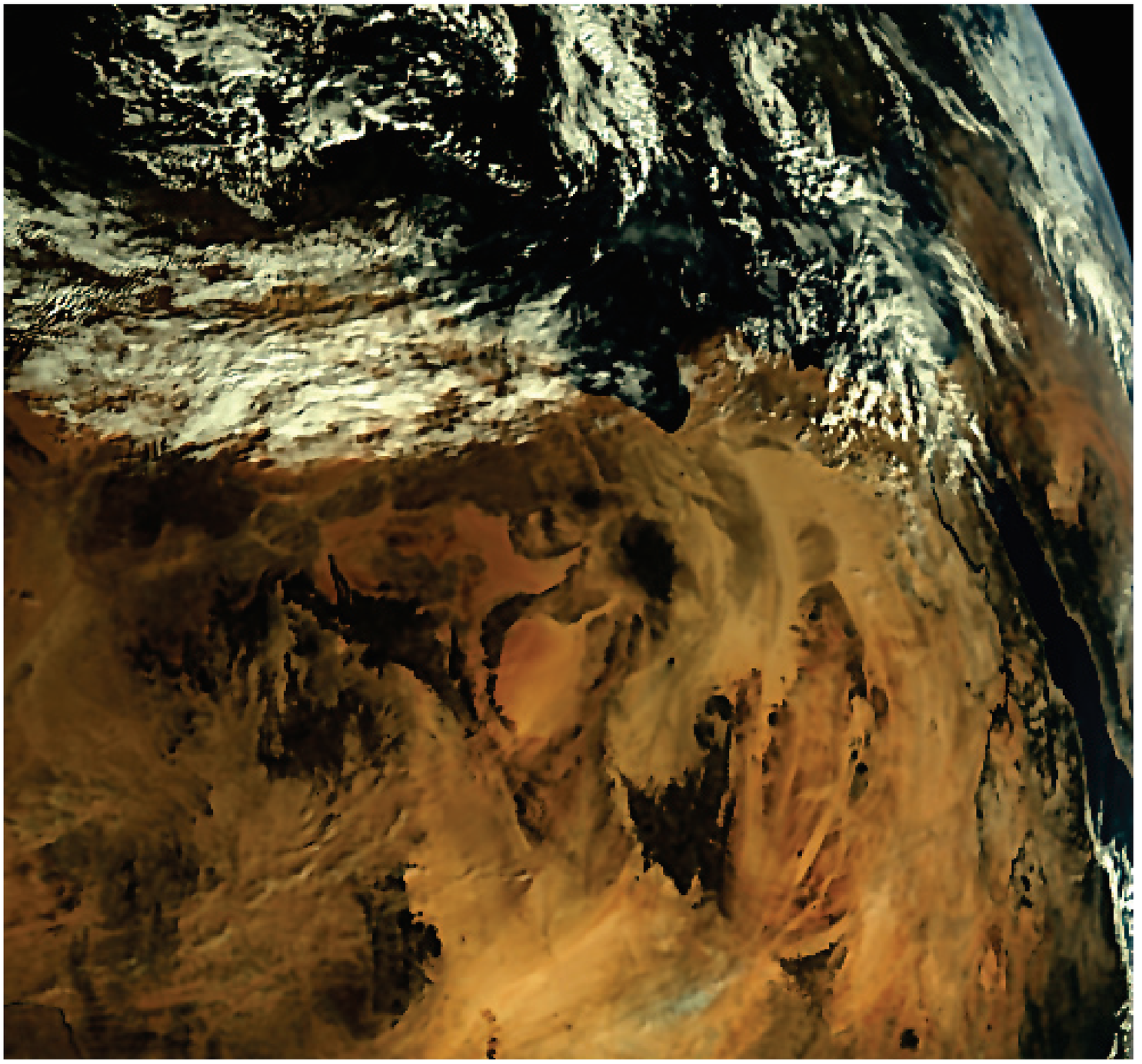
Against this backdrop, it is heartening to note that the Space Applications Centre has brought out a compilation of images acquired by Mars Colour Camera (MCC) and results from other onboard instruments, in the form of an atlas.

I appreciate the efforts put in by the centre in bringing out this unique atlas. I am sure that this atlas will serve as a reference volume to have a better understanding about the topography and atmospheric properties of the planet.

आ सी किरण कुमार

(आ. सी. किरण कुमार)
(A. S. Kiran Kumar)

Bangalore
August 31, 2015



Sahara Desert as seen by Mars Colour Camera onboard MOM while cruising towards Mars.

तपन मिश्रा
निदेशक
Tapan Misra
Director

सत्यमेव जयते

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PREFACE

Mars is one of the closest celestial objects to the Earth and it has attracted humans towards itself since the invention of telescopes. In the space age significant progress has been made to understand our celestial neighbors in the solar system and beyond. After the success of Chandrayaan-1, India decided to explore Mars and took challenge to develop key critical technologies required for interplanetary missions. Space Applications Centre (SAC) at Ahmedabad contributed three out of five instruments for the first Indian mission to Mars- Mars Orbiter Mission (MOM). Mars Colour Camera (MCC), Thermal Imaging Spectrometer (TIS) and Methane Sensor for Mars (MSM) were designed and developed in record time of less than fifteen months and successfully integrated with Mars Orbiter Mission.

A large amount of data is now available from these payloads developed at SAC, Ahmedabad. MOM Spacecraft has now entered in the extended mission life time around Mars and it is expected to provide more scientific information about Mars for much longer period. Data from these sensors is being analyzed at SAC and many aspects about the Mars are being explored. To popularize the images captured by MCC and science results of other payloads of MOM, Space Applications Centre is bringing out a compilation of images in the form of a scientific atlas. I acknowledge the efforts in bringing out this science atlas and would like to place on record my appreciation to the team at the Space Applications Centre for bringing out this unique science atlas and completing this task in a time bound manner.

Tapan Misra
(तपन मिश्रा)
(Tapan Misra)

Ahmedabad
30 Aug 2015

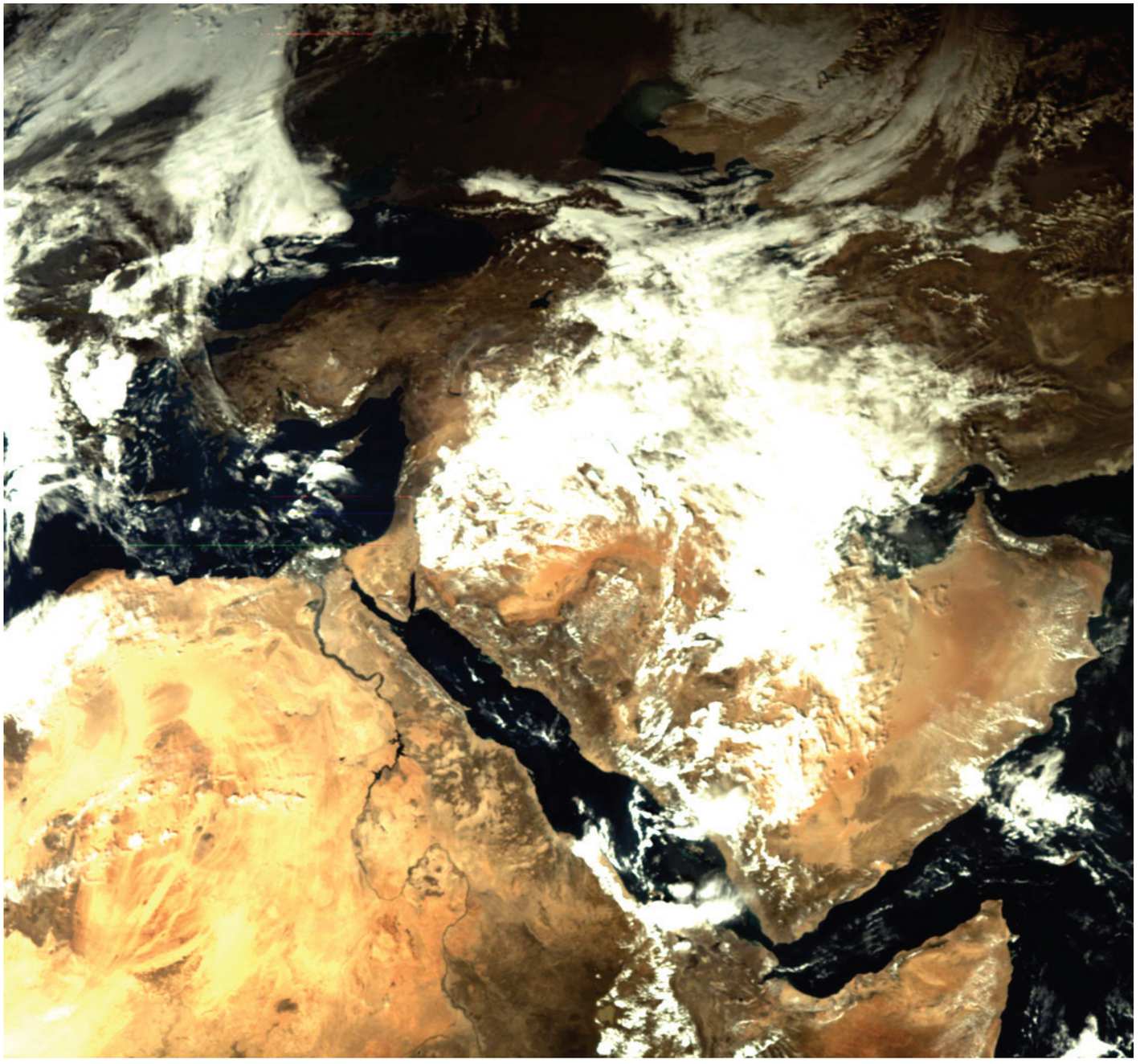

Image of Red Sea and north eastern part of Africa captured by Mars Colour Camera (MCC) on 19-11-2013
at a spatial resolution of 2 km from an altitude of 38953 km during the MOMs journey towards Mars.

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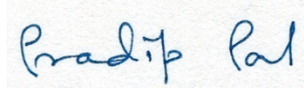
ACKNOWLEDGEMENT

Mars Orbiter Mission has been successfully going around the Mars since September 24, 2014 in an elliptical orbit. The data from three payloads namely Mars Colour Camera (MCC), Methane Sensor for Mars (MSM) and Thermal Imaging Spectrometer (TIS) is being analyzed by teams at Space Applications Centre, Ahmedabad. The images from MCC have provided unique information about Mars at varying spatial resolutions. It has obtained Mars Global data showing clouds, dust in atmosphere and surface albedo variations, when acquired from apoapsis at around 72000km. On the other hand high resolution images acquired from periapsis show details of various morphological features on the surface Mars. Some of these images have been show cased in this atlas and have been categorized depending upon the processes on the surface and atmosphere of Mars.

We are extremely thankful to Shri Tapan Misra, Director, Space Applications Centre, for his initiative in bringing out this atlas and his constant encouragement. The entire MOM science data analysis team expresses, our thanks to Shri A. S. Kiran Kumar, Chairman, ISRO for his keen interest in Martian science and providing us continuous motivation. We are grateful to entire MOM mission team for excellent coordination in executing MOM project and providing the scientists opportunity to study Mars. I also thank the payload and data product teams at SAC and all my colleagues in supporting this activity.



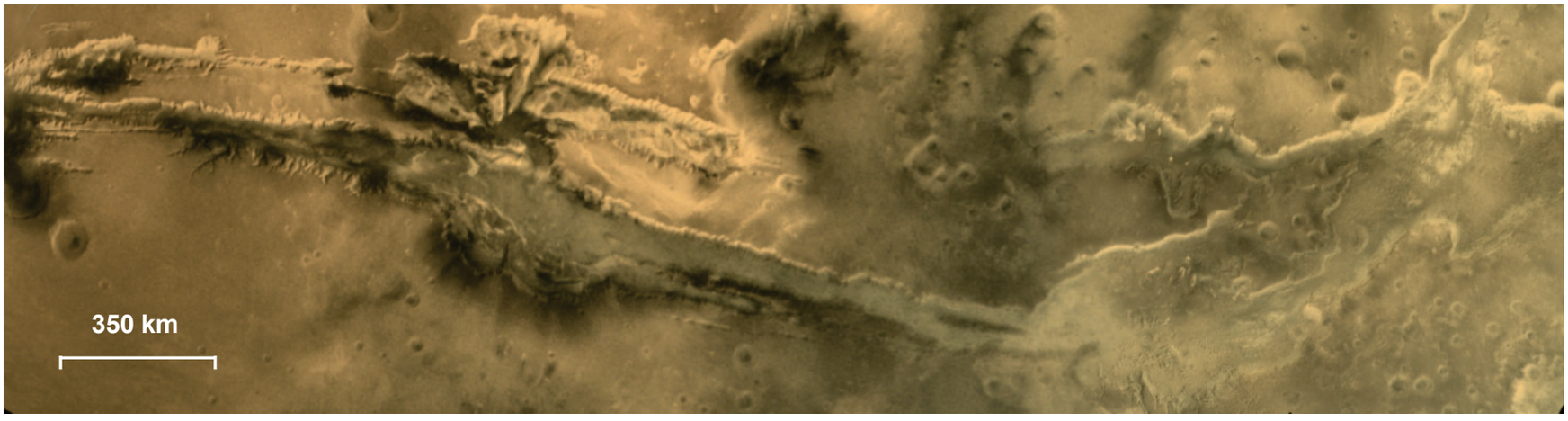
Ahmedabad
August 30, 2015

(P. K. Pal)
Deputy Director, EPSA

About this Mars Atlas

Remote exploration of the Mars by various space missions like Mars-Odyssey, Mars Express and Mars Reconnaissance Orbiter (MRO) has provided a considerable amount of data to understand the geological features, its chemical composition and atmospheric dynamics. However, the key questions about its geological evolution, absence of surface water, loss of atmosphere etc. are not yet fully understood. With the launch of Mars Orbiter Mission (MOM) on 5th November 2013, India has ushered into a new era of Planetary Exploration of Mars and its environment. MOM spacecraft carries five scientific instruments to do surveys for understanding the surface morphology, atmospheric processes like dust in lower atmosphere, impact catering process, detection and quantification of Methane in the Martian Atmosphere, to map the variability of surface temperature, studies related to neutral particles in the upper atmosphere and studies related to escape of Martian atmosphere.

This scientific Mars atlas provide glimpses of the various morphological features and atmospheric phenomenon occurring on Mars as captured by different instruments onboard Mars Orbiter Mission (MOM), in particular by Mars Colour Camera (MCC).

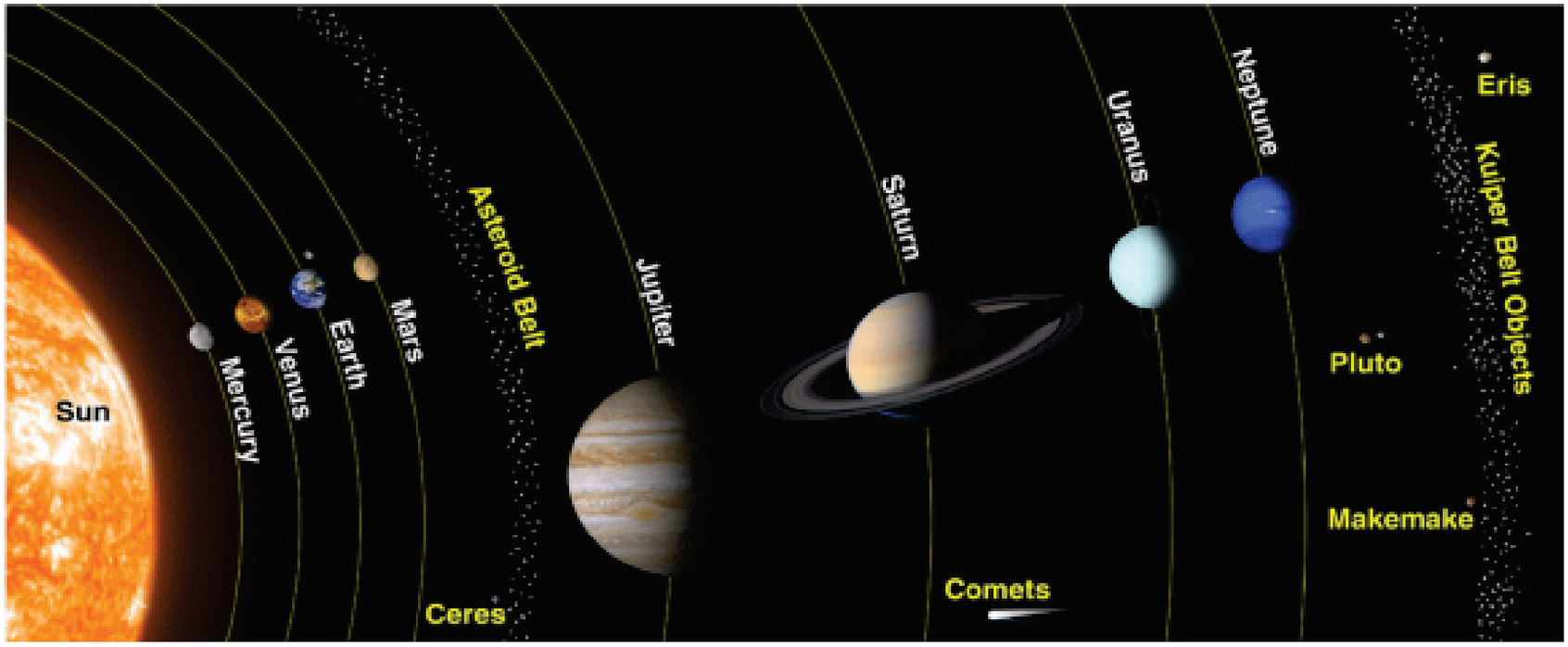


Mosaic of Valles Marineris from MCC data.

Contents

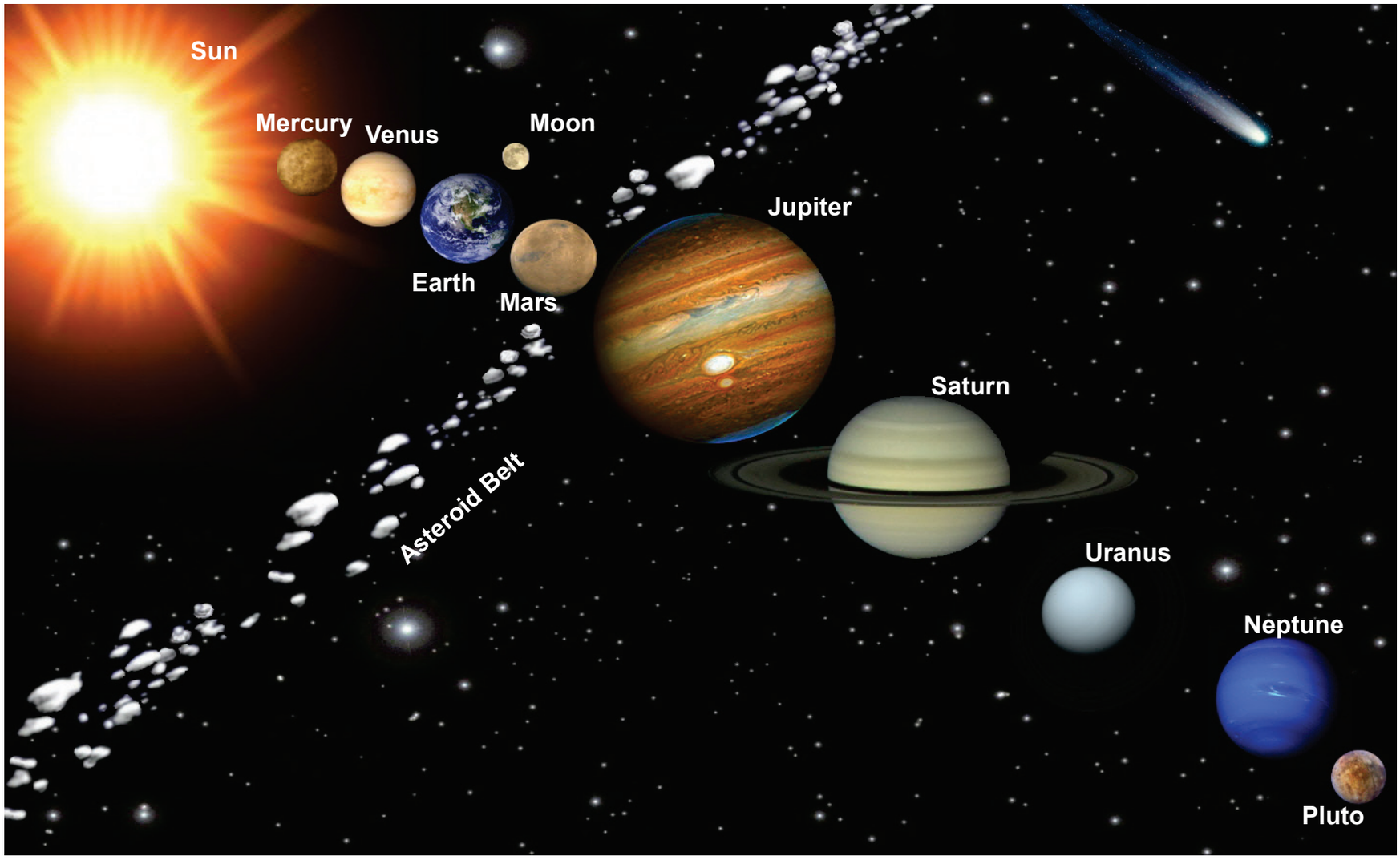
The Solar System

The solar system consists of the Sun at its center. Sun is the largest object in our solar system and contains 99.86% of the mass in the solar system. The Sun is composed of hydrogen (70% by mass), helium (28%), and heavier elements (2%). The Sun produces energy through nuclear fusion at its center, hydrogen atoms combining to form helium and releasing energy that eventually makes its way to the Sun's surface as visible sunlight. Temperature at the centre of Sun, where fusion takes place is ~15.7 million K, while the temperature at the visible surface, the photosphere, is estimated to be ~6400 K. The Sun has an outer atmosphere called the corona, which is visible during solar eclipses, through the use of specially designed telescopes, called coronagraphs. In addition to eight planets, the Solar system also consists of 165 known natural satellites (moons), trillions of comets (greater than 1 km in diameter), one million asteroids (greater than 1 km in diameter), minor planets, dust and gas. The planets orbit the Sun in roughly the same plane, known as the ecliptic (the plane of the Earth's orbit). The four inner planets are Mercury, Venus, Earth, and Mars are made up mostly of iron and rocks. The terrestrial planets all have solid surfaces, and their surfaces preserve a partial record of how each planet has evolved. The outer planets are Jupiter, Saturn, Uranus, and Neptune. All the outer planets are giant worlds surrounded by layers of gases. Pluto was considered to be the ninth planet of our Solar System. This changed in 2006 with the adoption of a formal definition of planet. Now it is called dwarf planet and considered as a part of the Kuiper belt.



Source: https://spacetechinfo.worldpress.com

Solar System

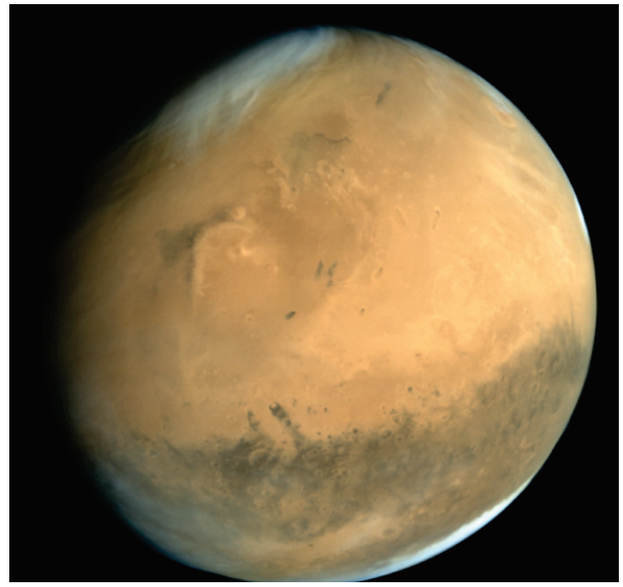


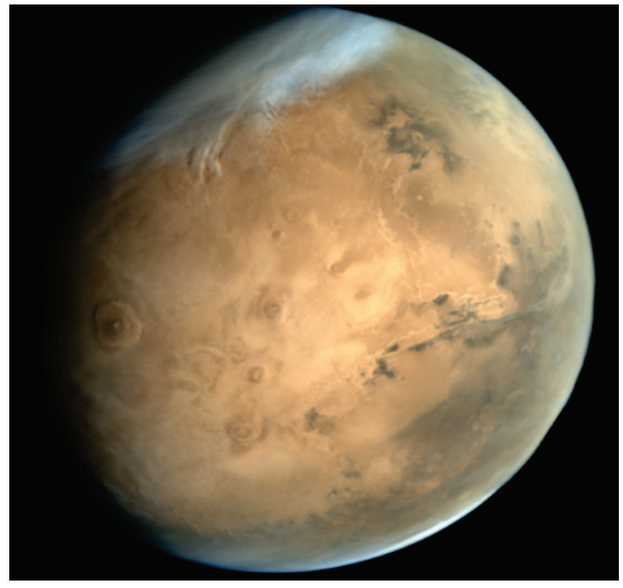
An artistic view of our solar system.

Source: https://spacetechinfo.worldpress.com

The Mars

Mars is the fourth planet from the Sun in our Solar System. It orbits the Sun in ~687 Earth days. Its rotation is little longer than Earth, 24 hours 37 minutes and 23 seconds, so a Martian day is similar to an Earth day. Mars has nearly the same inclination of its rotational axis as Earth, 25 degrees 12 minutes, so Mars has seasonal changes. Its radius across its equator is about 3383 kilometers. The red colour of Mars is due to oxidised iron in the Martian rocks. Its atmosphere is composed primarily of carbon dioxide (95.32%) with small amounts of other gases such as Nitrogen (N_2) (2.7%), Argon (Ar) (1.6%), Oxygen (O_2) (0.13%), Water (H_2O) (0.03%), Neon (Ne) (0.00025 %). Martian air contains only about 1/1,000 times the water when compared to Earth. This small amount can condense out, forming clouds high in the atmosphere and at the slopes of towering volcanoes. The average recorded temperature on Mars is ~-63°C with a maximum temperature of 20°C and a minimum of -140°C.The atmospheric carbon dioxide condenses in the form of snow at both the polar caps. It evaporates again during the spring season in each hemisphere.





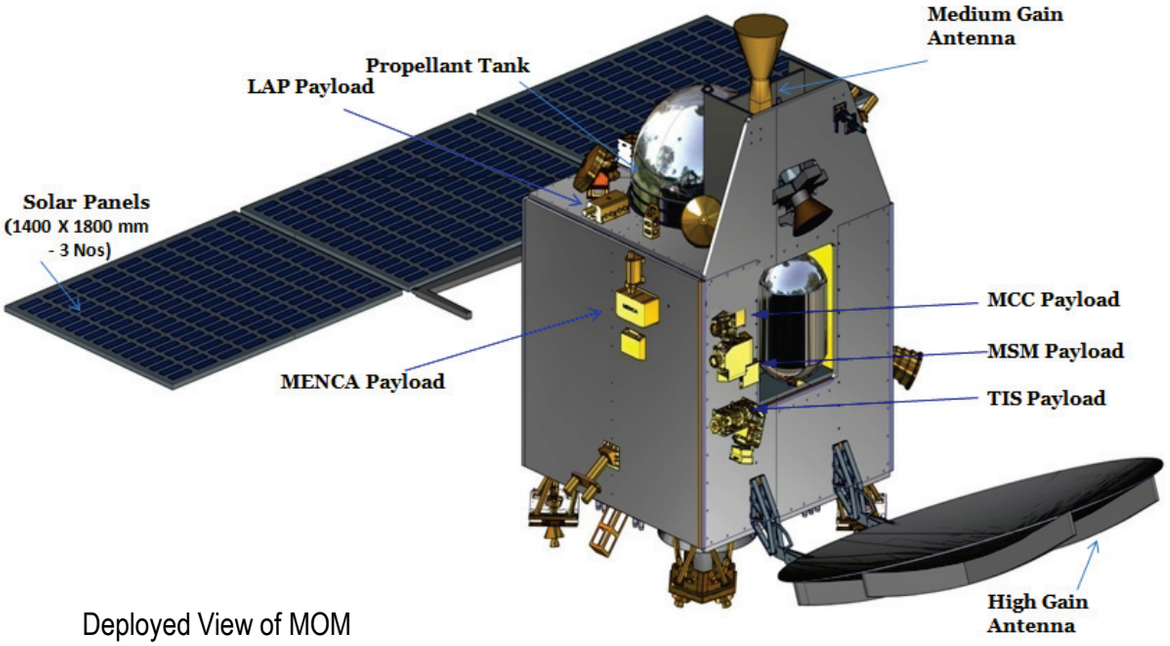
Different geologic processes involving volcanism, tectonism, water, ice, and impacts have shaped the planet on a global scale. The northern part of the planet is an enormous topographic depression. The southern hemisphere is heavily cratered and characterized by rugged surfaces. Mars' western hemisphere is a massive volcano-tectonic province known as the Tharsis region. Tharsis contains the highest elevations on the planet and the largest known volcano, called Olympus Mons in the Solar System. A smaller volcanic province lies in Elysium region. Near the equator in the western hemisphere lies an immense system of deep canyons and troughs collectively known as the Valles Marineris. The canyon system extends eastward from Tharsis for a length of over 4,000 km. The canyons are up to 300 km wide and ~8 km deep. The largest impact basin on Mars is Hellas basin located in the southern hemisphere which contains lowest elevations on the planet. Mars has two small moons, Phobos and Deimos, which are thought to be captured asteroids.

Mars Orbiter Mission Spacecraft

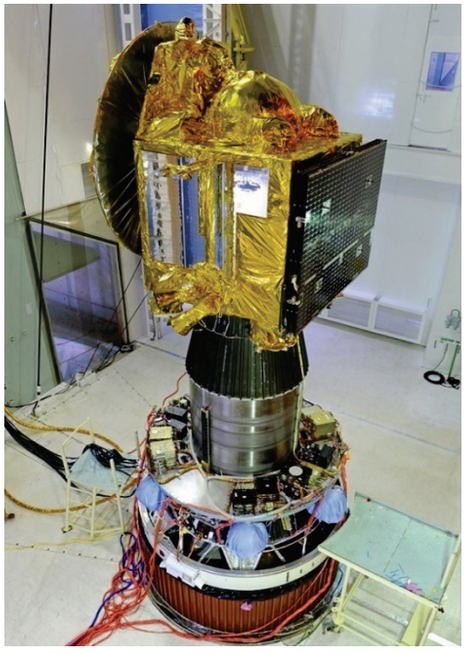
Mars Orbiter Mission (MOM) is ISRO's first interplanetary space probe dedicated for the Mars research. Mars Orbiter Mission (MOM) was launched from Sriharikota, India using a Polar Satellite Launch Vehicle (PSLV) rocket on November 5, 2013.

The major objectives of the MOM included, design and realization of an interplanetary spacecraft with a capability to survive and perform Earth-bound manoeuvres, cruise phase, Mars orbit insertion, and on-orbit phase around the Mars. The science objectives include exploration of the surface of Mars and its atmosphere.

Mars Orbiter Mission spacecraft



Deployed View of MOM

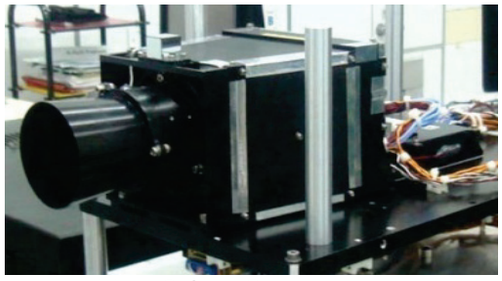


MOM integrated with PSLV launcher

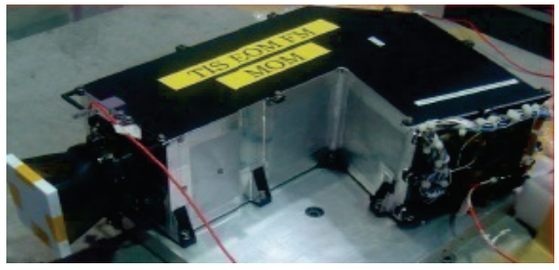
Sensors on board MOM

The scientific exploration of Mars is driven by key science questions such as whether Mars was, is or can be a habitable world. This requires observations on geologic, climatic and atmospheric processes acting on Mars. Considering these requirements, five scientific payloads have been put onboard MOM. These five scientific payloads are, Mars Colour Camera (MCC), Thermal Infrared Imaging Spectrometer (TIS), Methane Sensor for Mars (MSM), Mars Exospheric Neutral Composition Analyser (MENCA) and Lyman Alpha Photometer (LAP).

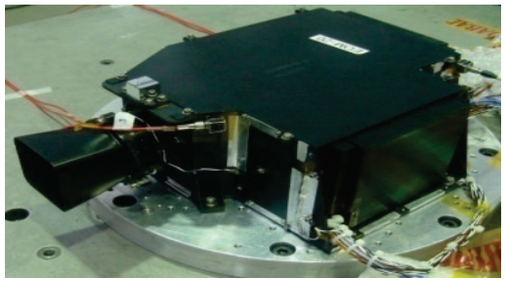
Mars Colour Camera (MCC) is an electro-optical sensor imaging surface of Mars in three colours, varying spatial resolution between 19 m to 4 km in 16 different exposure modes, depending on its position in orbital plane and illumination conditions. Important science objectives of MCC include studying morphology of landforms, dynamic processes such as dust storms in different seasons. Thermal Infrared Imaging Spectrometer (TIS) instrument is aimed to observe thermal emission from Mars surface to detect its temperature and hot spot regions or hydrothermal vents on Martian surface. The TIS is designed to observe emitted infrared radiation from Martian environment in 7–13 μm region of electromagnetic spectrum using micro bolometer device. Methane Sensor for Mars (MSM) is a differential radiometer based on Fabry–Perot Etalon filters to measure columnar methane (CH_4) in the Martian atmosphere at several parts per billion (ppb) levels. This differential signal is to provide a measure of columnar amount of CH_4. The possible finding of methane in Martian atmosphere will provide clues about the presence of life on Mars. Measurements of D/H (deuterium/ hydrogen) ratio from Lyman Alpha Photometer (LAP) allow us to understand the water loss process from Mars surface through the atmosphere. Mars Exospheric Neutral Composition Analyser (MENCA) is a quadrupole mass spectrometer covering the mass range of 1–300 amu with mass resolution of 0.5 amu. MENCA, provides *in-situ* measurement of the neutral composition and density distribution of Martian exosphere.



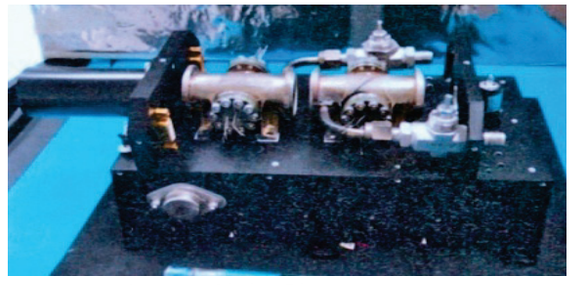
Mars Colour Camera



Thermal-Infrared Imaging Spectrometer



Methane Sensor for Mars



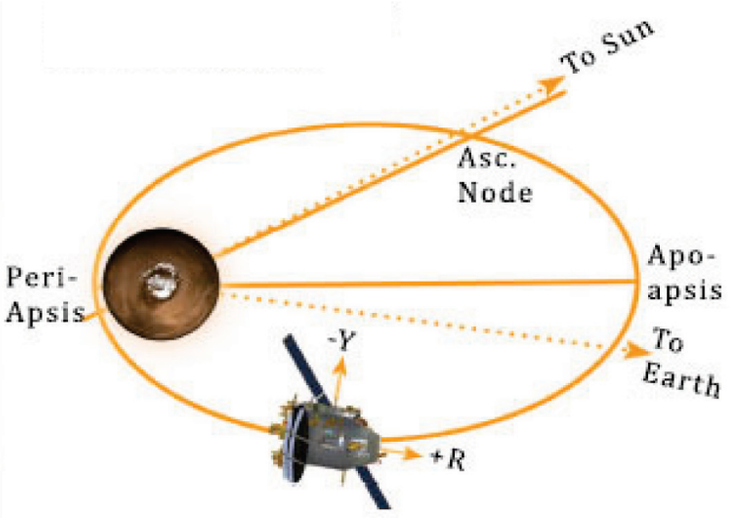
Lyman Alpha Photometer

Mars Exospheric Neutral Composition Analyzer

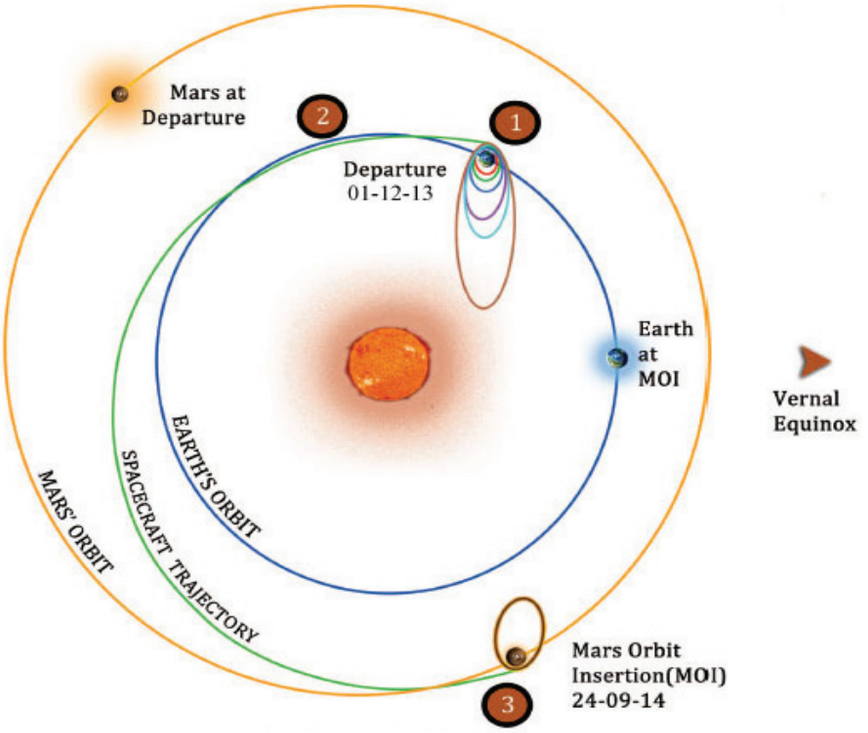
Orbit of MOM around Mars

The Mars orbiter was placed in an orbit of 477 x 77,000 km around Mars on September 24, 2014. The spacecraft moves around Mars in an elliptical orbit with Peri-apsis of 370 km and Apo-apsis of about 71,000 km.

The Spacecraft is now circling in 350 x 71000 km orbit around Mars and MCC camera acquires images of Mars Surface with ~4 km spatial resolution from apoapsis and ~19 m from periapsis.



Martian Orbit



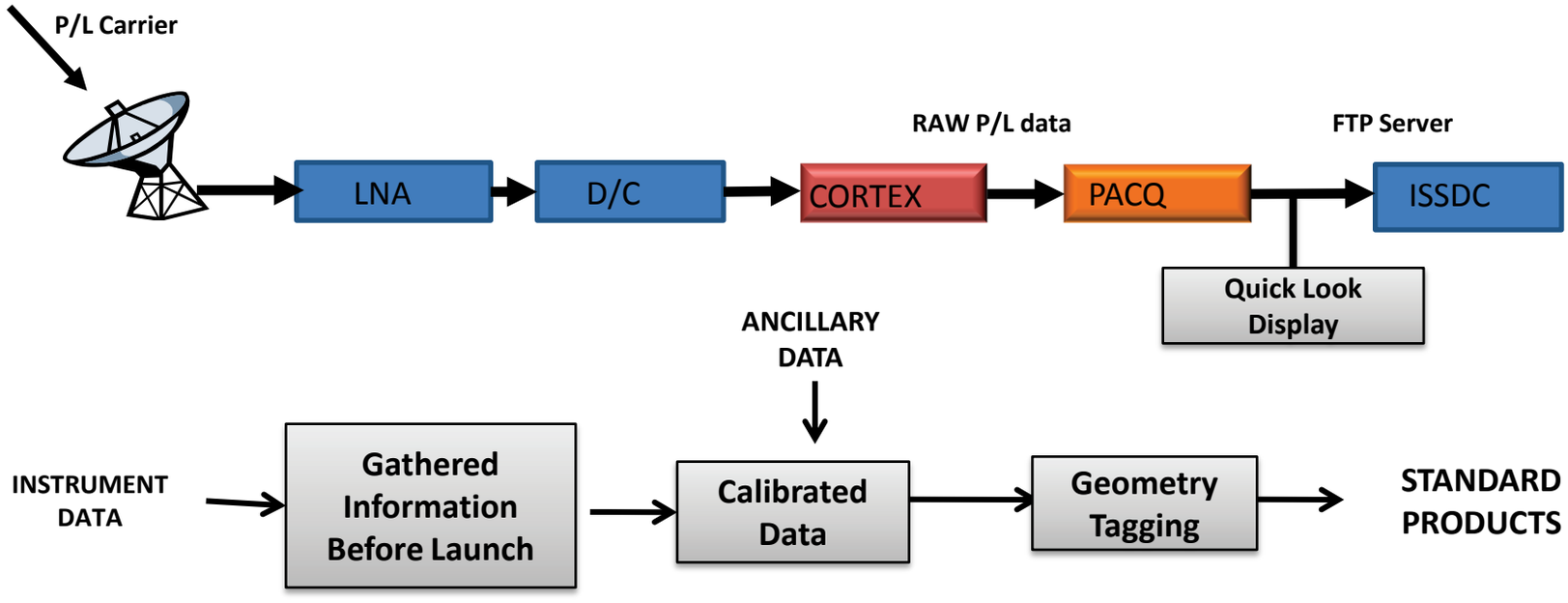
Trajectory Design

Orbital parameters	
Periapsis	350 km
Apo-apsis	71000 km
Inclination	150^0
Sun Elevation	6.8^0
Period to complete one orbit	72 hr

ISSDC and ISRO Planetary Data Pipelines

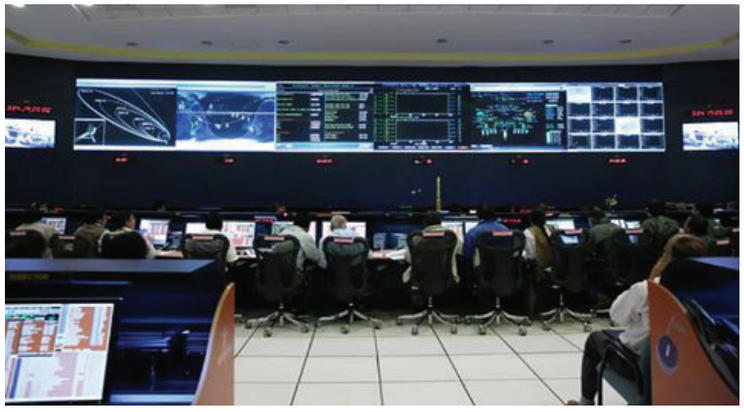
Science and housekeeping data arrives at the Indian Space Science Data Centre, (ISSDC), Bailalu near Bangalore through Indian Deep Space Network in form of telemetry packets. Within the ISSDC the raw science data is transformed into Level-0 data product in Planetary Data System (PDS) format compatible files. Spacecraft transmits data both primary (instrument data) and auxiliary (house keeping data) in a manner through onboard hardware and received using identified specialized ground systems known as Payload Data Acquisition System (PACQ). If the primary data or science data is compressed onboard for reducing data rates, it will be decompressed in ground processing. Both primary and ancillary data is placed to the storage identified at data archive centre ISSDC.

ISRO Planetary Data Pipelines: The ground segment for planetary missions comprises four major elements, namely Deep Space Network (DSN), Spacecraft Control Centre (SCC), Indian Space Science Data Centre (ISSDC) and Payload Operations Centre (POC). The ground segment is responsible for making the data available for the scientists along with auxiliary information, in addition to storage of payload, spacecraft data and product to identified users.



MOM data reception at ISSDC Ground Station

ISSDC COMPLEX



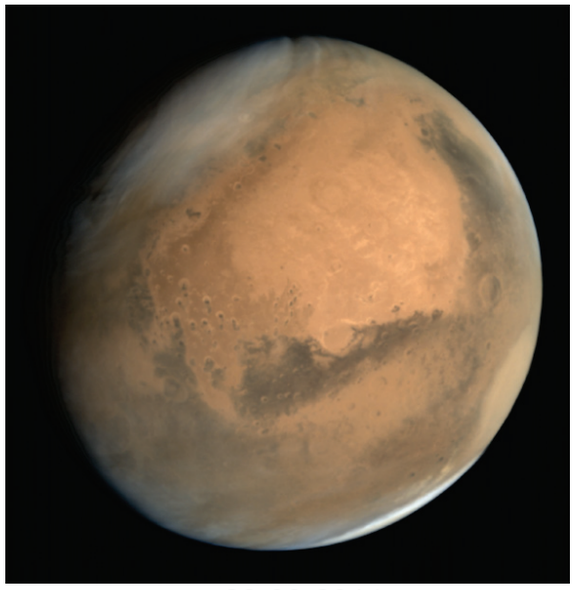
MOX Mission Operations Centre

ISSDC STORAGE

DSN 32 meter antenna

02 Global Views of Mars

Global views of Mars captured by MCC on different dates



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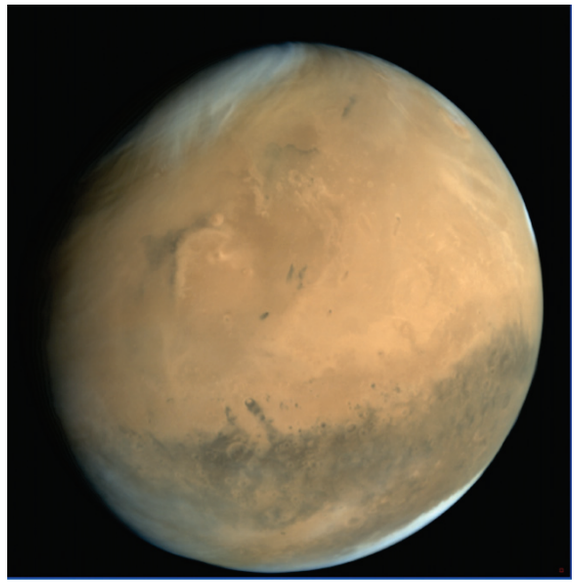

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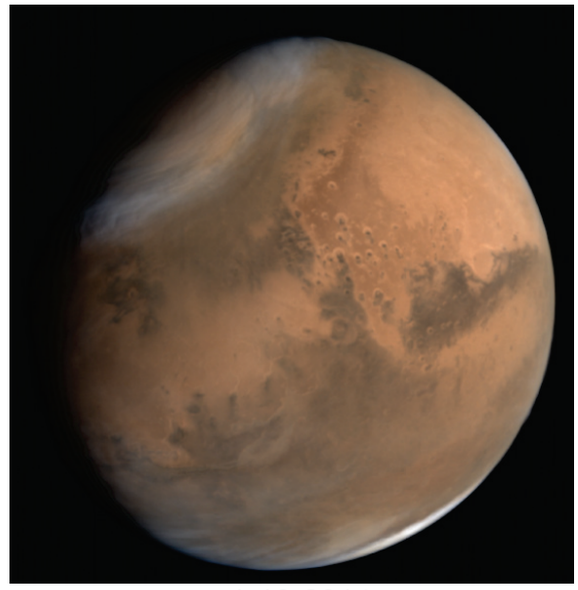

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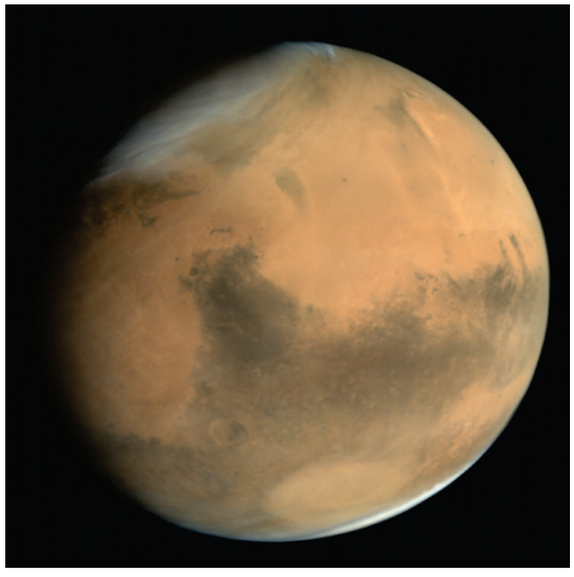

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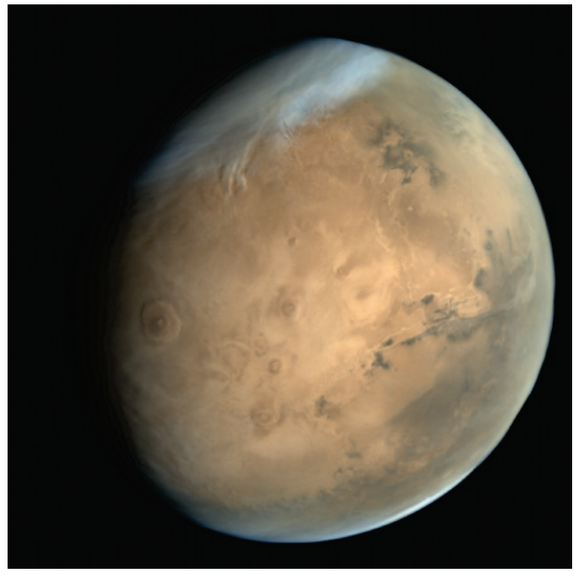

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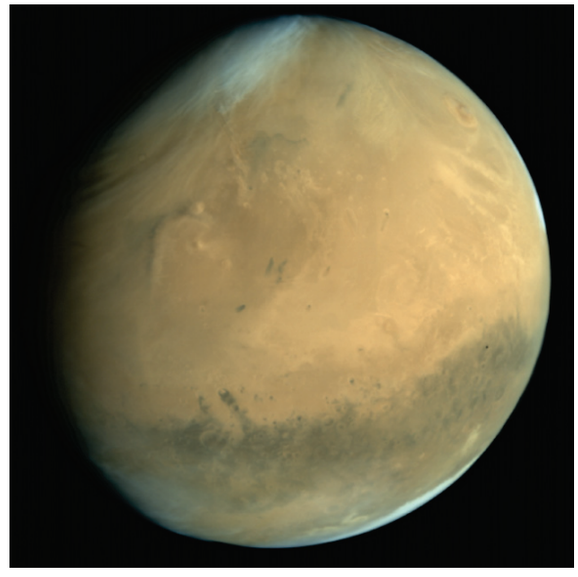


7-10-2014

Global view of Mars

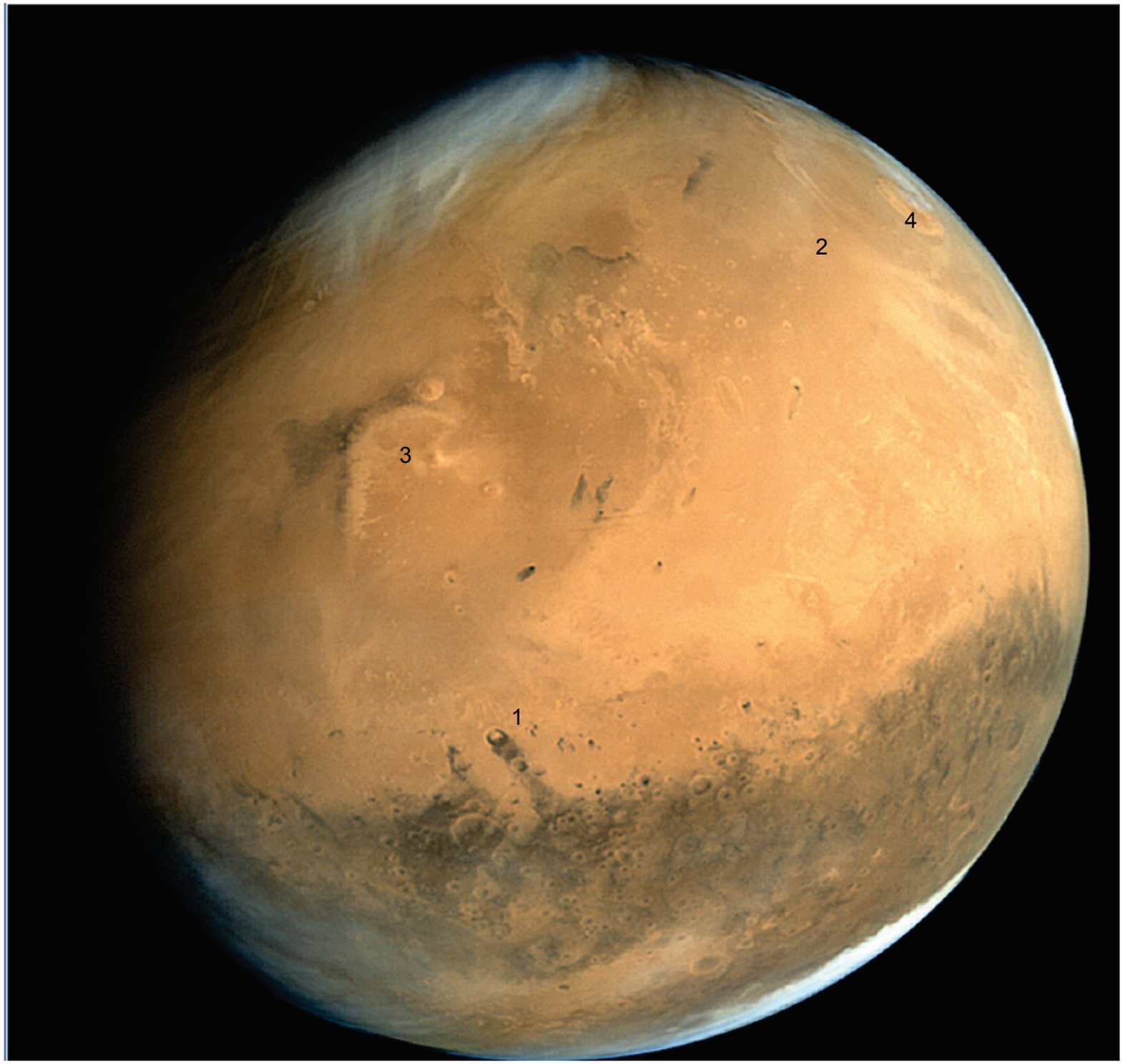
This global image of Mars was acquired by Mars Colour Camera (MCC) on 30-09-2014 at a spatial resolution of ~3.5 km from an altitude of 66552 km. This image shows major geological features of Mars namely, 1) Gale crater, 2) Amazonis Planitia, 3) Elysium Mons and 4) Olympus Mons.

1) Gale crater is about 3.5 to 3.8 billion years old impact crater and is located below Elysium Planitia region of Mars.

2) Amazonis Planitia is located between the two main volcanic provinces on Mars namely Tharsis and Elysium. It contains the youngest fluvial deposits and lava flows on the planet.

3) Elysium Mons volcanic province is located at the eastern hemisphere of Mars. It is the second largest volcanic province on Mars.

4) Olympus Mons is largest volcano in the solar system which is present on planet Mars. The altitude of Olympus Mons is nearly three times the altitude of the largest peak on Earth i.e. Mt. Everest.


4
2
3
1

Global view of Mars

This global view of Mars was acquired by Mars Colour Camera (MCC) on 4-10-2014 at a spatial resolution of ~4.0 km from an altitude of 76680 km. Following major volcanic and tectonic features of Mars, 1) Olympus Mons, 2) Arsia Mons, 3) Pavonis Mons, 4) Ascraeus Mons and 5) Valles Marineris are clearly seen in this image.

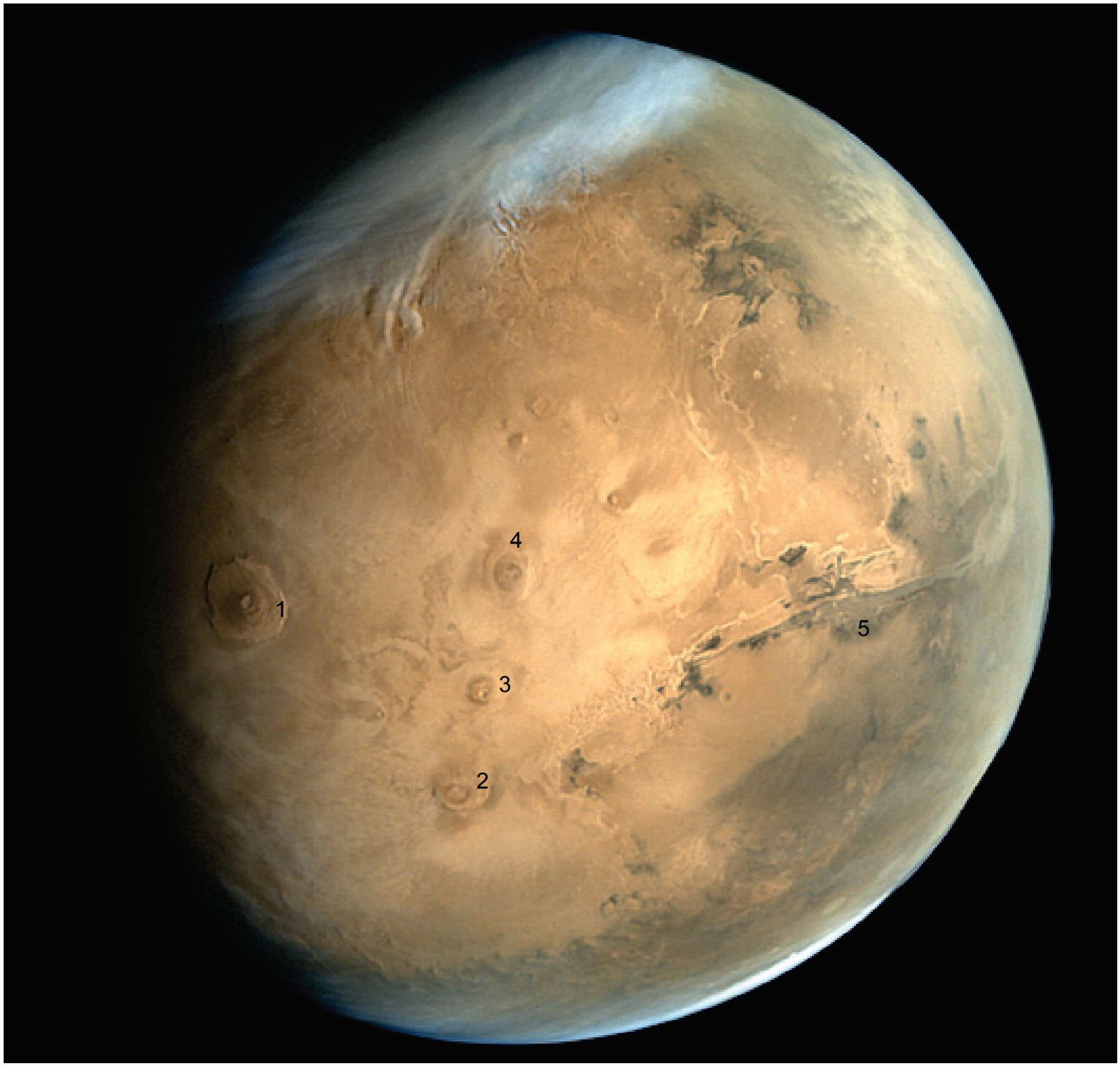
1) Olympus Mons is largest volcano in the solar system present on planet Mars. It is a shield volcano. The height of Olympus Mons is about 22 km from surrounding region.

2) Like Olympus Mons, Arsia Mons is also a shield volcano. It is the southernmost volcano of the three Tharsis Montes. It is 30 times bigger than Mauna Loa in Hawaii (the largest volcano on the Earth) by volume. It has an height of around 12 km from surrounding region.

3) Pavonis Mons is the middle volcanic cone within the Tharsis Montes. It consists the lava flows of early Amazonian age.

4) Ascraeus Mons is located at northern part of the Tharsis Montes. Ascraeus Mons was built by large number of basaltic lava flows.

5) Valles Marineris is grand canyon system present along the equator of Mars. The Valles Marineris is a large tectonic crack present on the Martian crust running up to a length of around 4000 km.

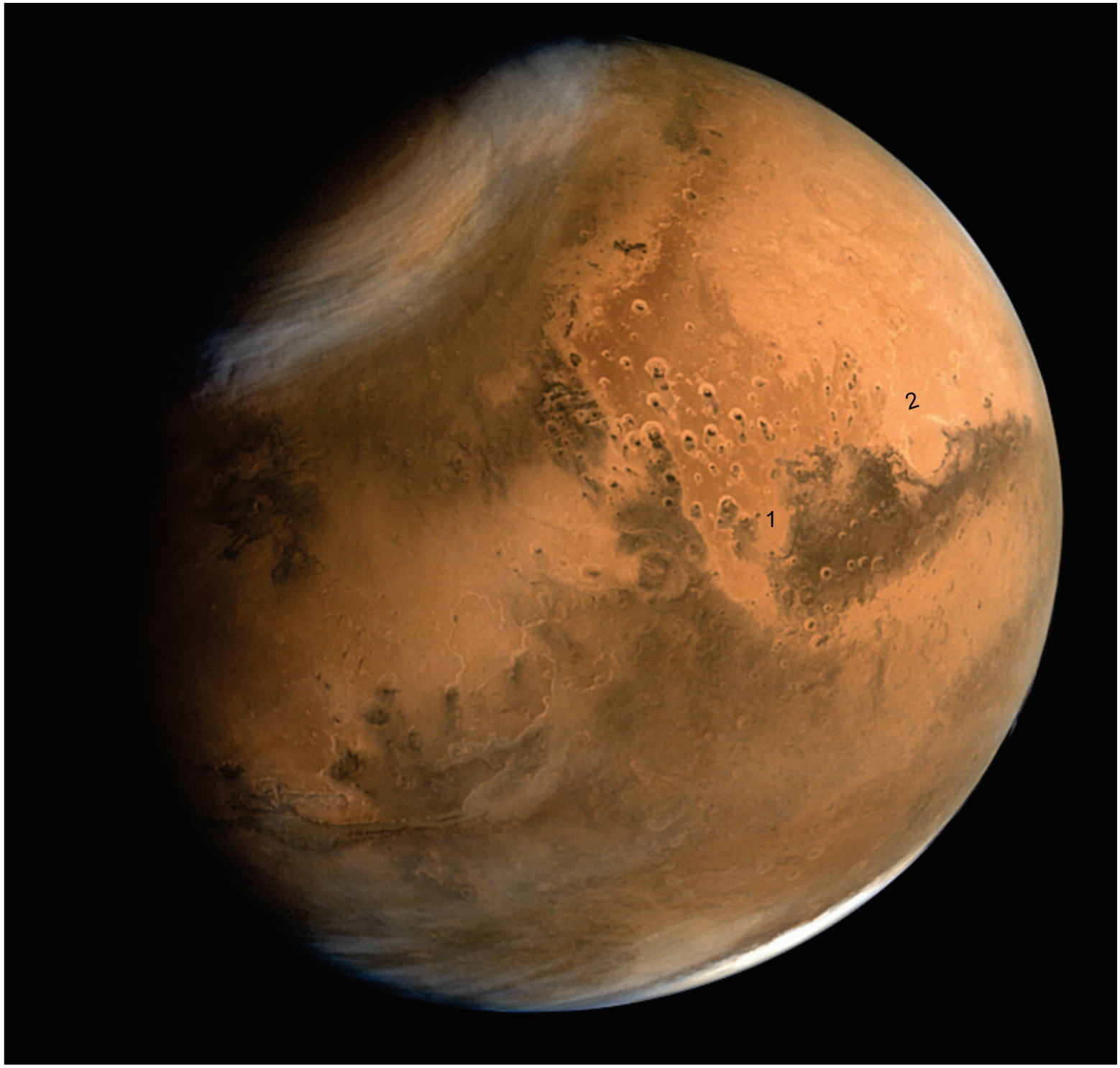

1
2
3
4
5

Global view of Mars

The adjoining image was acquired by Mars Colour Camera (MCC) on 1-10-2014 at a spatial resolution of 4.0 km from an altitude of 76247 km. Meridiani Planum and Arabia Terra regions on Mars are seen in this image.

1) Meridiani Planum is a flat plain on Mars where the mineral, grey hematite is found in large concentrations by Mars Reconnaissance Orbiter Mission of USA, which indicate that water was present in this area for long periods. The second Mars Exploration Rover (MER), named, Opportunity, landed in Meridiani Planum.

2) Huge dust deposition occurs in the Arabia Terra region, therefore it looks a more brighter region on Mars.


2
1

Global view of Mars

This image was taken by Mars Colour Camera (MCC) on 4-10-2014 at a spatial resolution of 3.8 km from an altitude of 72940 km. This image shows various geological terrains of Mars such as: 1) Huygens crater, 2) Syrtis Major complex, 3) Isidis Plantia, 4) Utopia Plantia, 5) Hellas basin, and 6) Arabia Terra.

1) Huygens is an impact crater present to the north of Hellas Basin. The surrounding area of Huygens crater is known for aqueous minerals such as carbonates and phyllosilicates. Such minerals form due to the presence of water.

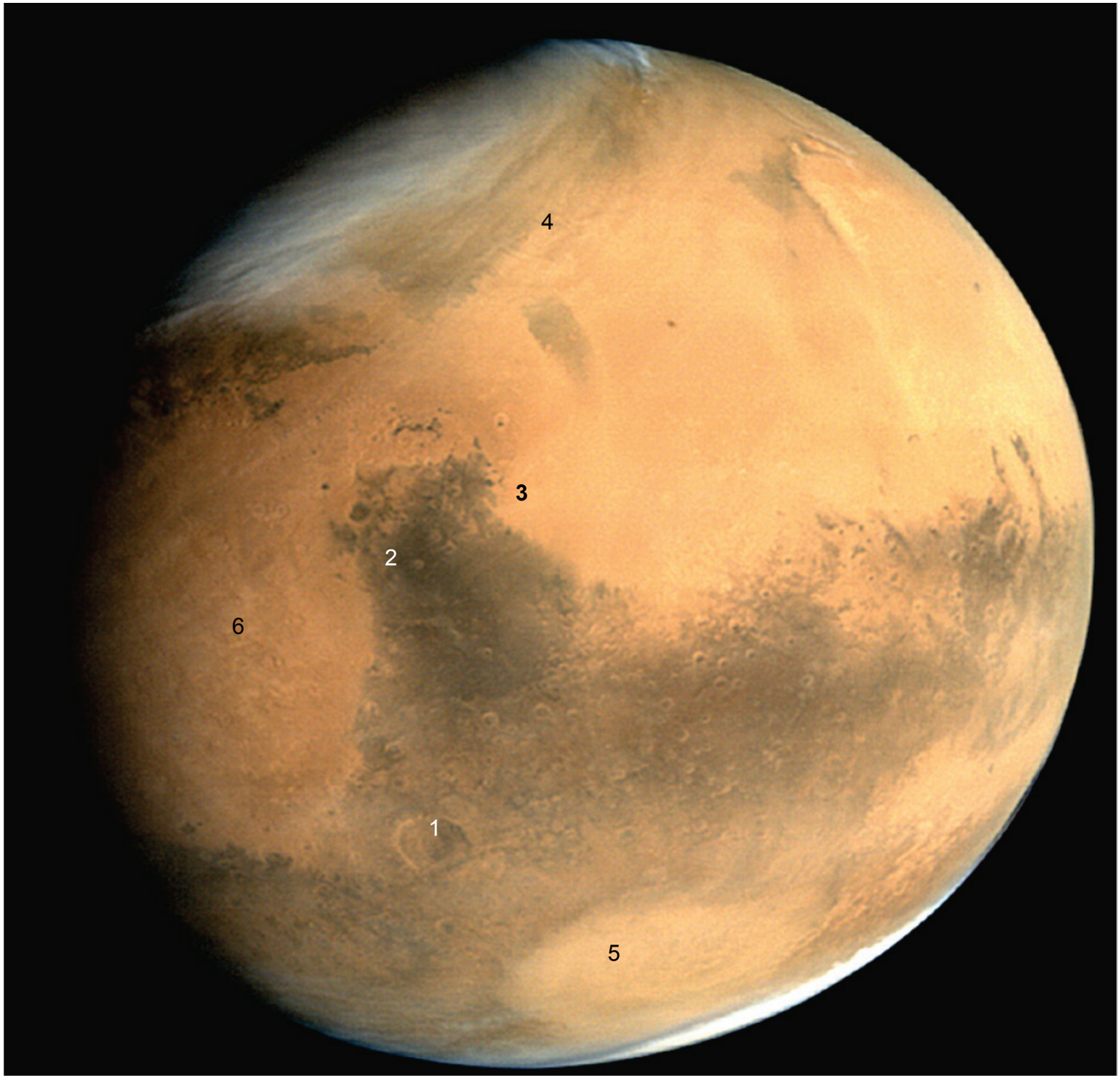
2) Syrtis Major is the most prominent Hesperian volcanic complexes on Mars.

3) Isidis Planitia is third giant impact basin on Mars after the Hellas and Argyre basins. Deposits of carbonates have been reported around this region, which indicates the presence of water in its past history of Mars.

4) Utopia Planitia is the impact basin on Mars. It was the landing site of Viking-2 lander of NASA.

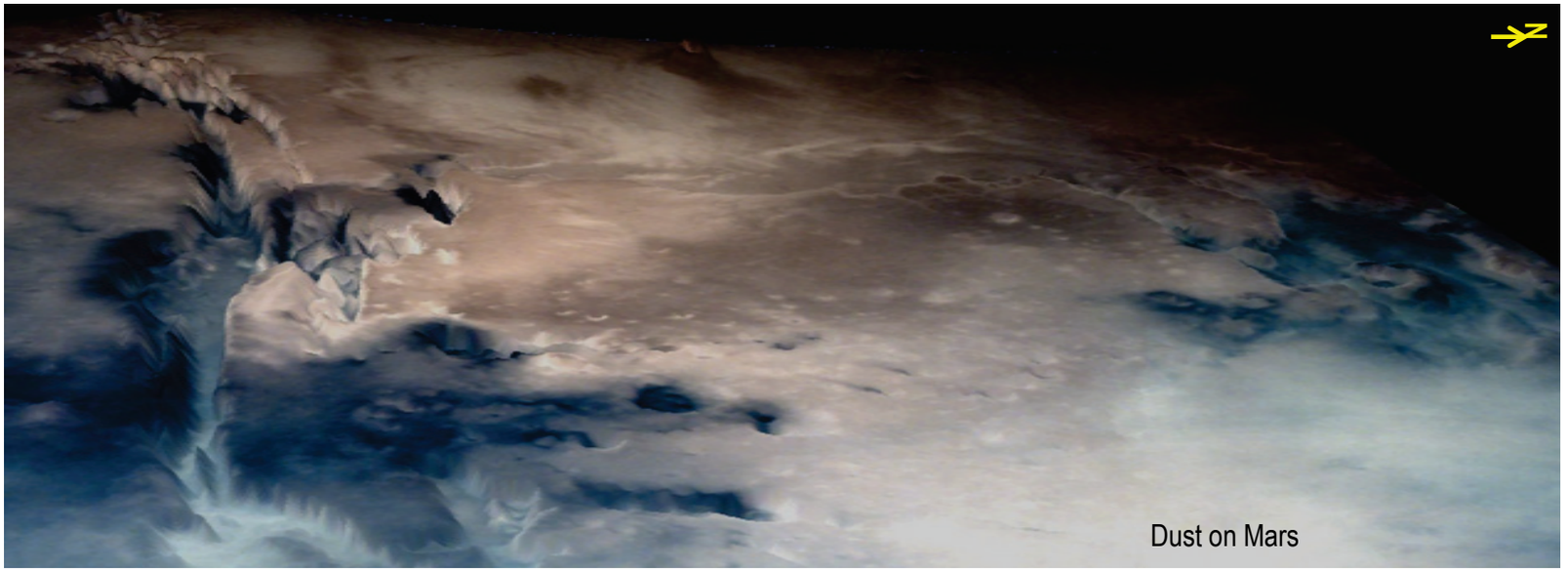
5) Hellas Planitia is large Impact Basin located in southern hemisphere of Mars. The diameter of Hellas basin is about 2,300 km. The depth of basin is around 9,000 m .

6) Arabia Terra is a dusty area on Mars. It is covered with huge amount of dust deposits, and appears as brighter region on Mars.


4
3
2
6
1
5

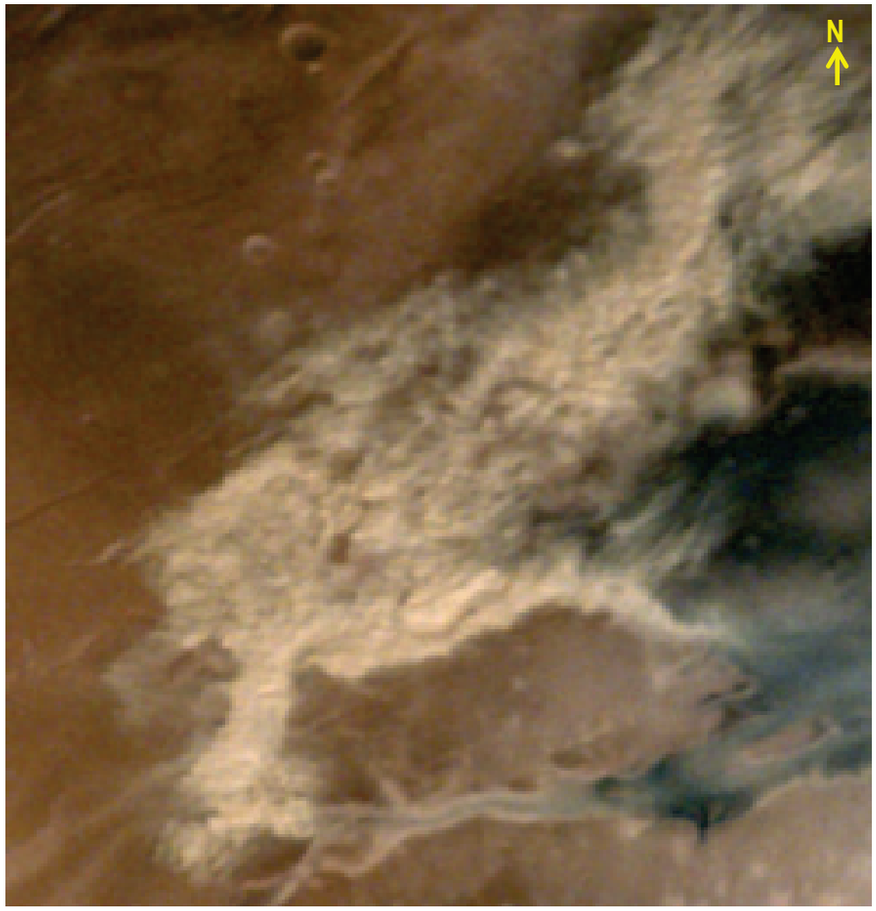
Dust Detection on Mars

Lunae Planum region on Mars contain impressions of many paleo-river valleys. Many outflow channels have been identified in this region by previous space missions to Mars. It is believed that the water once flowed in this region and this water flow carved Lunae Planum region. A thick regional scale ~500 km^2 size detached layer of atmospheric dust was detected using MCC on October 20, 2014 around the Lunae Planum region of Mars (see the front page). On an another day of October 28, 2014 image over same region does not show this dust layer. This indicates about the dynamic atmospheric processes such as wind, which is very active on Mars. The dust dynamics on Mars also affects the solar radiation budget and surface temperature.

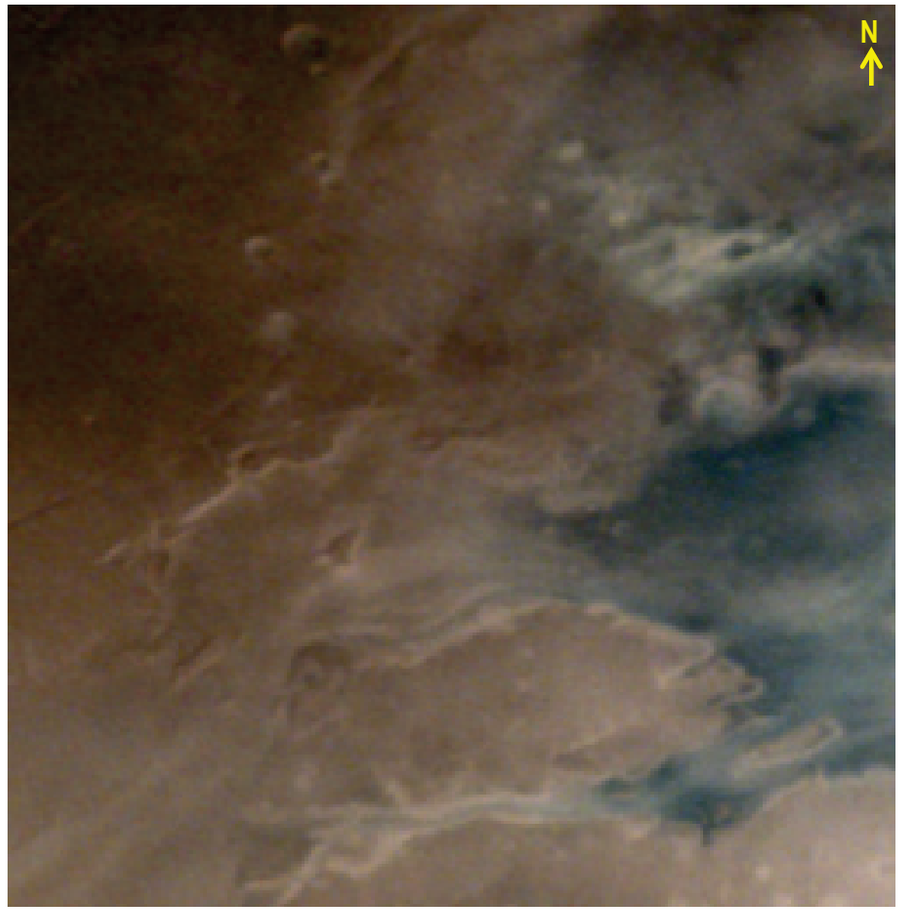


Three dimensional view of Lunae Planum region of Mars showing dust activity on October 20, 2014.

Dust Detection on Mars

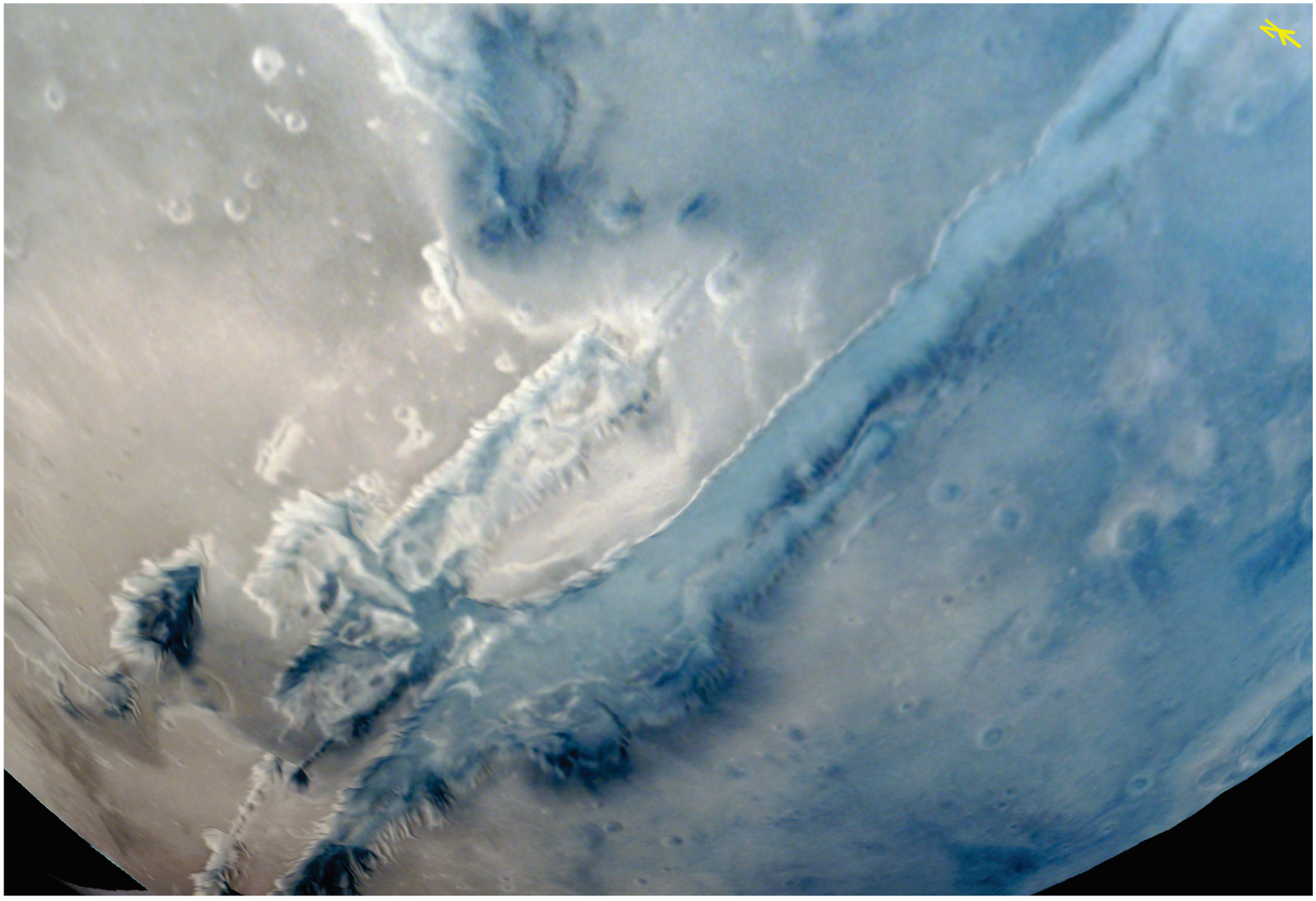


Detected dust layer on Mars on October 20, 2014



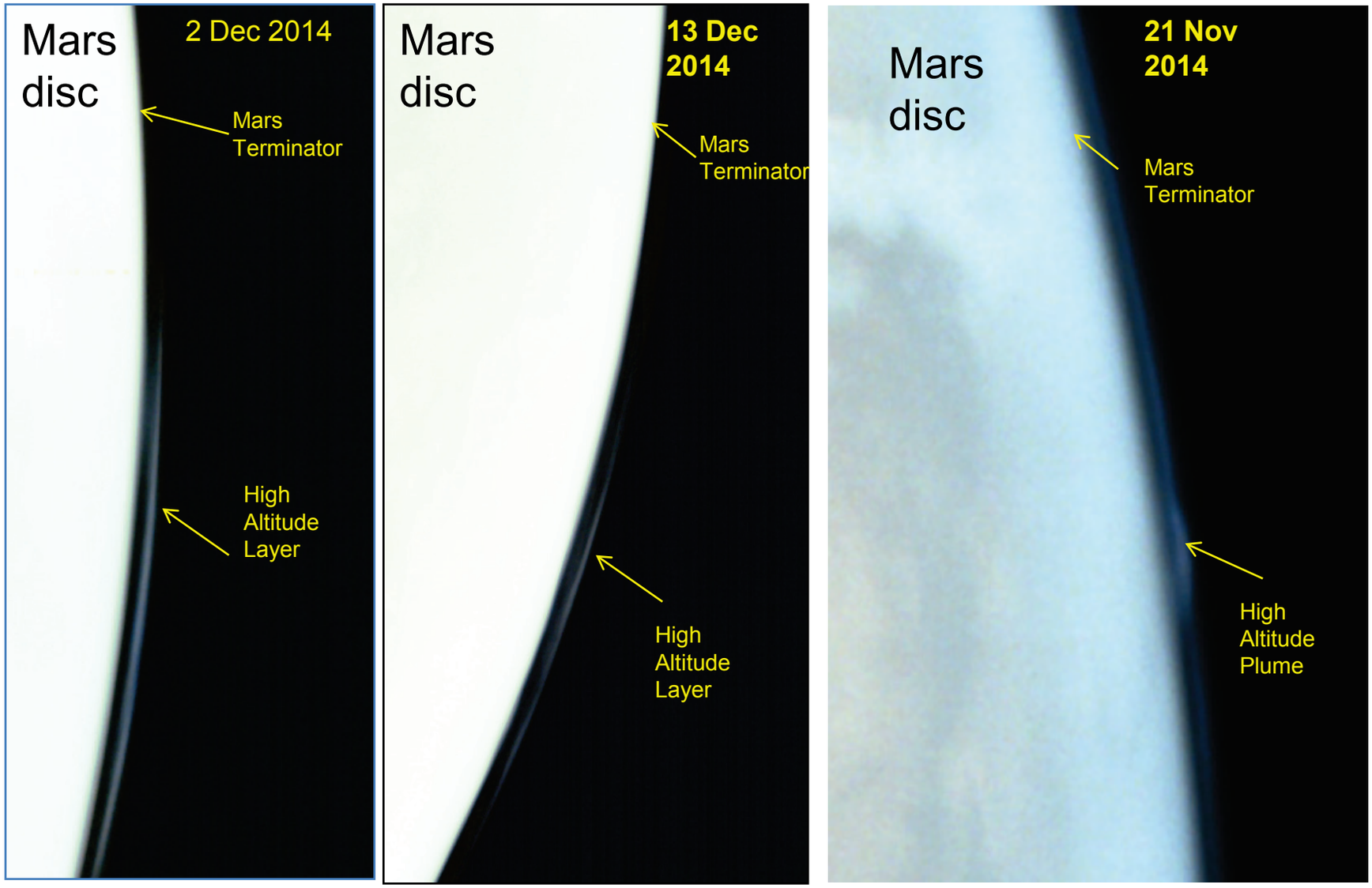
Dust layer cleared on Mars on October 28, 2014

Dust Detection on Mars



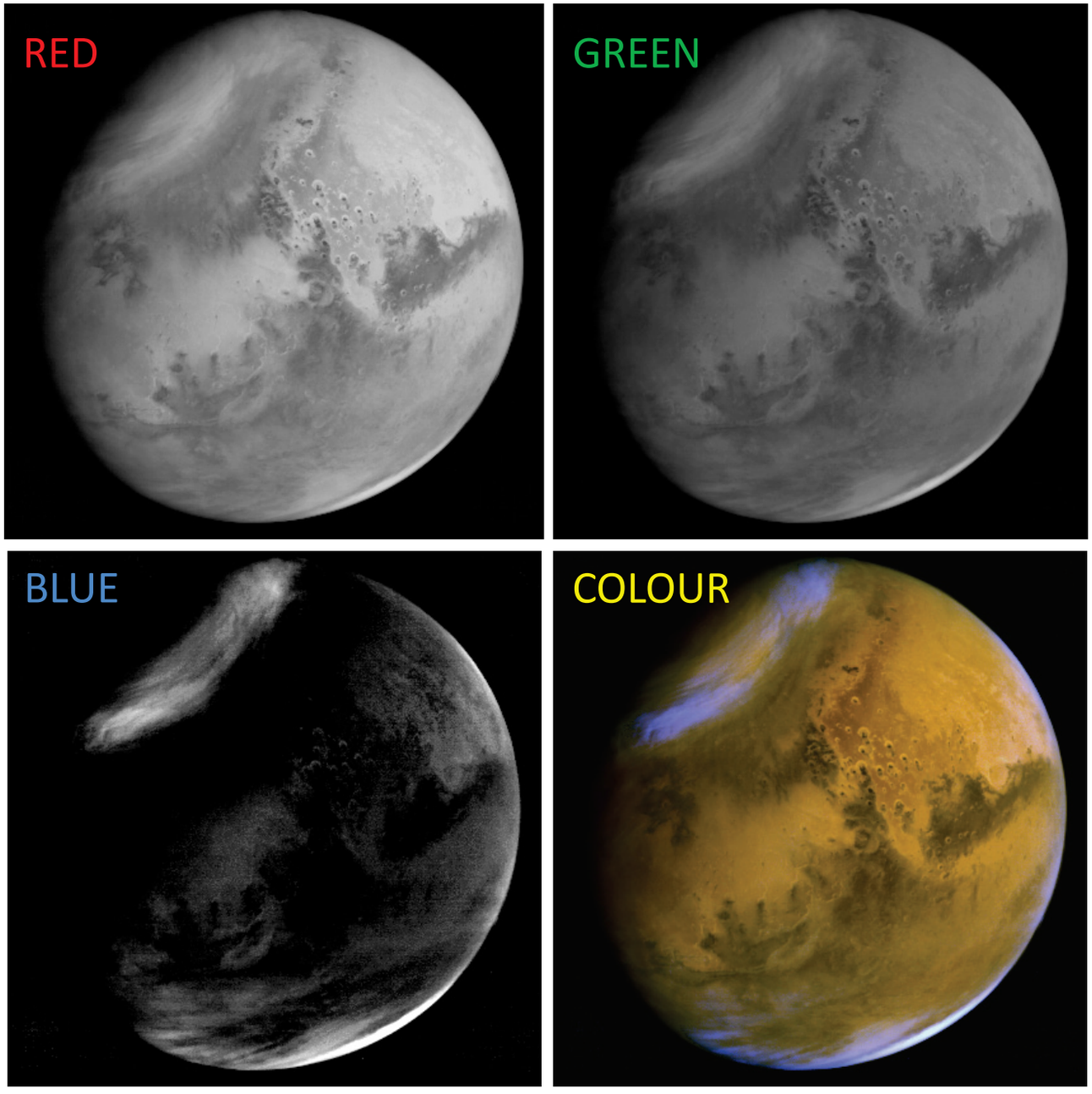
Haze detected within and around Valles Marineris region of Mars as seen in a mosaic of MCC data. Three dimensional view is created with MCC and MOLA digital elevation (DEM) data sets.

High Altitude Dust Layers in limb views of Mars



Limb images of Mars captured by Mars Colour Camera (MCC) have shown very mysterious high altitude scattering layers on different dates. These layers are suspected to be of dust or can be of high altitude clouds. The origin of this phenomenon is still unknown.

Mars Seen in Three Colours

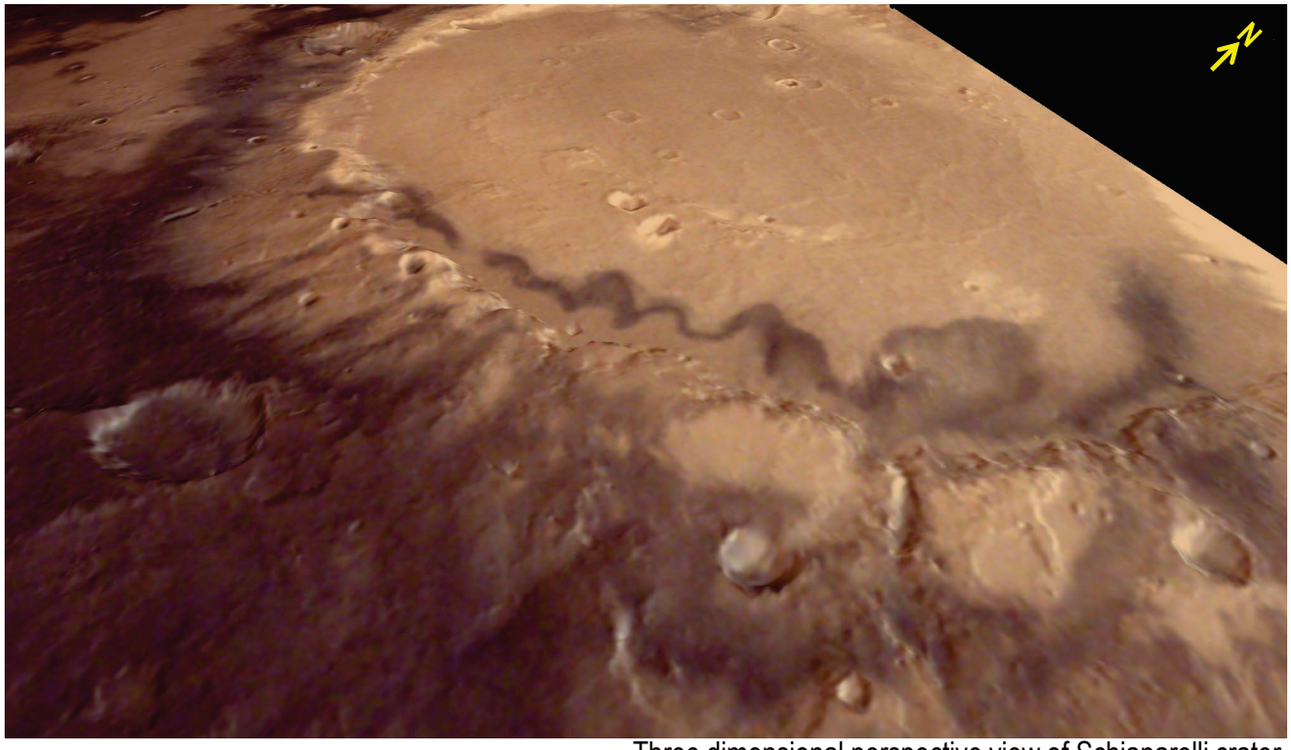


This global view of Mars is shown in three different colours. The red colour image shows higher reflectance, compared to green and blue colour images. This higher reflectance of sun light in red gives Mars its typical colour. The blue filter image exhibits atmospheric features such as dust particles and north polar hood cloud.

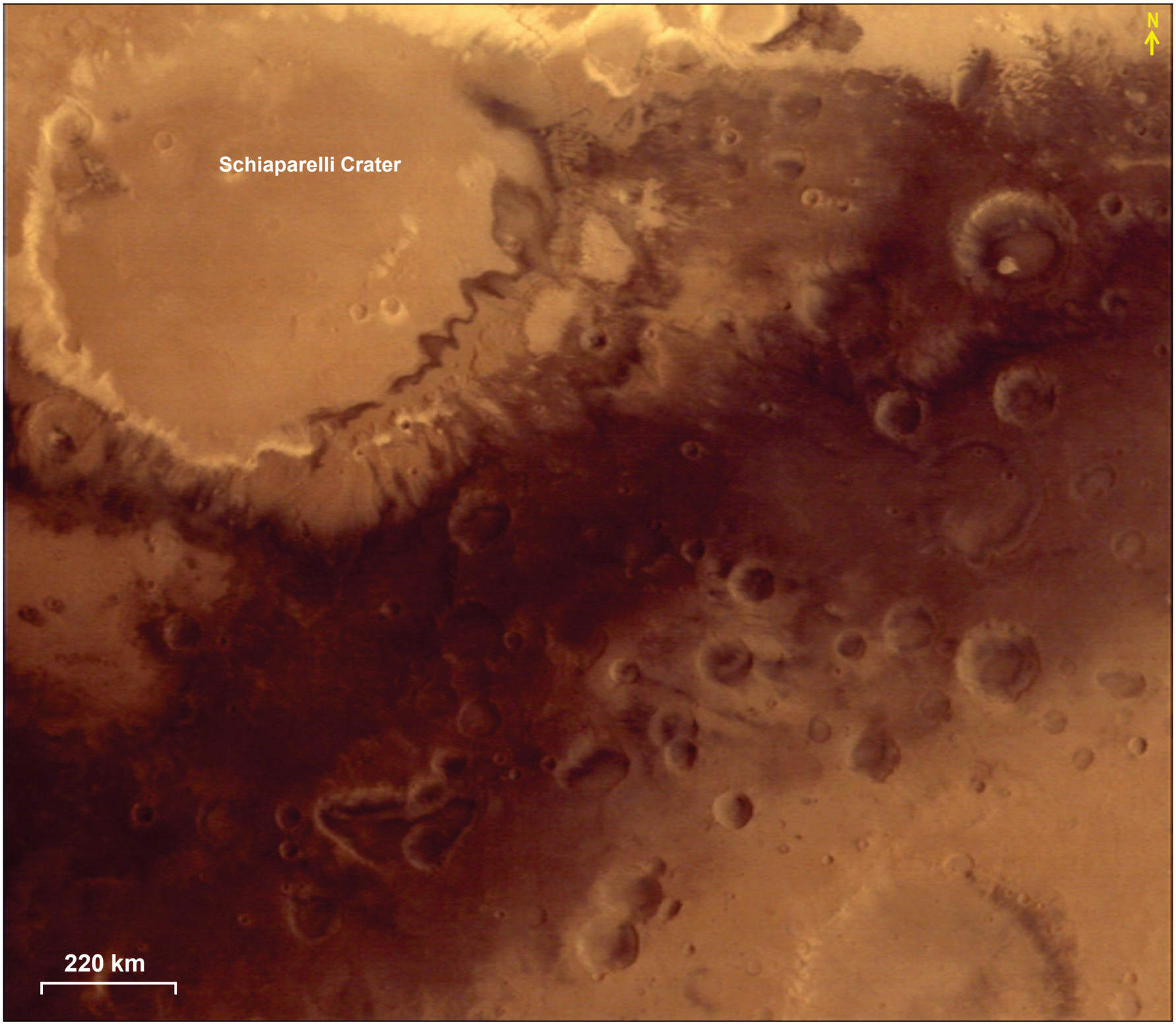
03 Impact Craters on Mars

Schiaparelli Crater

Schiaparelli crater is an impact crater on Mars having a diameter of ~460 km and located at ~3^0 S, 17^0 E. This crater is situated near the Martian equator in western Arabia Terra region on Mars. This image of Schiaparelli crater was taken by Mars Colour Camera (MCC) on 15-01-2015 at a spatial resolution of ~470 m from an altitude of 9000 km. Small craters located in the floor and adjoining regions of the crater are clearly seen in image.

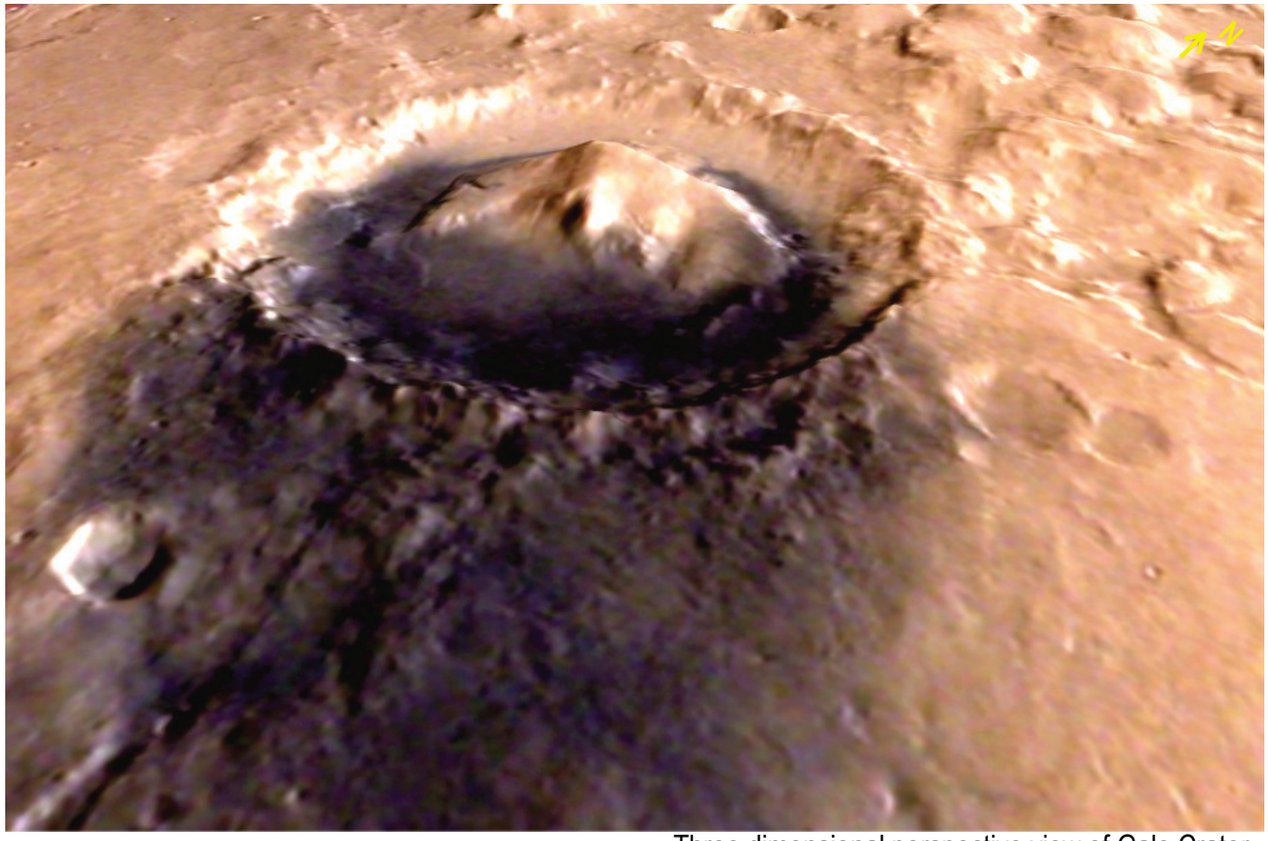


Three dimensional perspective view of Schiaparelli crater

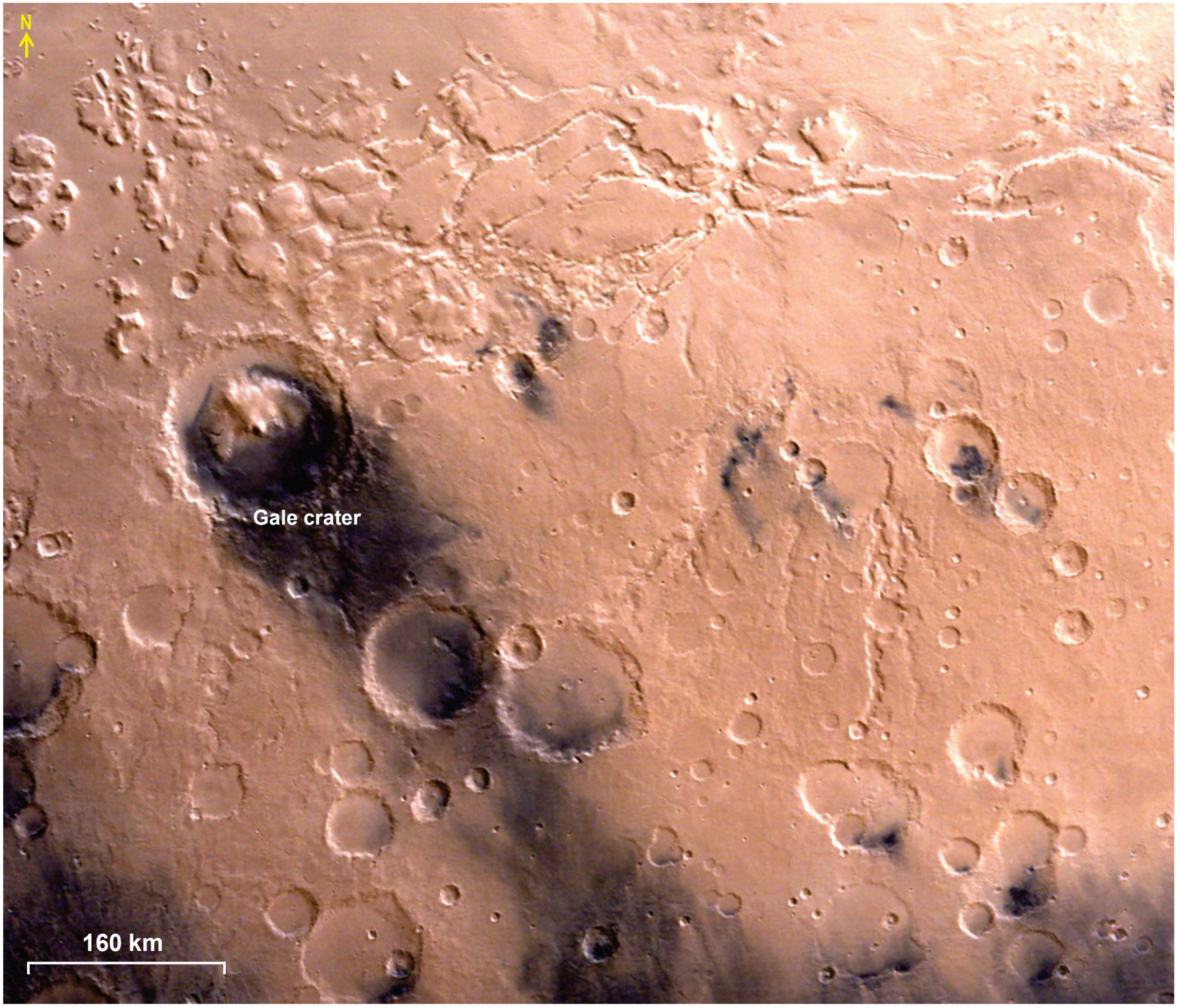

Schiaparelli Crater
N
220 km

Gale Crater

Gale crater on Mars is around 154 km diameter and estimated to be 3.5 -3.8 billion years old. It is located at 5^0S, 138^0 E in Aeolis Planum region on Mars. This crater has been named after Walter F Gale, an astronomer who observed Mars in late nineteenth century. This image of Gale crater and adjoining regions was taken by Mars Colour Camera (MCC) on 17-01-2015 at a spatial resolution of ~530 m from an altitude of 10000 km. This crater is the landing site of Curiosity rover of Mars Science Laboratory (MSL) mission of NASA.

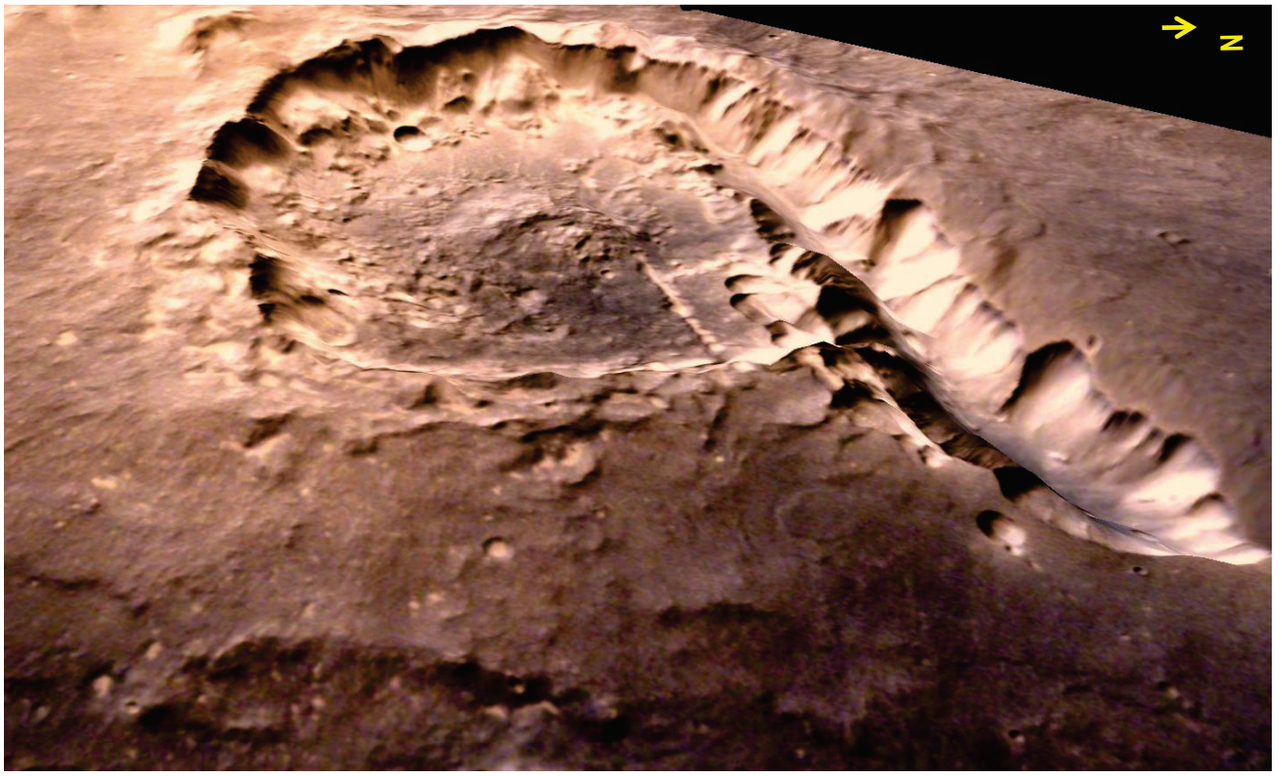


Three dimensional perspective view of Gale Crater

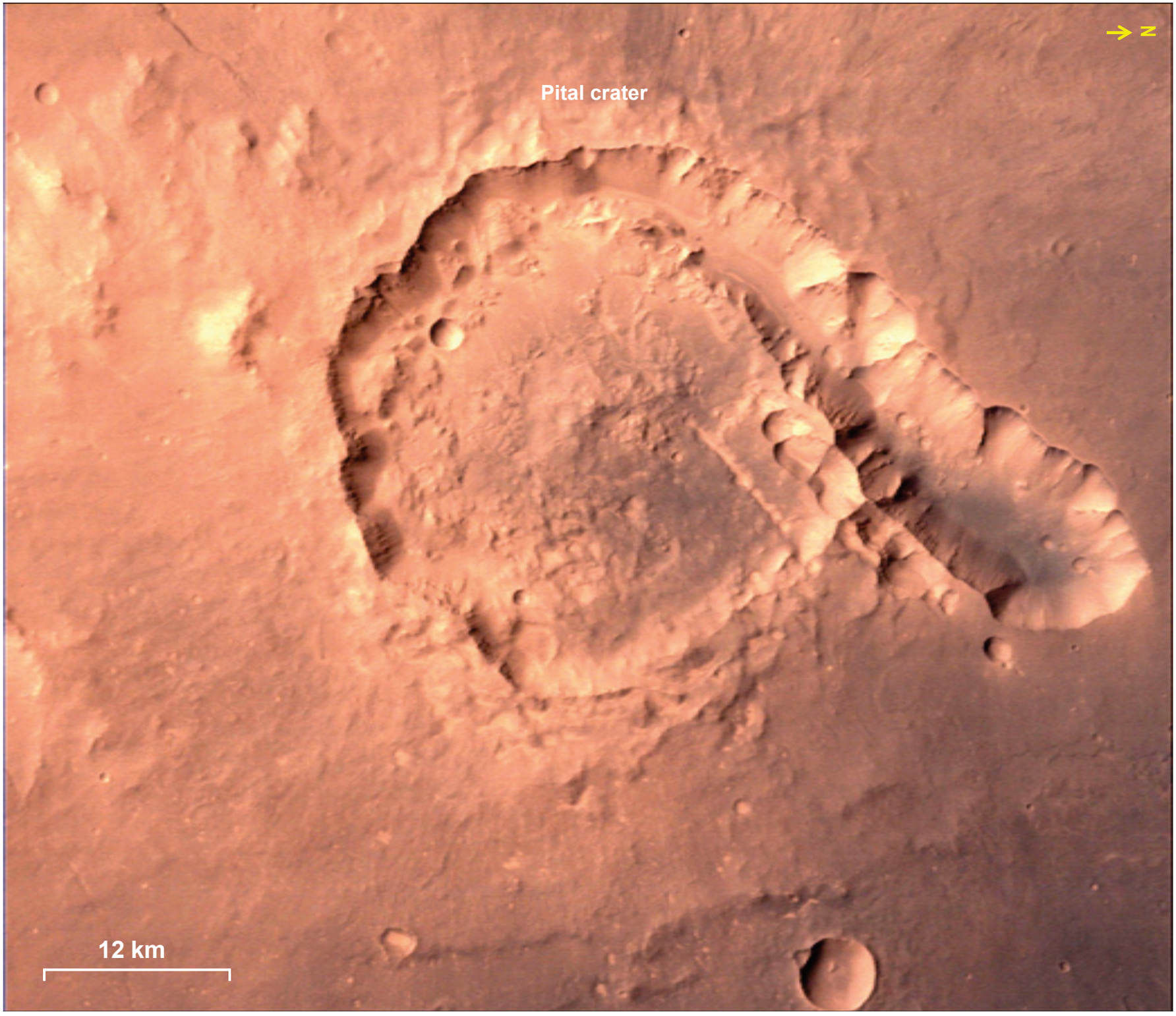

N
Gale crater
160 km

Pital Crater in Ophir Planum

Pital crater is an impact crater on Mars having a diameter of ~40 km and located at 9^0S, 62^0 W and is situated in Ophir Planum on Mars. This Image of Pital crater was taken by Mars Colour Camera (MCC) on 23-04-2015 at a spatial resolution of ~45 m from an altitude of 800 km. Wall of the crater and chain of small impact craters are clearly seen in this image.



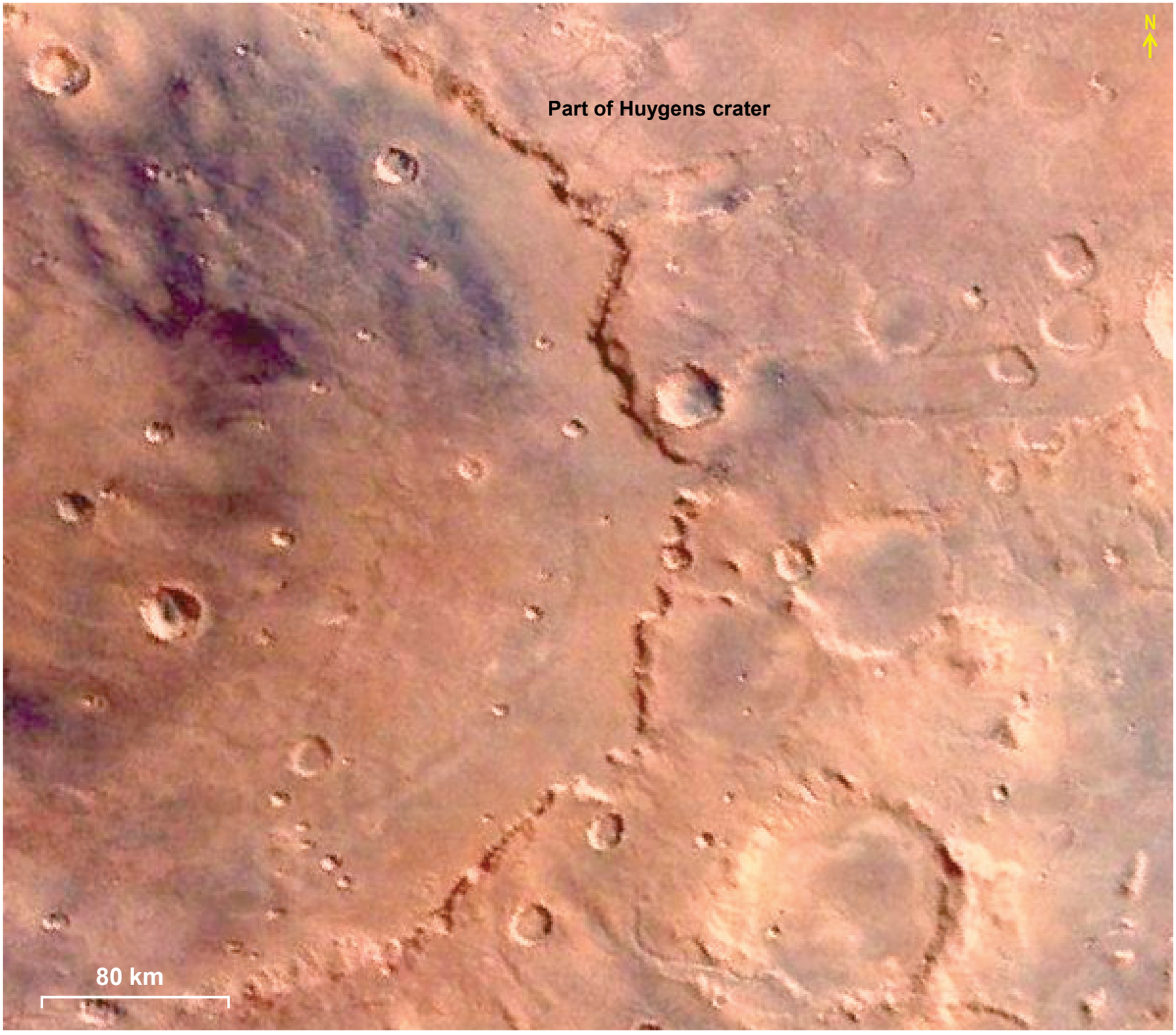
Three dimensional perspective view of Pital crater


N
Pital crater
12 km

Huygens crater

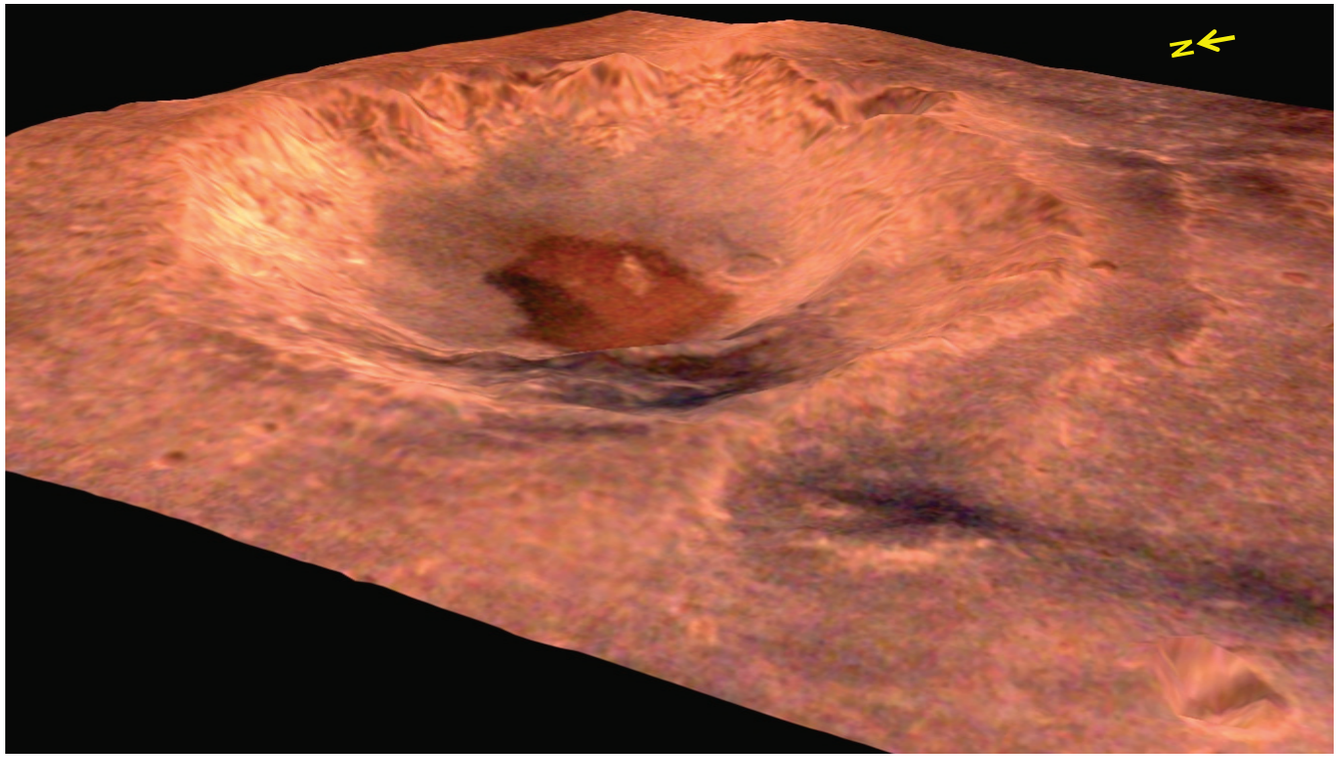
MCC mage of Huygens crater which is located to the north of Hellas basin region of Mars at 14^0 S, 55^0 E. This crater has been named in honor of the Dutch astronomer, mathematician and physicist Christiaan Huygens. The Huygens crater is ~456 km in diameter. This Image of Huygens crater was acquired by Mars Colour Camera (MCC) on 31-01-2015 at a spatial resolution of ~280 m from an altitude of ~ 5380 km. Multi rings of Huygens crater are clearly seen in this image.

Three dimensional perspective view of Huygens Crater

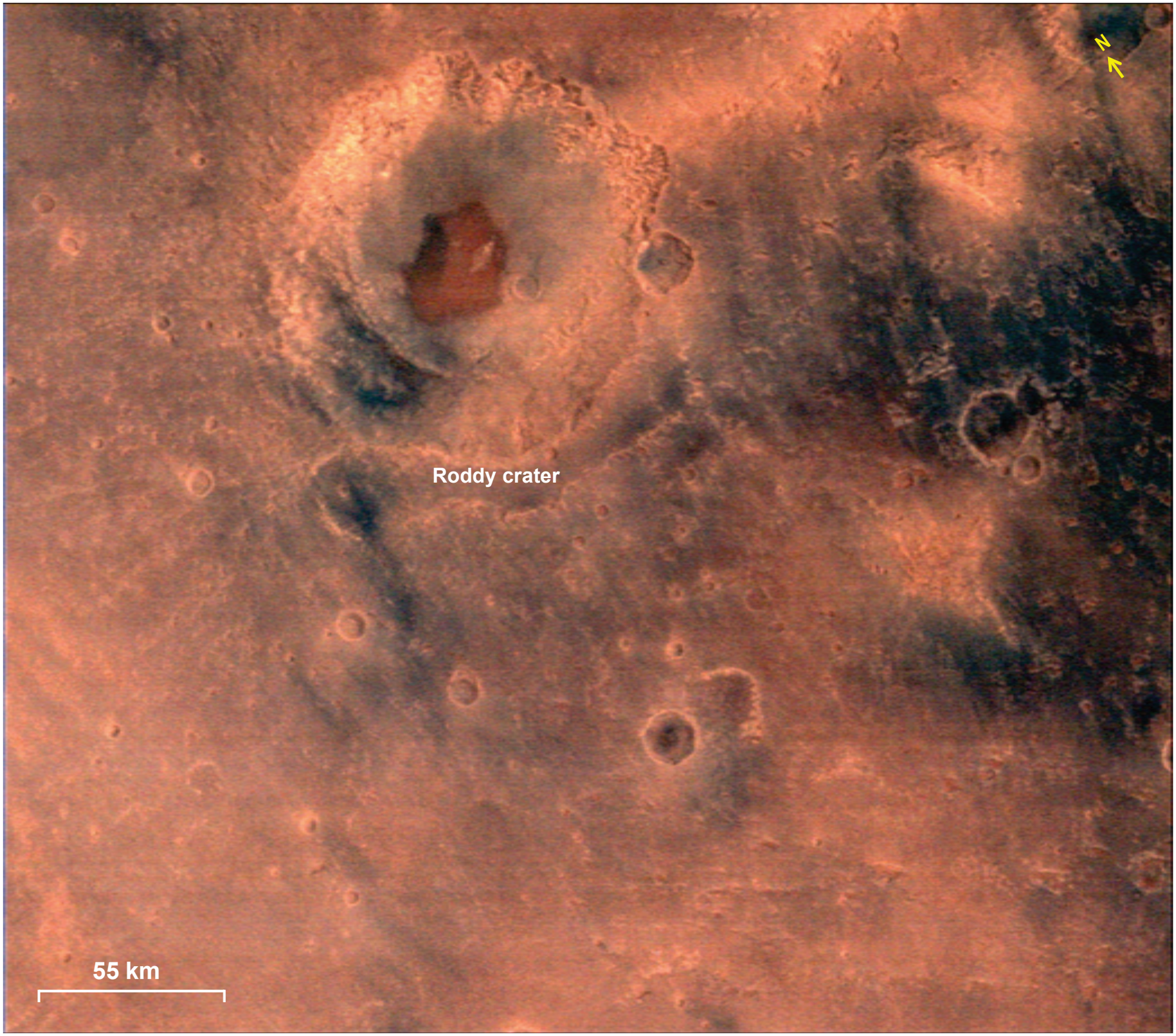

Part of Huygens crater
N
80 km

Roddy crater in Mare Erythraeum region

Roddy is an impact crater on Mars having a diameter of ~85 km and located at ~21^0 S, 39^0 W and is situated in Mare Erythraeum region on Mars. Image of Roddy Crater was taken by Mars Colour Camera (MCC) on 28-01-2015 at a spatial resolution of ~150 m from an altitude of ~2900 km. The floor of the crater have different composition which can be seen in this image.

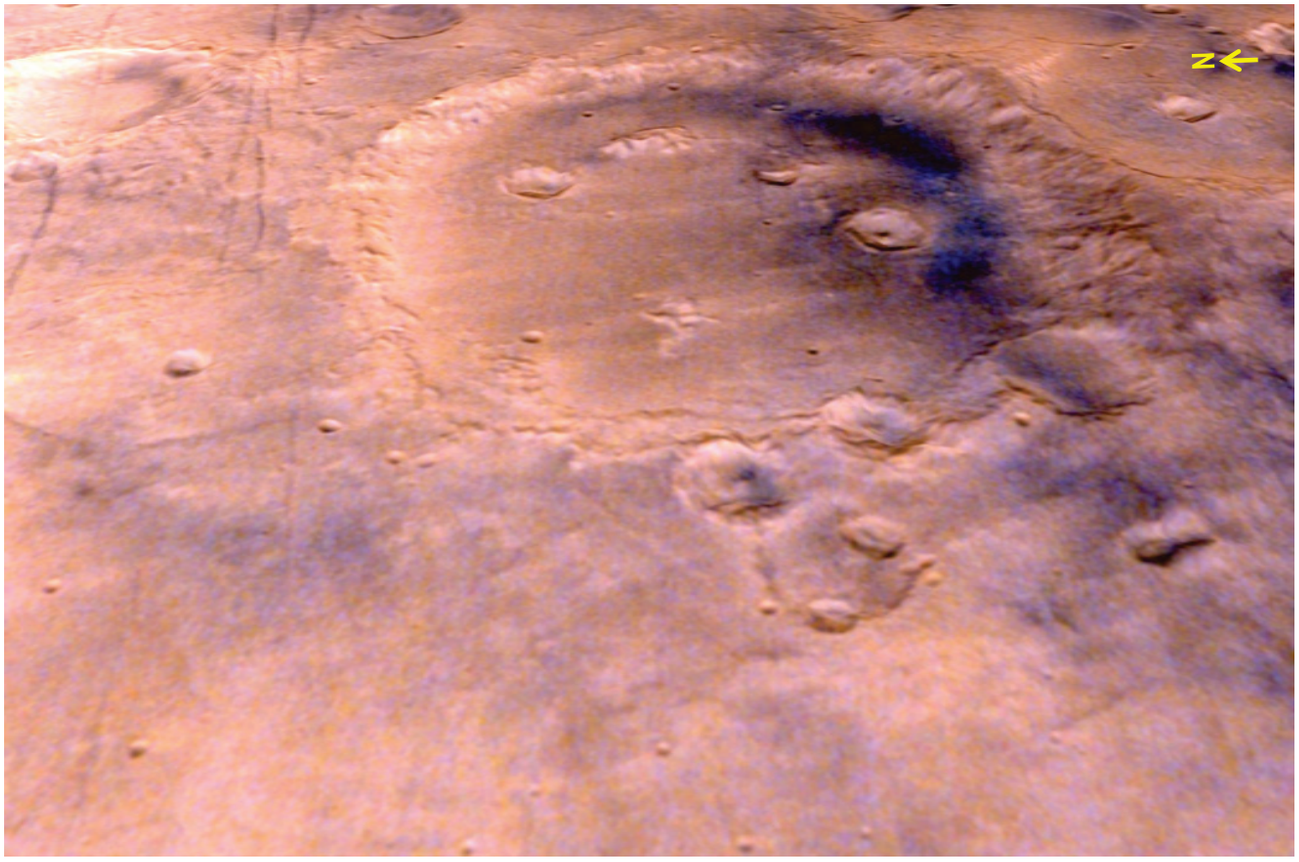


Three dimensional perspective view of Roddy Crater

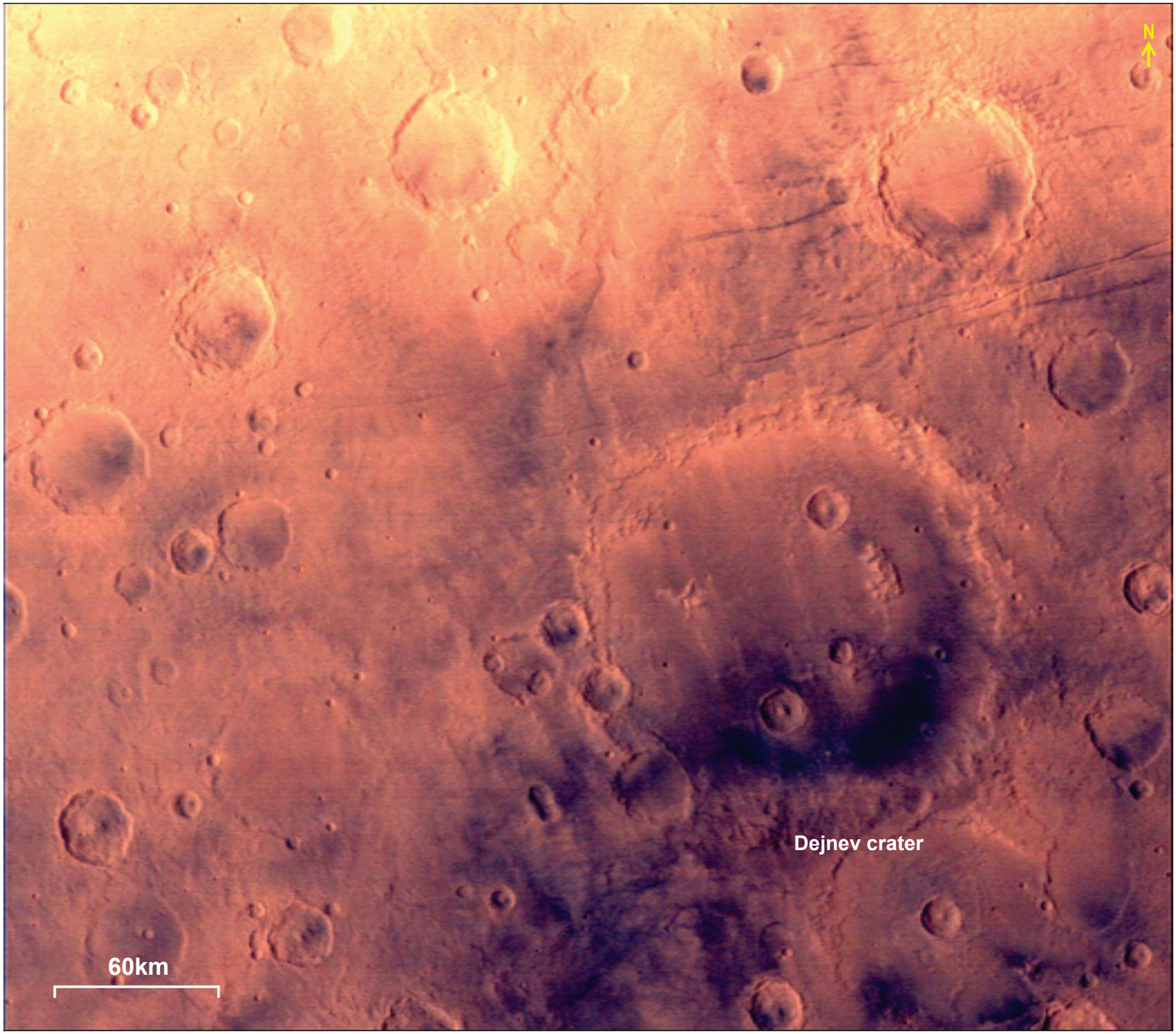

N
Roddy crater
55 km

Dejnev Crater in Terra Sirenum region

Dejnev crater is an impact crater on Mars having a diameter of ~150 km and located at 25^0 S, 164^0 W and is situated Terra Sirenum region on Mars. Image of Dejnev impact crater was taken by Mars Colour Camera (MCC) on 14-10-2014 at a spatial resolution of 192 m from an altitude of 3694 km. This crater is having the diameter of 156 km. Fractures lines are clearly seen above Dejnev crater, showing the distribution and orientation of fracture system. They also provide clues to the internal stress mechanism of Mars.

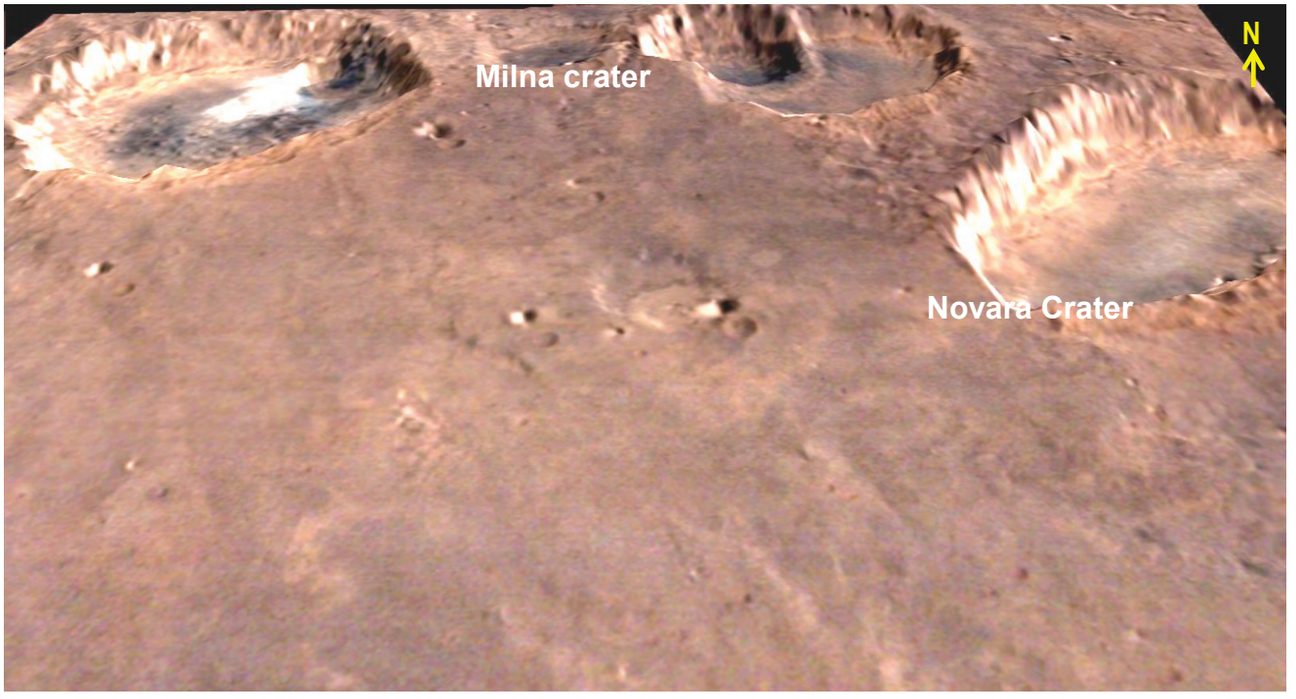


Three dimensional perspective view of Dejnev Crater

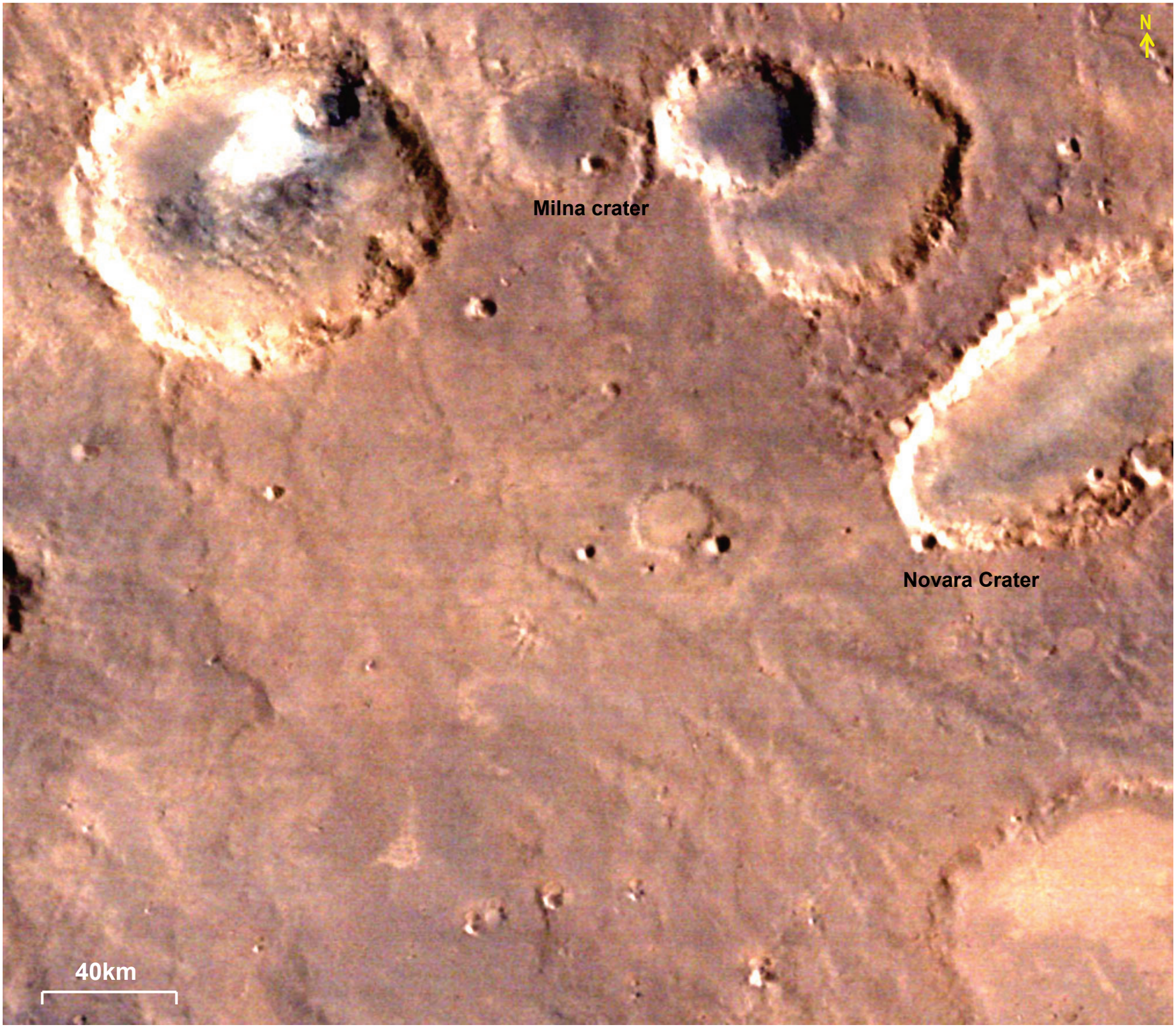

N
Dejnev crater
60km

Impact Craters near Samara Valles region

Milna and Novara are impact craters on Mars located near 25^0S, 13^0 W. They are situated south of Valles Marineris region on Mars. Novara is a crater having elongated shape. In this area overlapping of two craters are also seen. Image of these craters near Samara Valles region was taken by Mars Colour Camera (MCC) on 14-02-2015 at a spatial resolution of 121 m from an altitude of 2339 km.

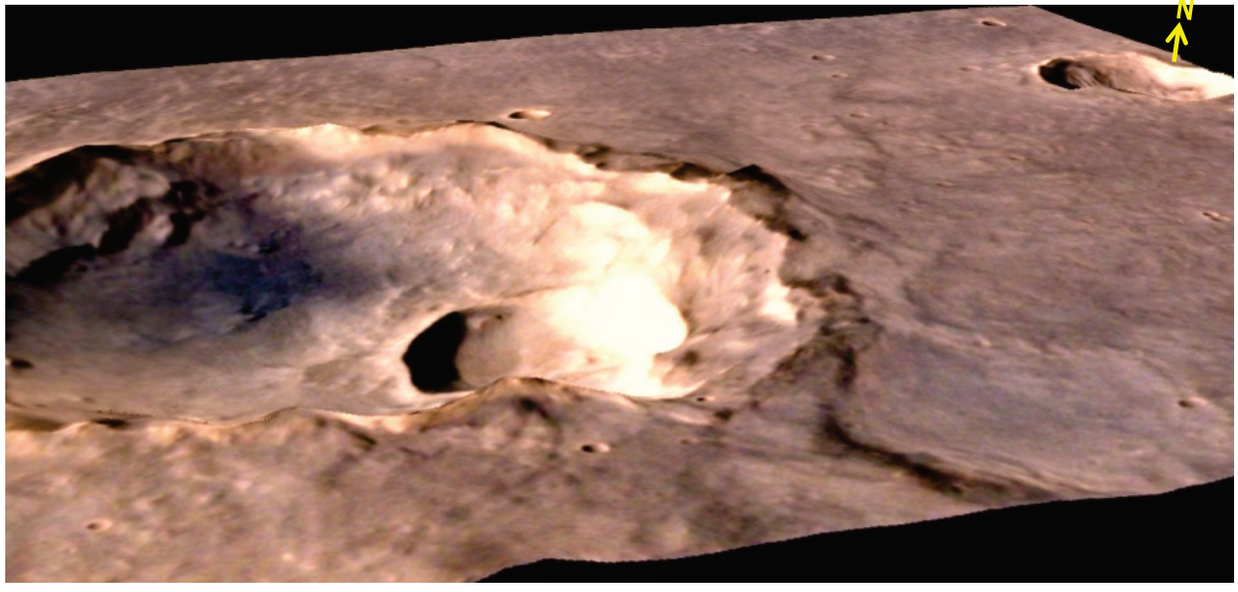


Three dimensional perspective view of Milna and Novara Crater

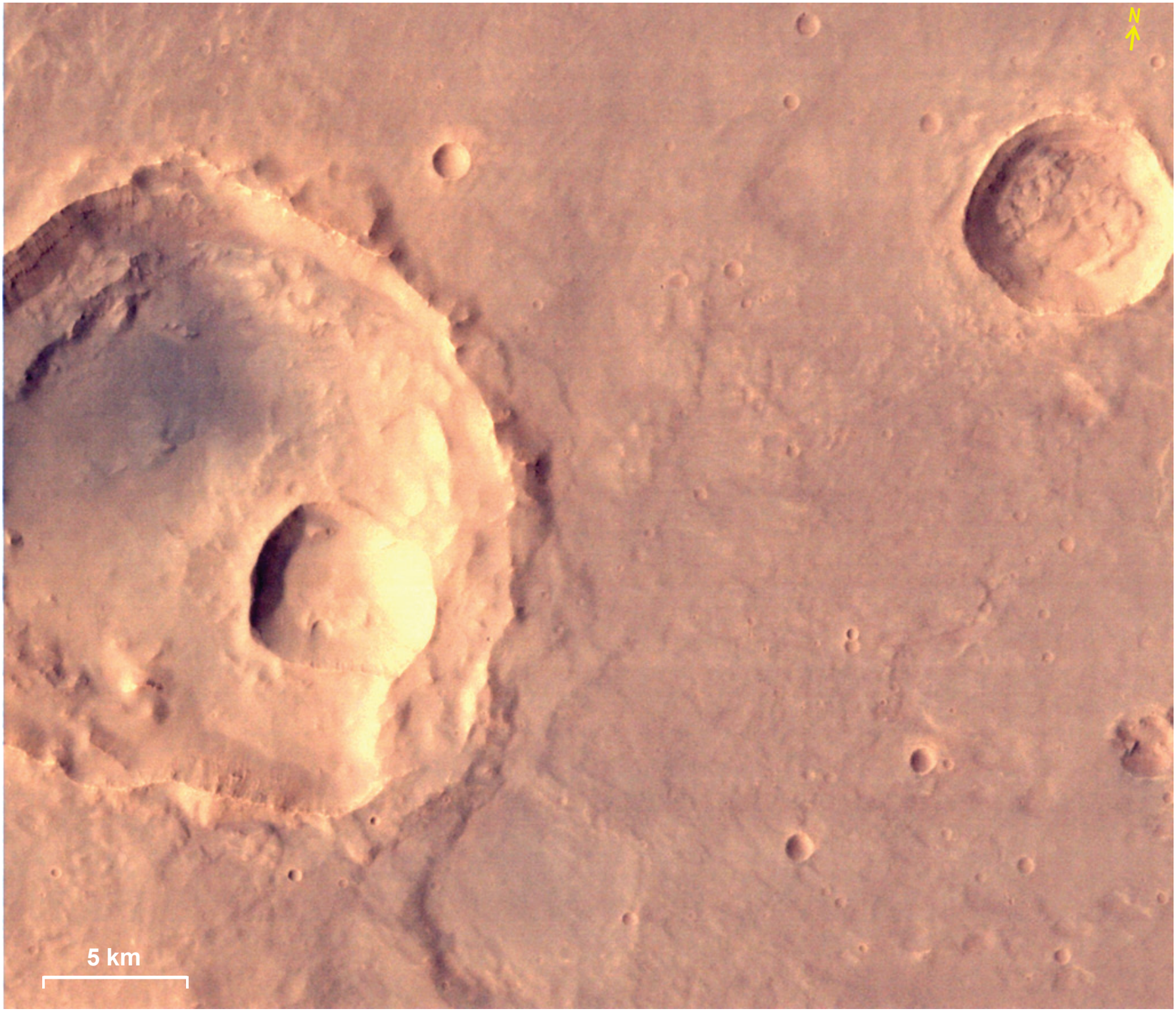

N
Milna crater
Novara Crater
40km

Impact Crater near to Her Desher Vallis region

Image of impact crater near to Her Desher vallis region was taken by Mars Colour Camera (MCC) on 19-02-2015 at a spatial resolution of 19 m from an altitude of 366 km. These craters are located at 25^0S, 45^0 W. Layered deposits on the crater wall are seen in this image. Impression of small impacts are also present within this crater, which represents different time period of impacts.

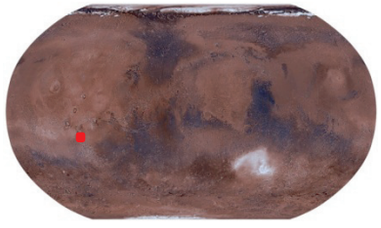


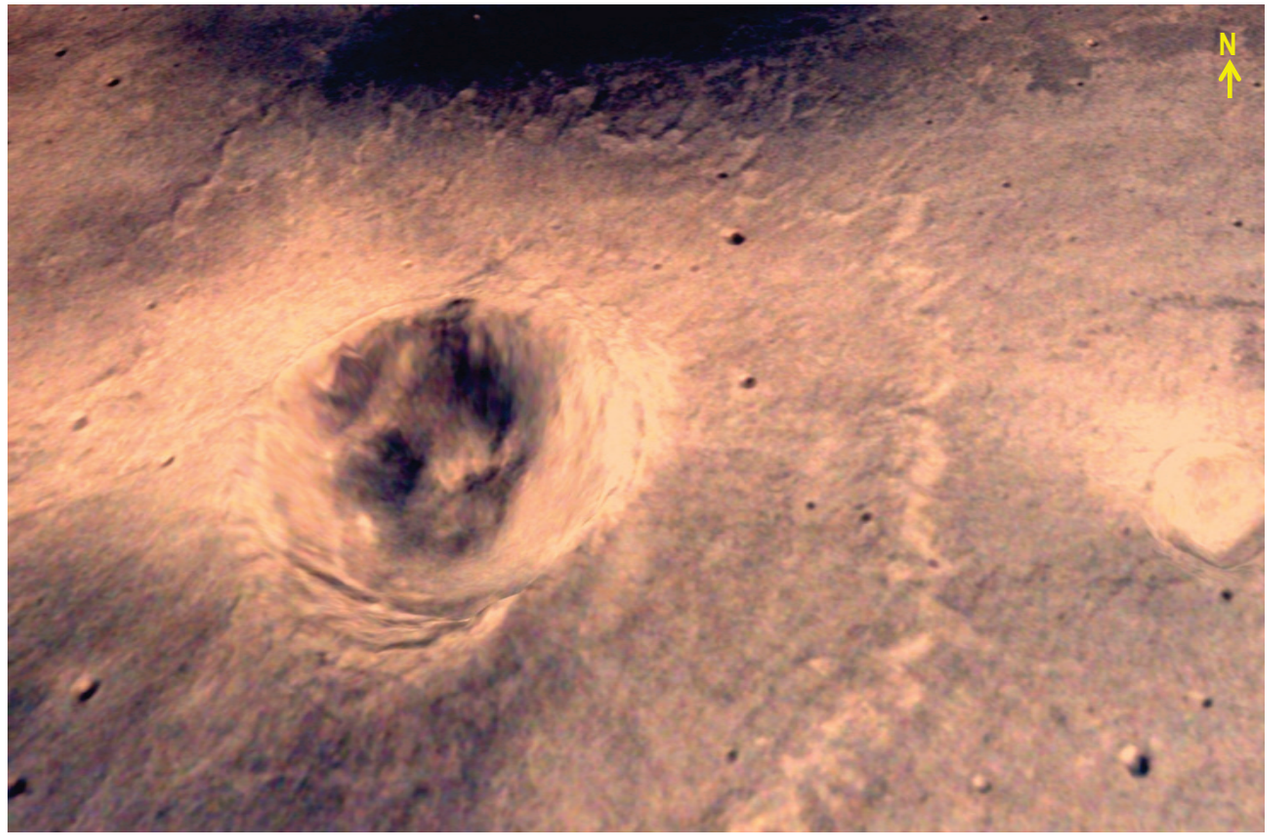
Three dimensional perspective view of Impact Crater near to Her Desher Vallis region


N
5 km

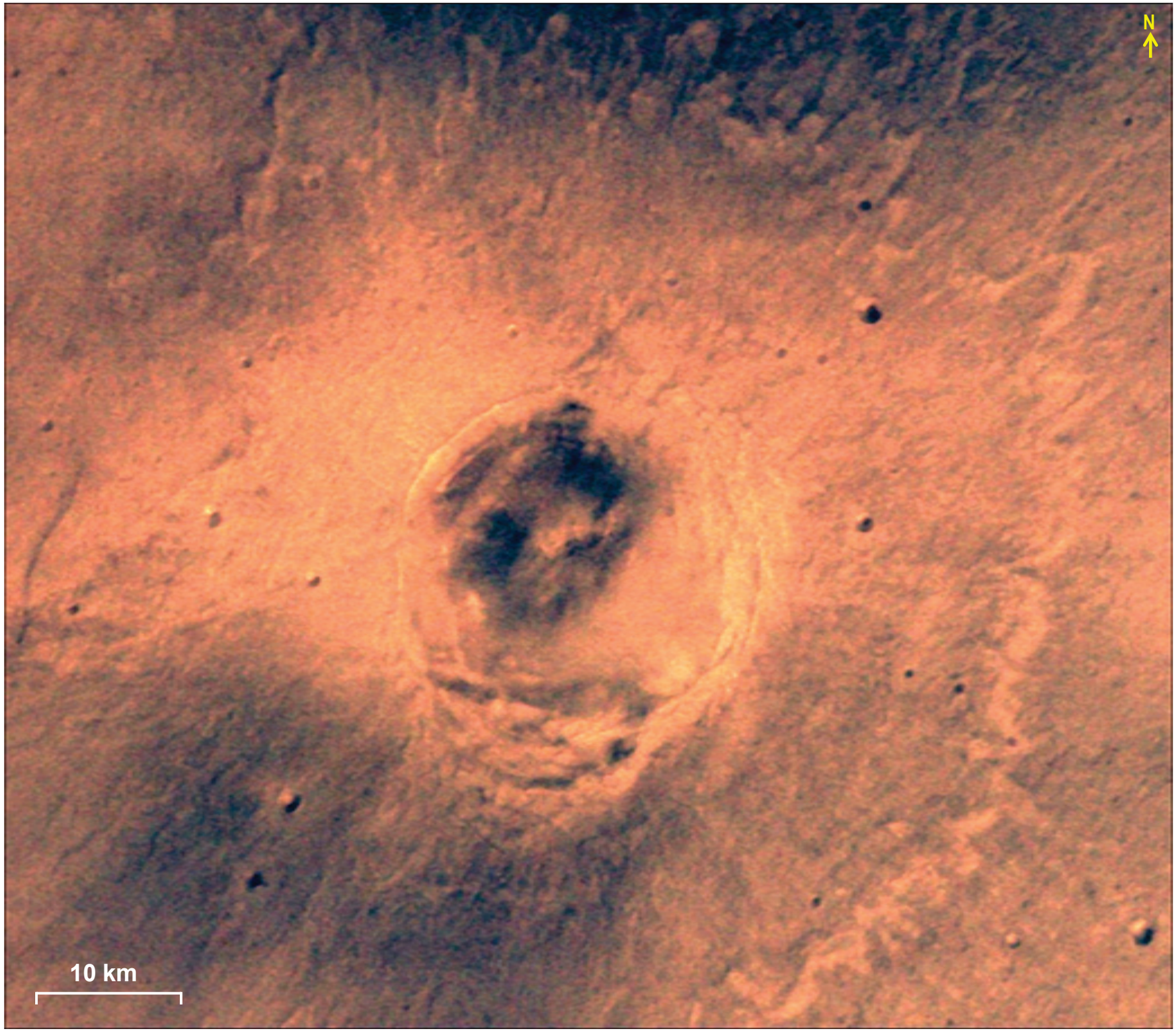
Rampart crater in Solis Planum region

Rampart crater having a diameter of ~20 km is located at ~30^0S, 90^0 W in Solis Planum region on Mars. Image of rampart crater was taken by Mars Colour Camera (MCC) on 19-02-2015 at a spatial resolution of 48 m from an altitude of 924 km. Rampart craters are specific type of impact craters on Mars which are accompanied by distinctive fluidized ejecta. Ejecta of rampart crater characteristically occurs in the form of layers. On Mars, these layers are generally formed by ground water or melting of subsurface ice due to impact heat. Fluidized ejecta blanket generally surrounds the crater. So presence of rampart craters provide evidence of ice or liquid water beneath the surface of Mars in its past history.



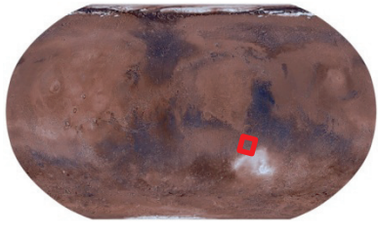


Three dimensional perspective view of Rampart Crater

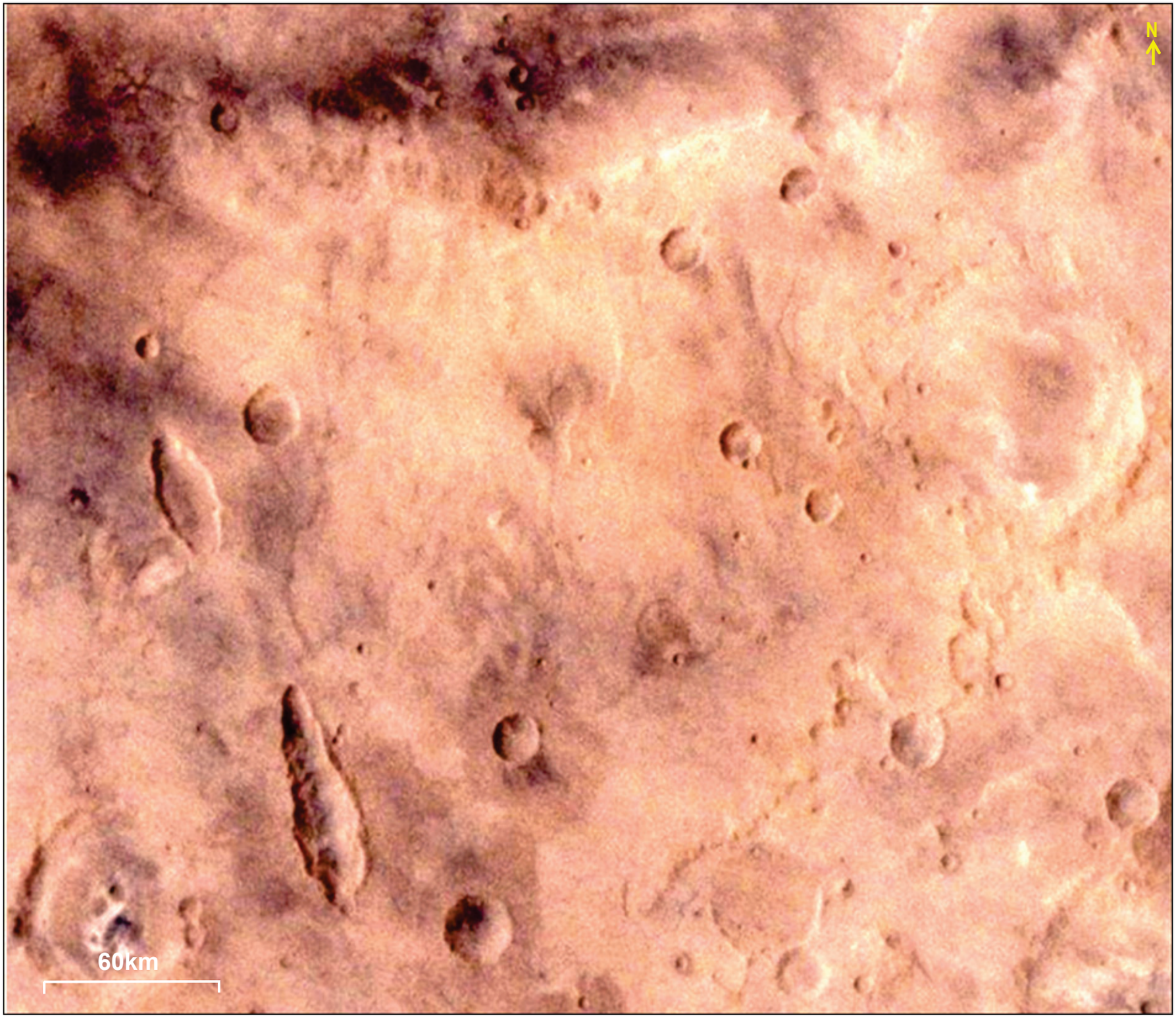

N
10 km

Region south of Huygens Crater

These impact craters in elongated shape are located on Mars near 20^0 S, 54^0 E. They are situated towards south of Huygens crater. Images of these elongated craters was taken by Mars Colour Camera (MCC) on 11-10-2014 at a spatial resolution of 230 m from an altitude of 4433 km. These two craters having diameter along major and minor axis of 80 km, 25 km (southern crater) and 45 km, 22 km (northern crater).

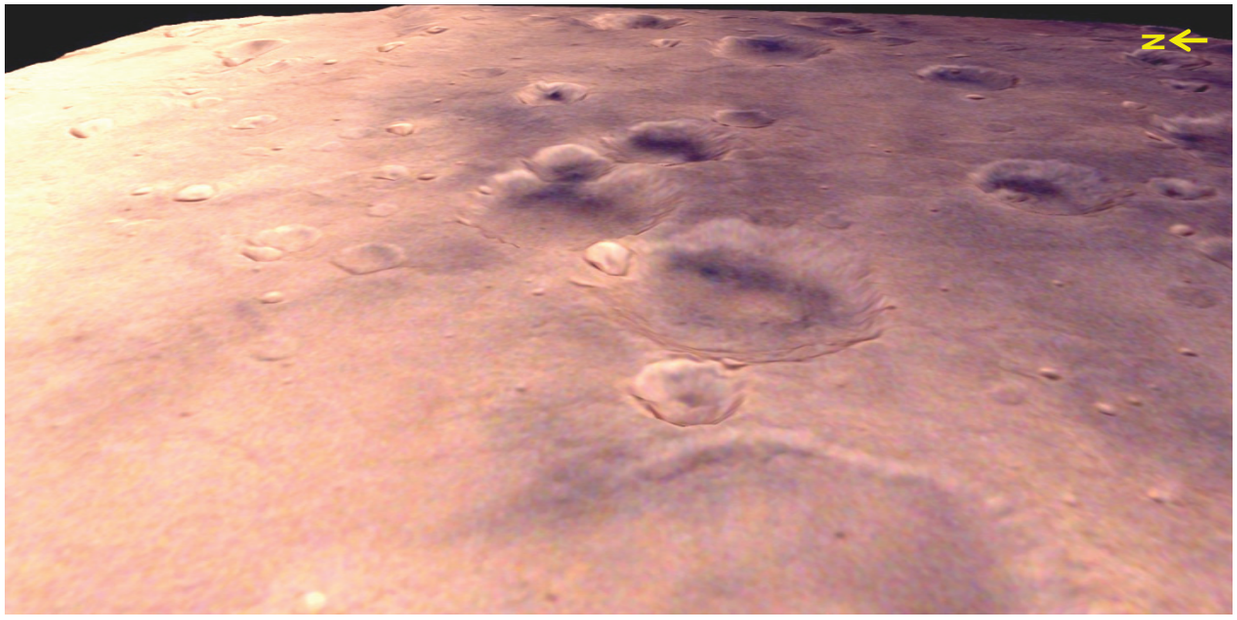


Three dimensional perspective view of elongated craters south of Huygens Crater

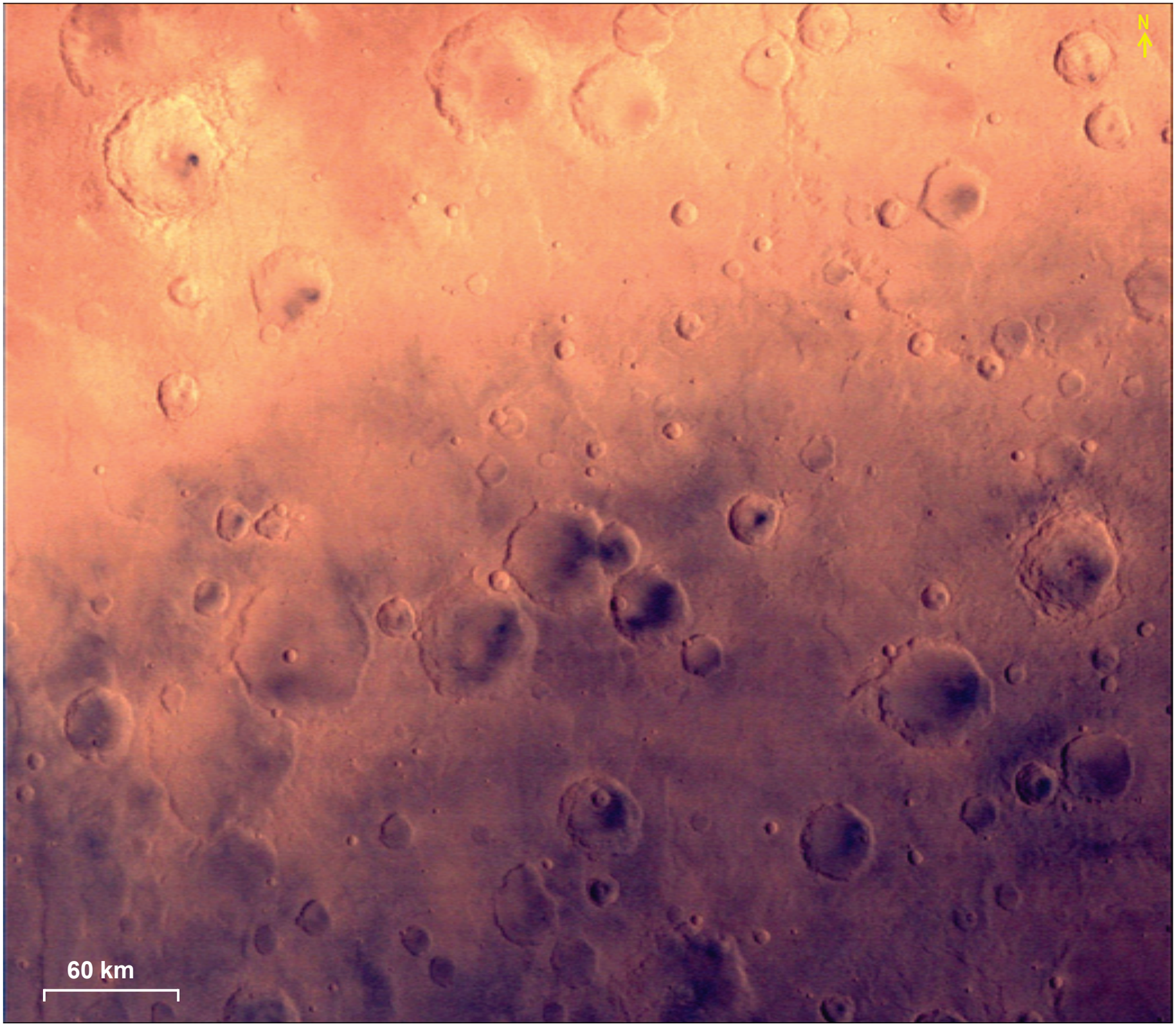

N
60km

Impact Craters in Terra Sirenum

This Image shows number of impact craters in Terra Sirenum region on Mars, indicating massive impact cratering has occurred in this region. Image of Impact craters in Terra Sirenum region was taken by Mars Colour Camera (MCC) on 14-10-2014 at a spatial resolution of 204 m from an altitude of 3923 km. Impact craters of various dimensions are clearly seen in this image. The central location of this image is ~22^{0}S, 171^0 W .

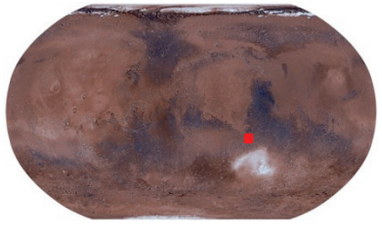


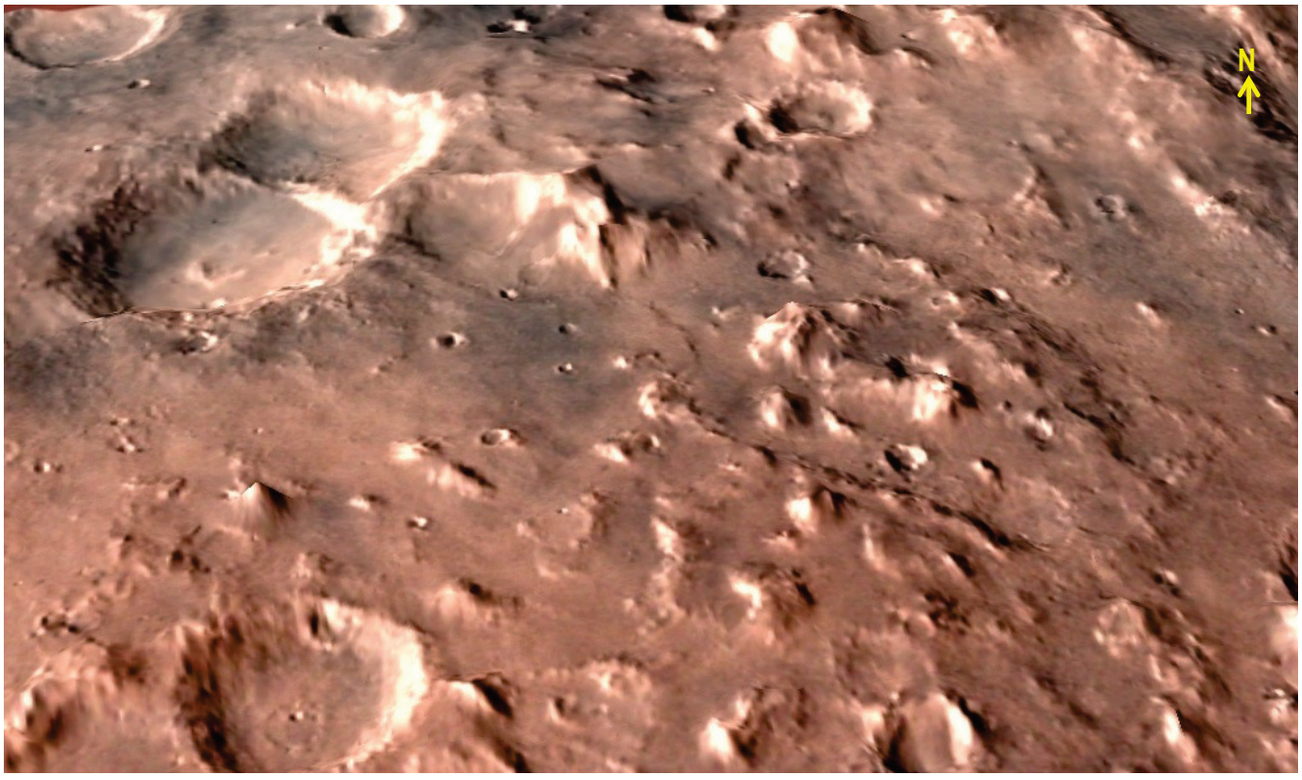
Three dimensional perspective view of Impact Craters in Terra Sirenum


N
60 km

Overlapping Crater

Harris crater is an impact crater on Mars having a diameter of ~85 km and located at ~21^{0}S, 66^0 E and is situated in north of Hellas basin region on Mars. Image of overlapping impact crater was taken by Mars Colour Camera (MCC) on 11-10-2014 at a spatial resolution of 191 m from an altitude of 3907 km.





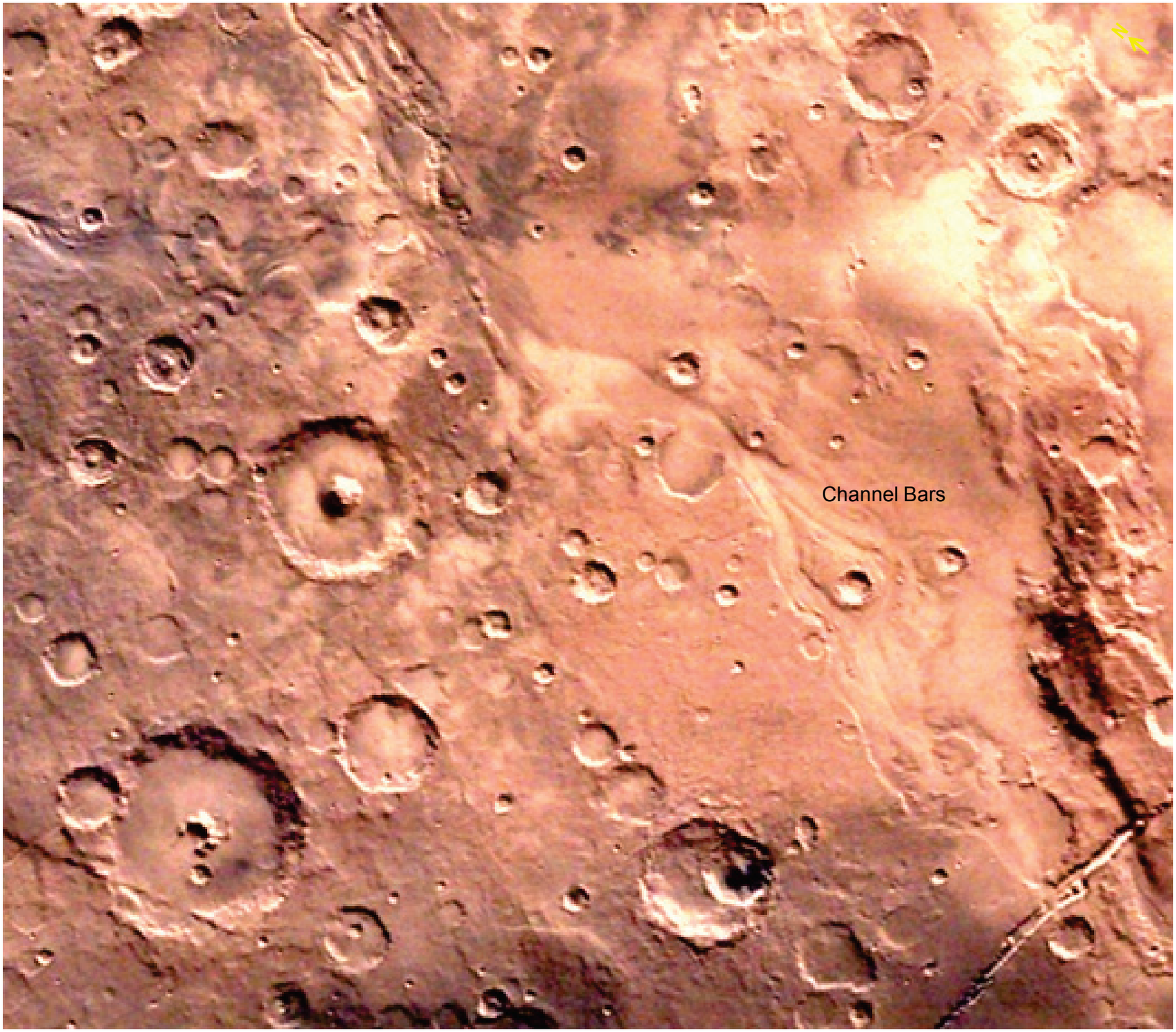
Three dimensional perspective view of overlapping crater Huygens Crater


N
Harris crater
105 km

04 Gradational Features

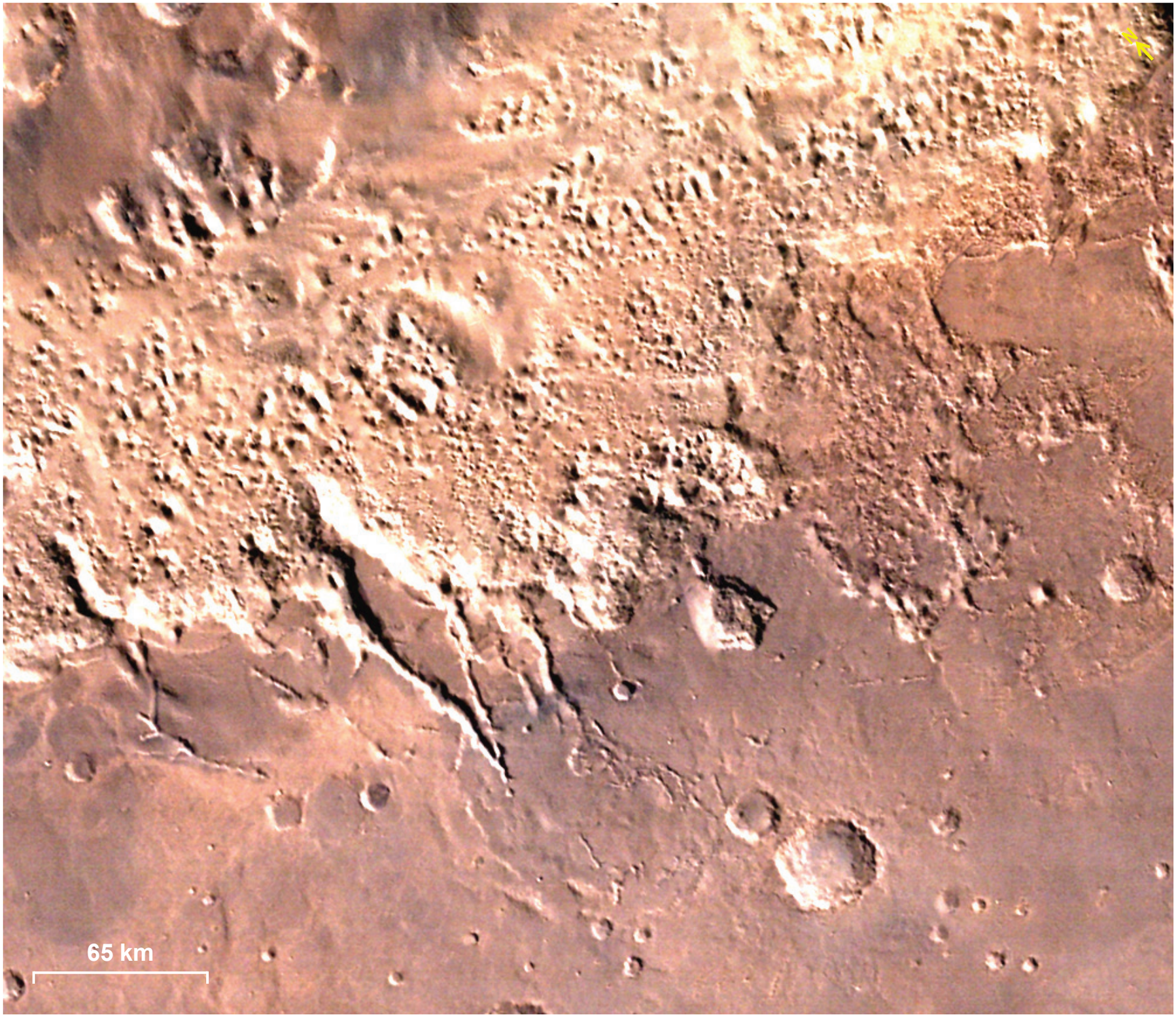
Channel bar in Mangala Valles

Mangala Valles is an outflow channel on Mars, located at ~10S, 151^0 W near the Tharsis region on Mars. It is believed that Mangala Valles was formed by catastrophic flooding process. The floor of Mangala valles has small channel bars trending from the NW-SE direction. These channels bar could be depositional (fluvial) landforms. Image of channel bar in Mangala Valles region was taken by Mars Colour Camera (MCC) on 24-11-2014 at a spatial resolution of 380 m from an altitude of 7336 km. Channel bar in the MCC images indicates towards flow of vast quantities of water in this area by catastrophic floods in ancient past. The floor of channel is fairly smooth with impression of some small impact craters.


Channel Bars

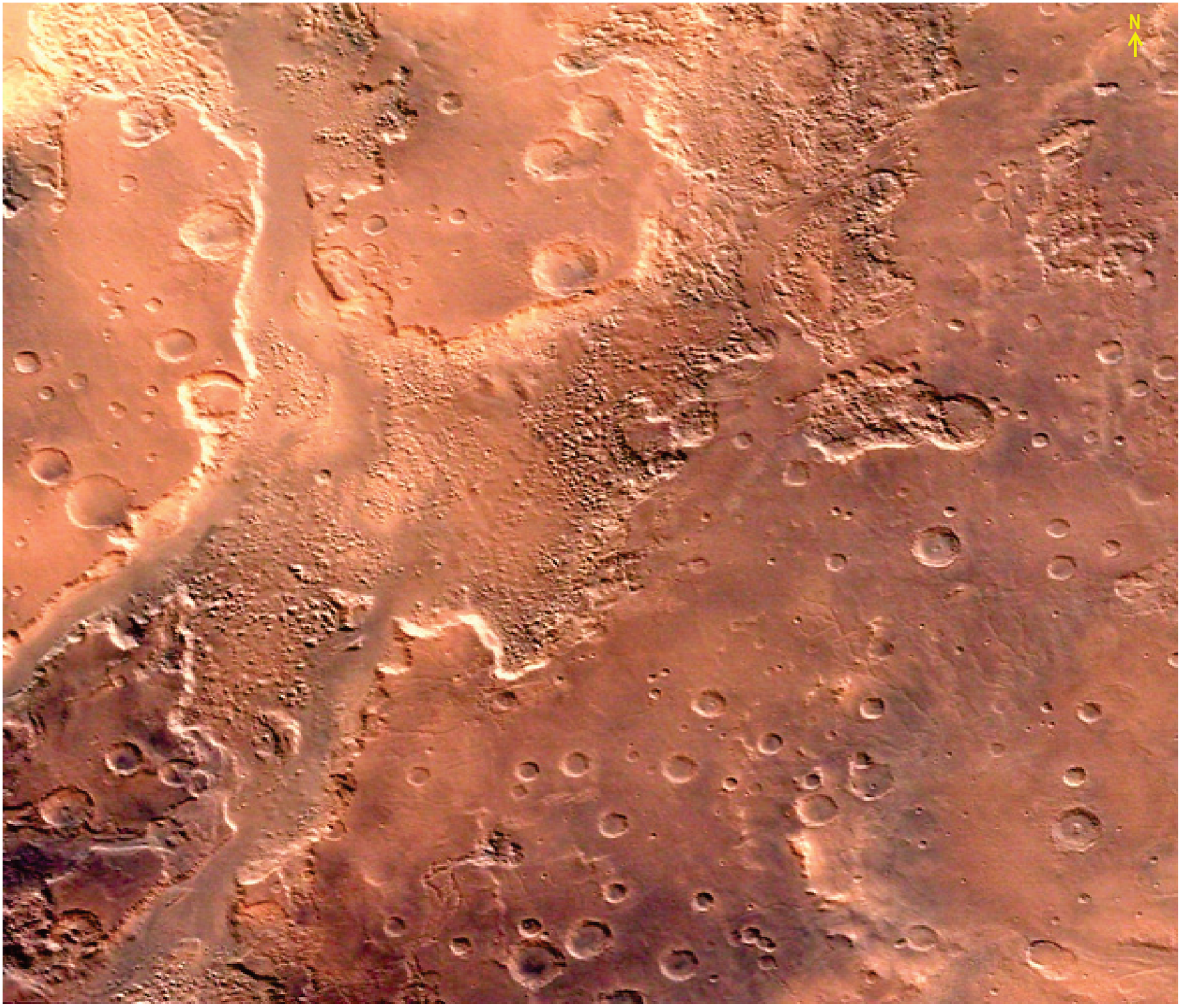
Eos Chaos

Eos Chaos is an eroded area in Valles Marineries region about 490 km long. It is located near ~17^{0}S, 47^0 W. Chaos means a distinctive area of broken terrain. Images of Eos Chaos region of Mars was taken by Mars Colour Camera (MCC) on 5-02-2015 at a spatial resolution of 229 m from an altitude of 4403 km. Eos Chaos is located at eastern part of Valles Marineris region. Fracture patterns at the edges of Valles Marineris are clearly seen at this resolution. Images at this resolution are useful for understanding geological processes at regional scale. Impact craters of smaller to larger dimensions are also seen in this image.


65 km

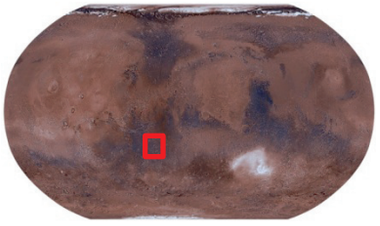
Part of Margaritifer Terra

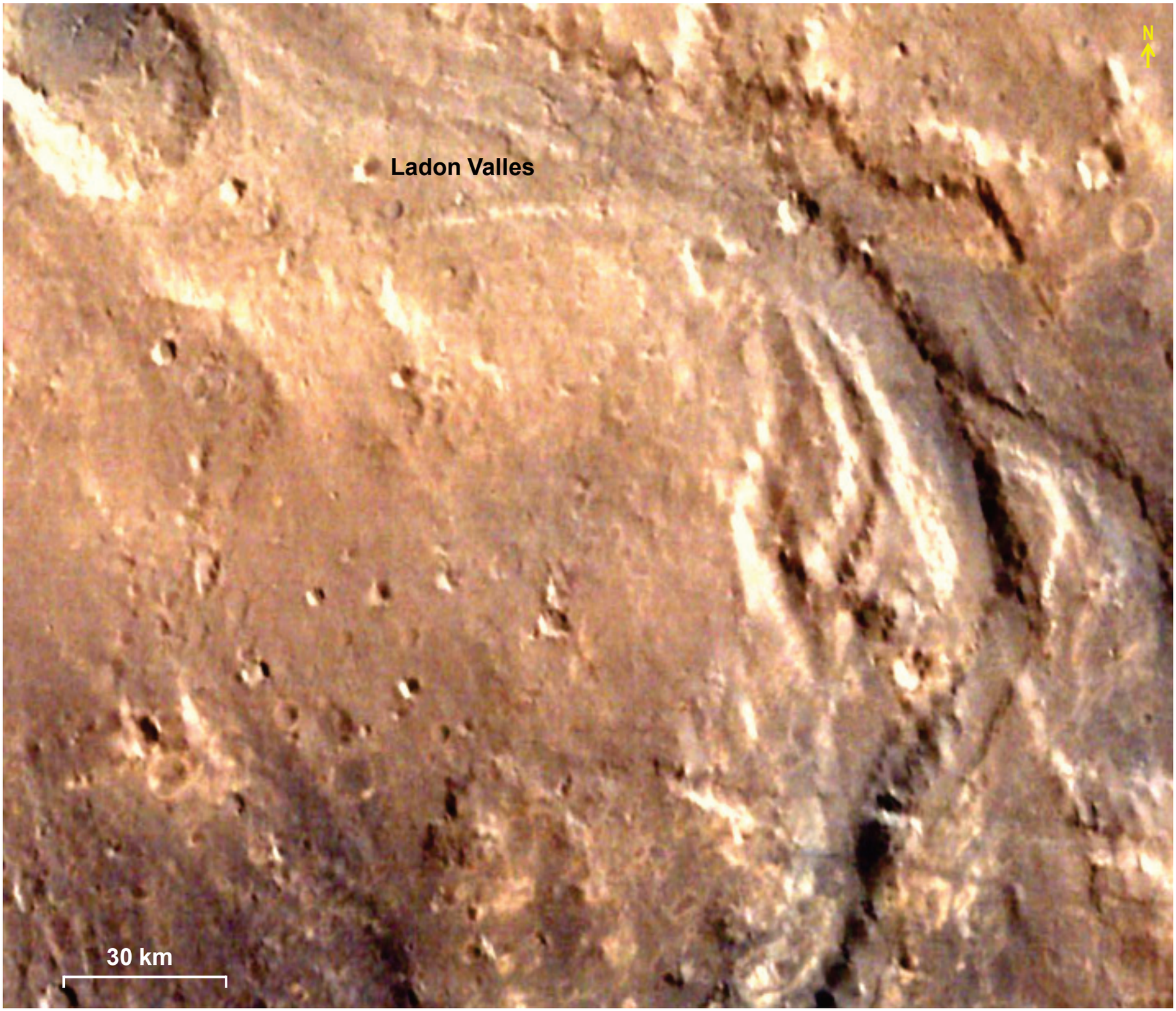
Margaritifer Terra on Mars preserves the record of aqueous processes of the Noachian-Hesperian age. It is located near ~9^0S, 32^0 W. Image of Aurorae Chaos, Pyrrhae Chaos and adjoining regions of Mars was taken by Mars Colour Camera (MCC) on 5-02-2015 at a spatial resolution of 535 m from an altitude of 10274 km. Region shown in this image is located in Magaritifer Terra, at the eastern end of Valles Marineris.


N

Flow channels in Ladon Valles

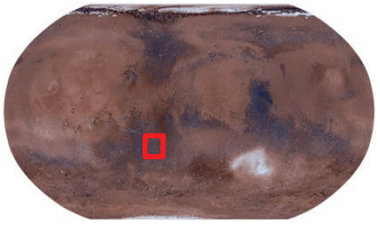
Ladon Valles is a fluvial valley present within the Margaritifer Sinus region of Mars. It is located near ~22^0S, 28^0 W. Ladon Valles is important region for the study of layered sediments of fluvial origin present in this region. It is believed that the Noachian water-lain sediments were transported through Ladon Valles and deposited within Ladon basin. Ladon Basin has preserved a record of fluvial and lacustrine sediments from the Noachian time, including clay minerals. Image of Ladon Valles region was taken by Mars Colour Camera (MCC) on 5-02-2015 at a spatial resolution of 152 m from a altitude of 2937 km. In this image impression of flow features shows significant sign of ancient river system. It gives the clear evidence that vast volumes of water once flowed in this region.

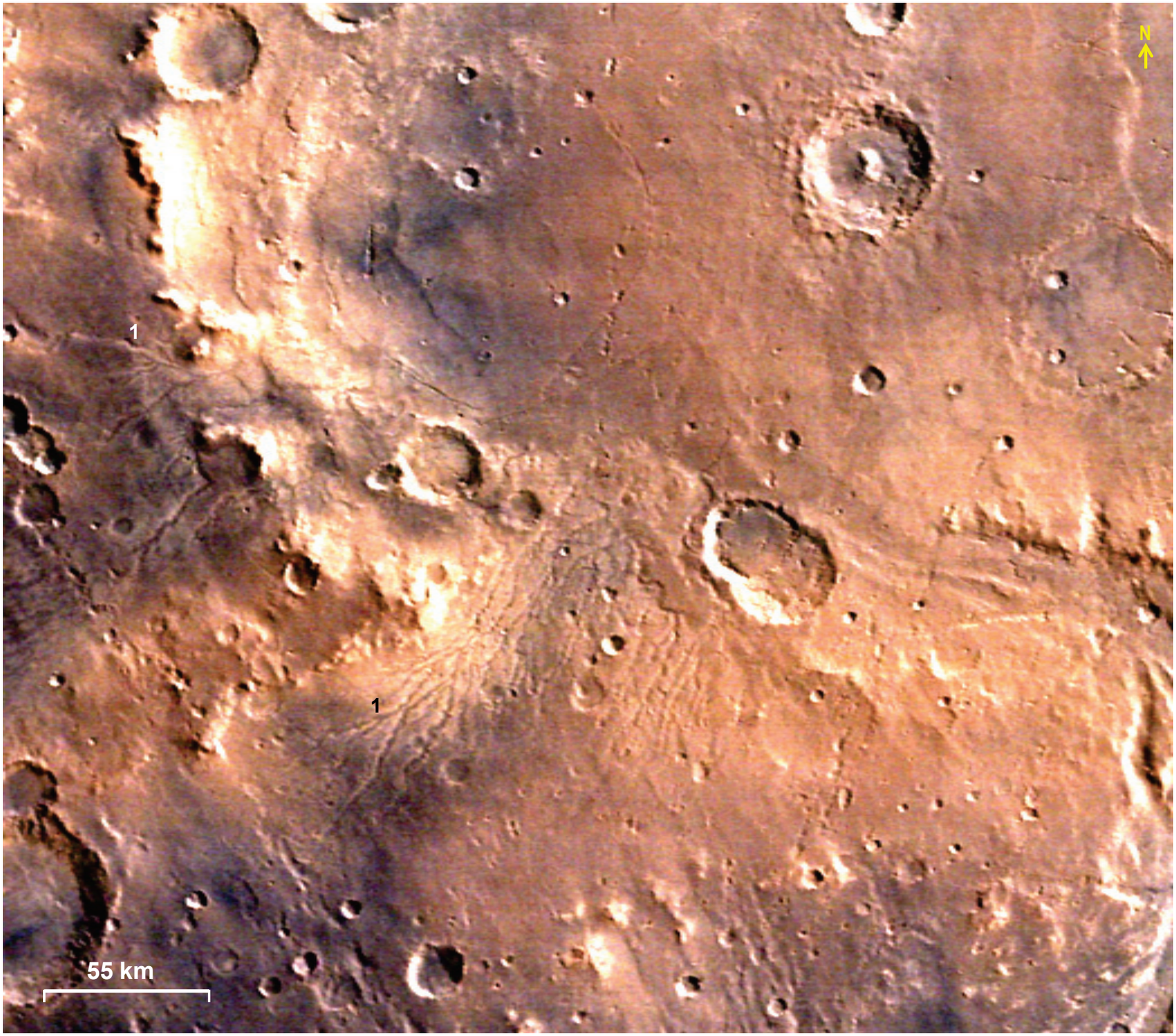



Ladon Valles
N
30 km

Flow channels in Ladon Valles

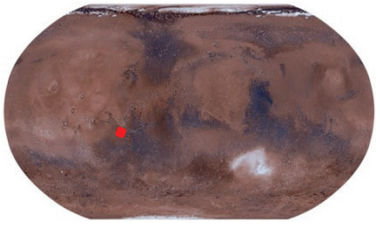
The region present in the MCC image is the part of Ladon Valles located near ~20^0S, 31^0 W. Dendritic pattern of flow channels (1) are seen in this image. Image of part of Ladon Valles region was taken by Mars Colour Camera (MCC) on 14-02-2015 at a spatial resolution of 197 m from a altitude of 3788 km.

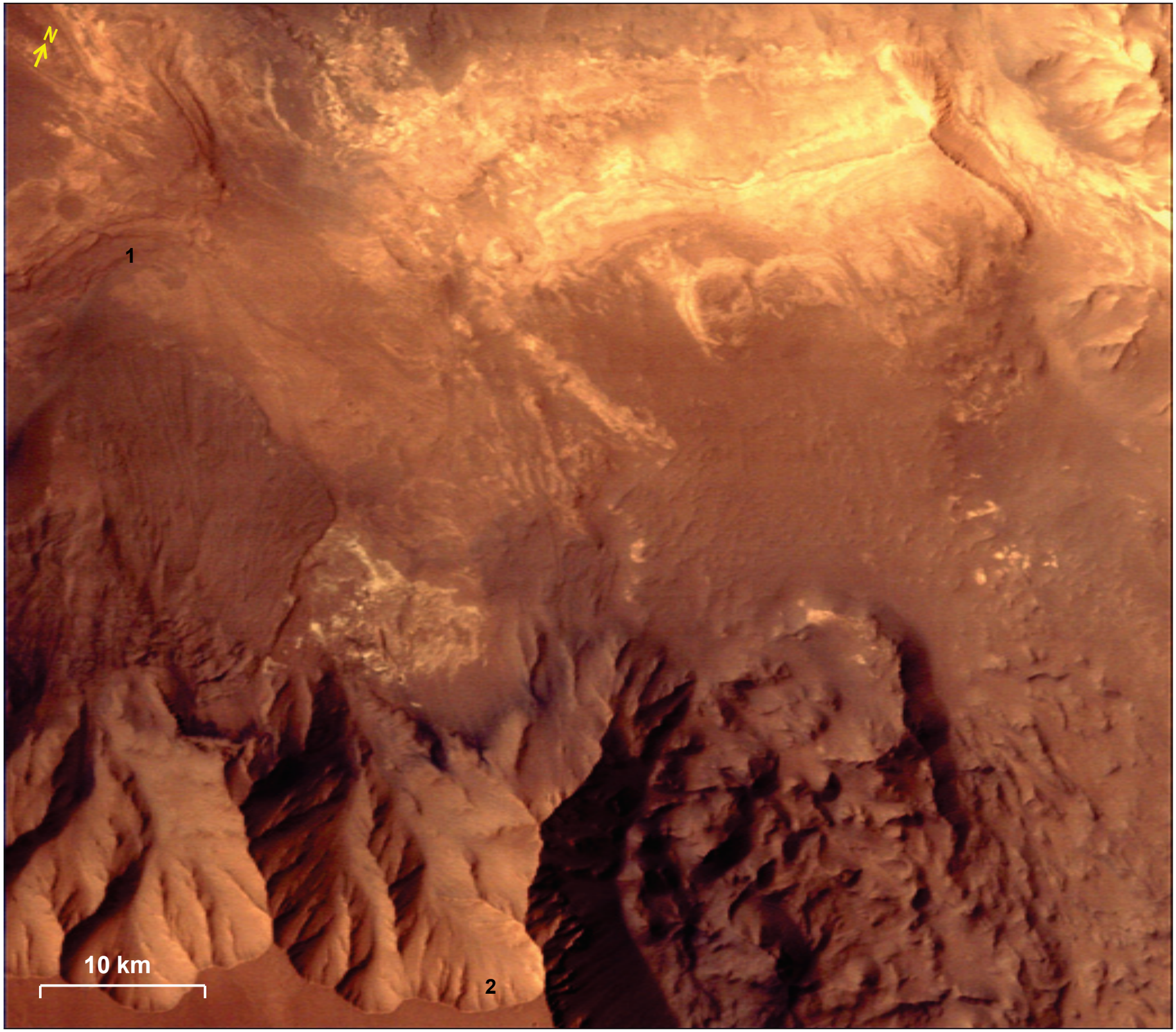



N
1
1
55 km

Part of Valles Marineris

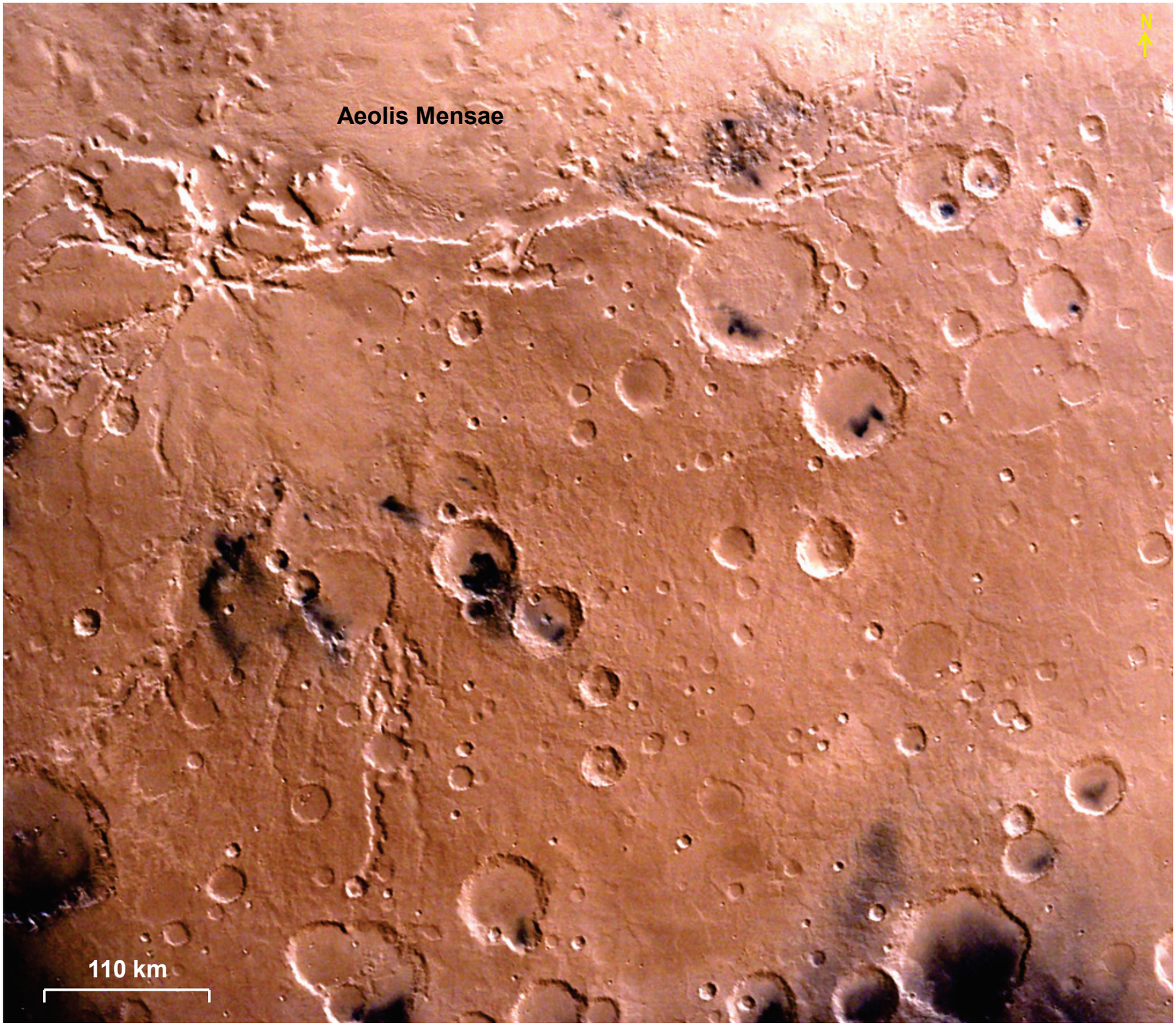
Image of part of Valles Marineris region was taken by Mars Colour Camera (MCC) on 23-04-2015 at a spatial resolution of 35 m from an altitude of 675 km. Layer deposits and erosion caused by flooding marked by (1) and landslides through the steep slopes marked by (2) are seen in this image.




N
1
2
10 km

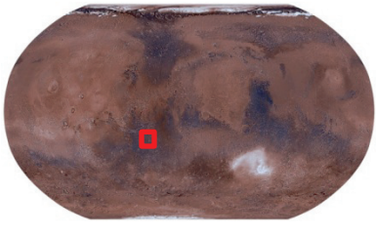
Part of Aeolis Mensae

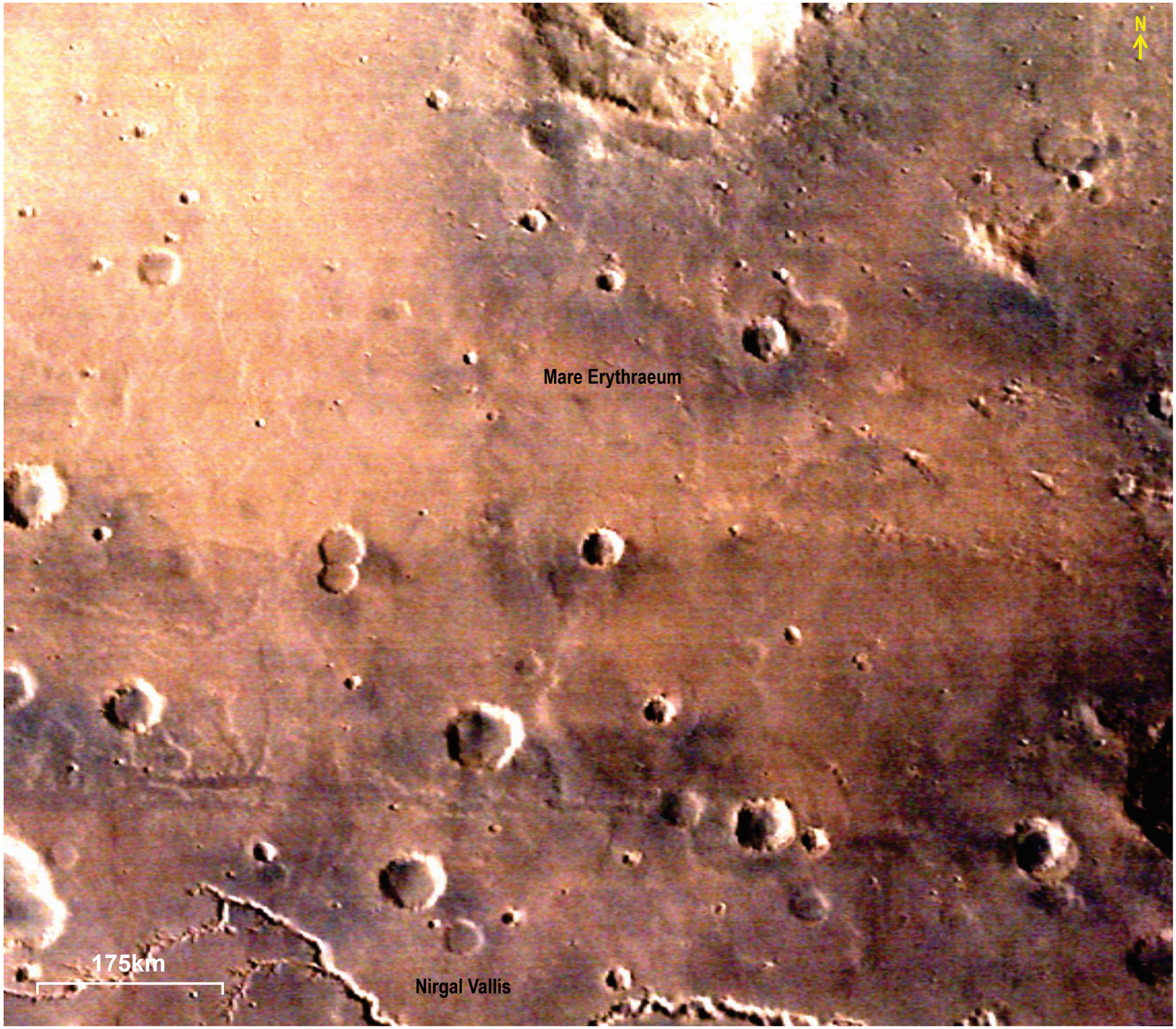
Image of part of Aeolis Mensae near Gale Crater region was taken by Mars Colour Camera (MCC) on 17-01-2015 at a spatial resolution of 405 m from an altitude of 7797 km. It is Located near ~2^0S, 140^0 E.


Aeolis Mensae
N
110 km

Nirgal Vallis

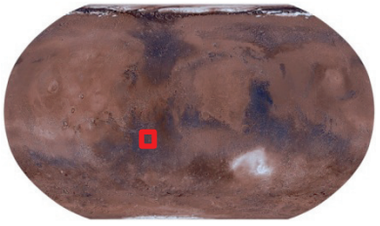
Nirgal Vallis is a long river channel with distance ~610 km long located in Mare Erythraeum region on Mars near ~25^0S, 41^0 W. It is a tributary of Uzboi Vallis, joining the larger system to the south of Holden crater. Previous studies using the high resolution CRISM hyperspectral datasets confirmed the presence of phyllosilicates (clay minerals) on the wall of the Nirgal Vallis. The image of part of Nirgal Valles was taken by Mars Colour Camera (MCC) on 17-10-2014 at a spatial resolution of 180 m from an altitude of 3477 km.

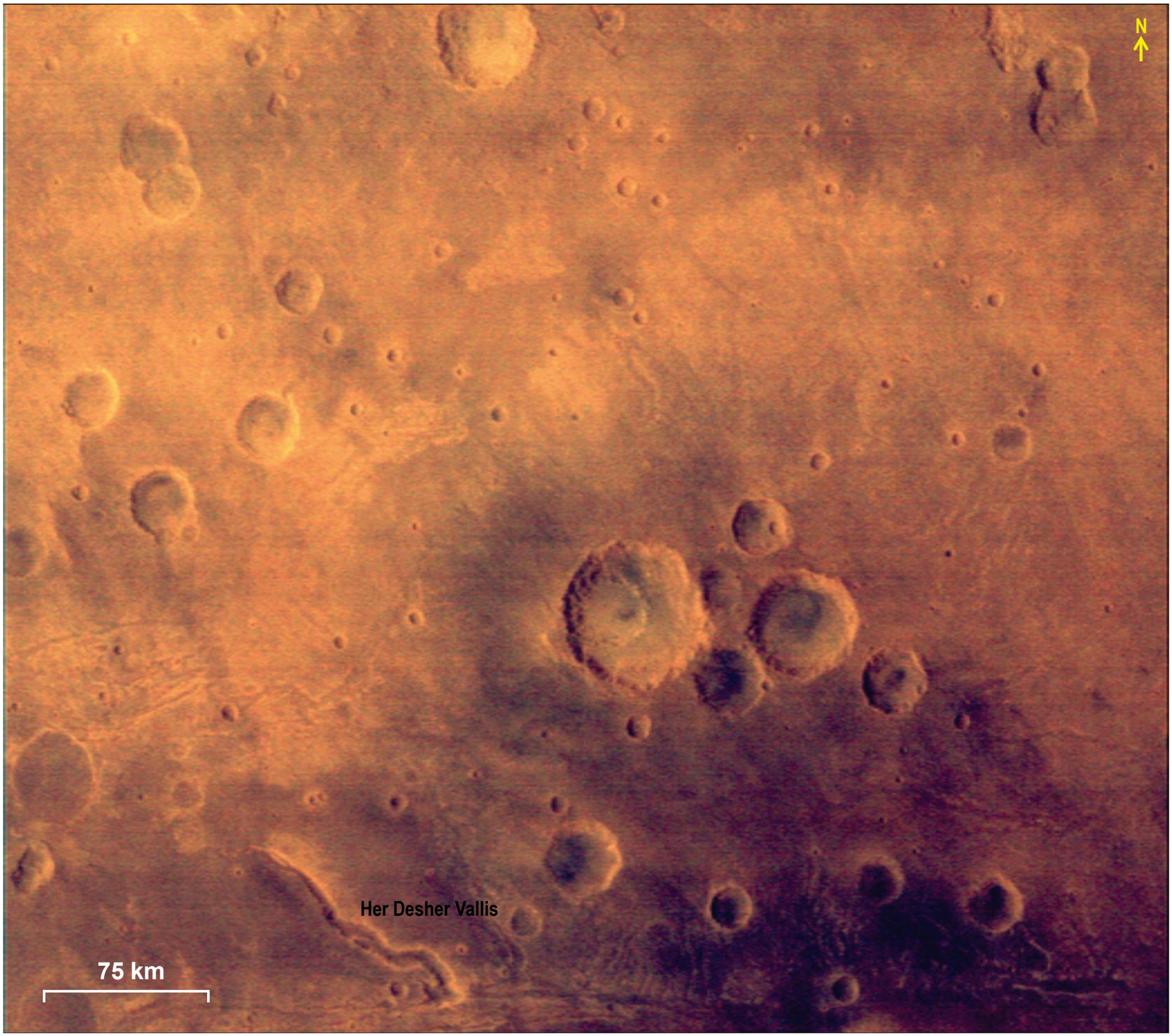



N
Mare Erythraeum
175km
Nirgal Vallis

Her Desher Vallis

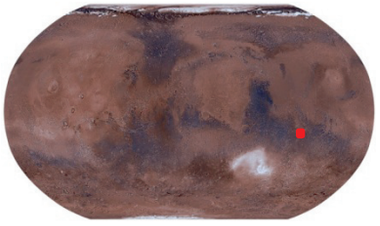
Her Desher Vallis is a small vallis system with distance ~117 km long located below Eos Chaos region. It is an ancient river valley located at 25.4^{0}S, 48^0 W. Her Desher Vallis is an isolated valley that does not connect to any craters or other valley system. The region is important for the study of clay deposits. Previous studies identified clay deposits on the walls of Her Desher Vallis. The image of part of Her Desher Vallis was taken by Mars Colour Camera (MCC) on 17-10-2014 at a spatial resolution of 191 m from an altitude of 3687 km.

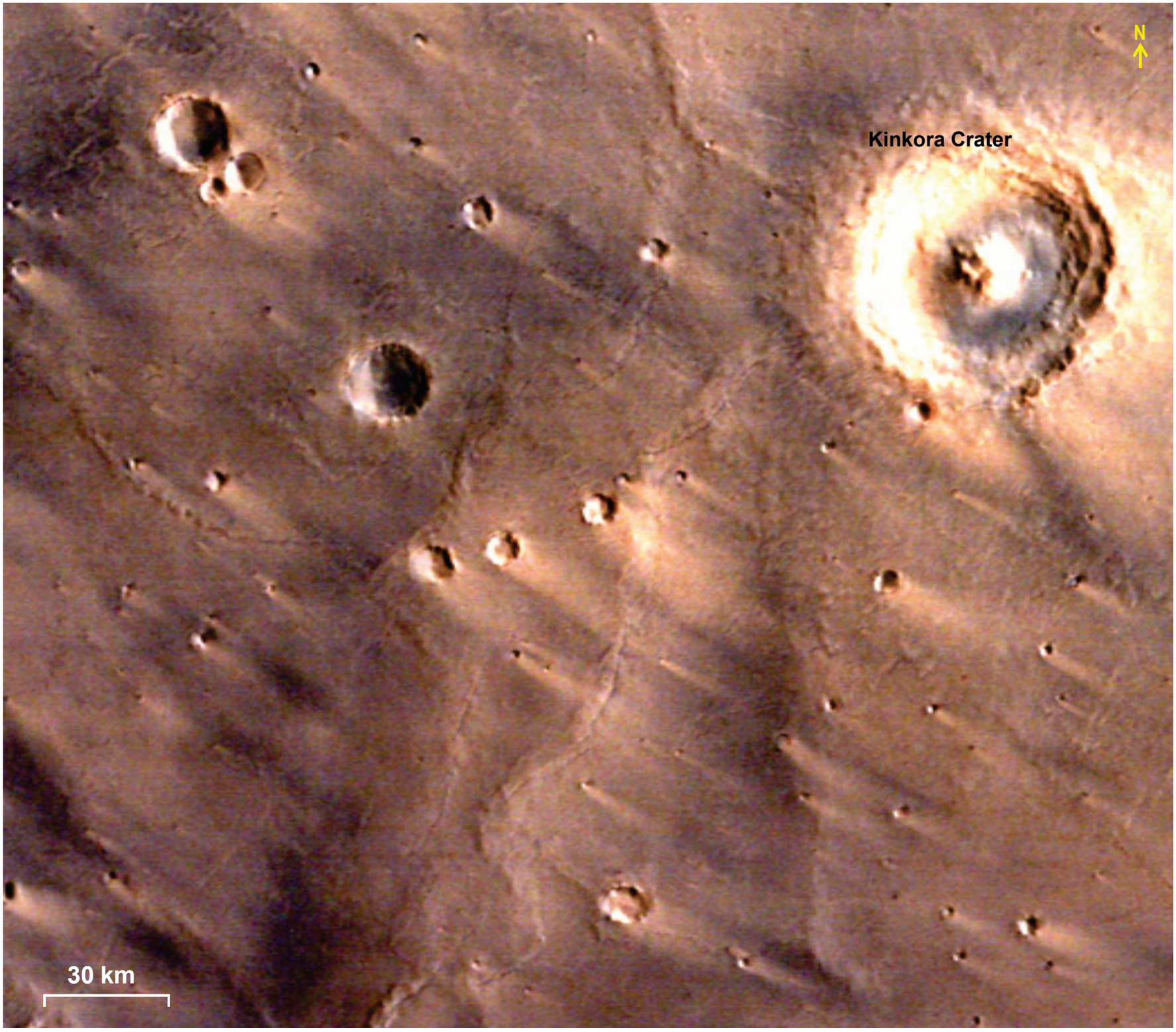



N
Her Desher Vallis
75 km

Wind streaks near to Kinkora crater

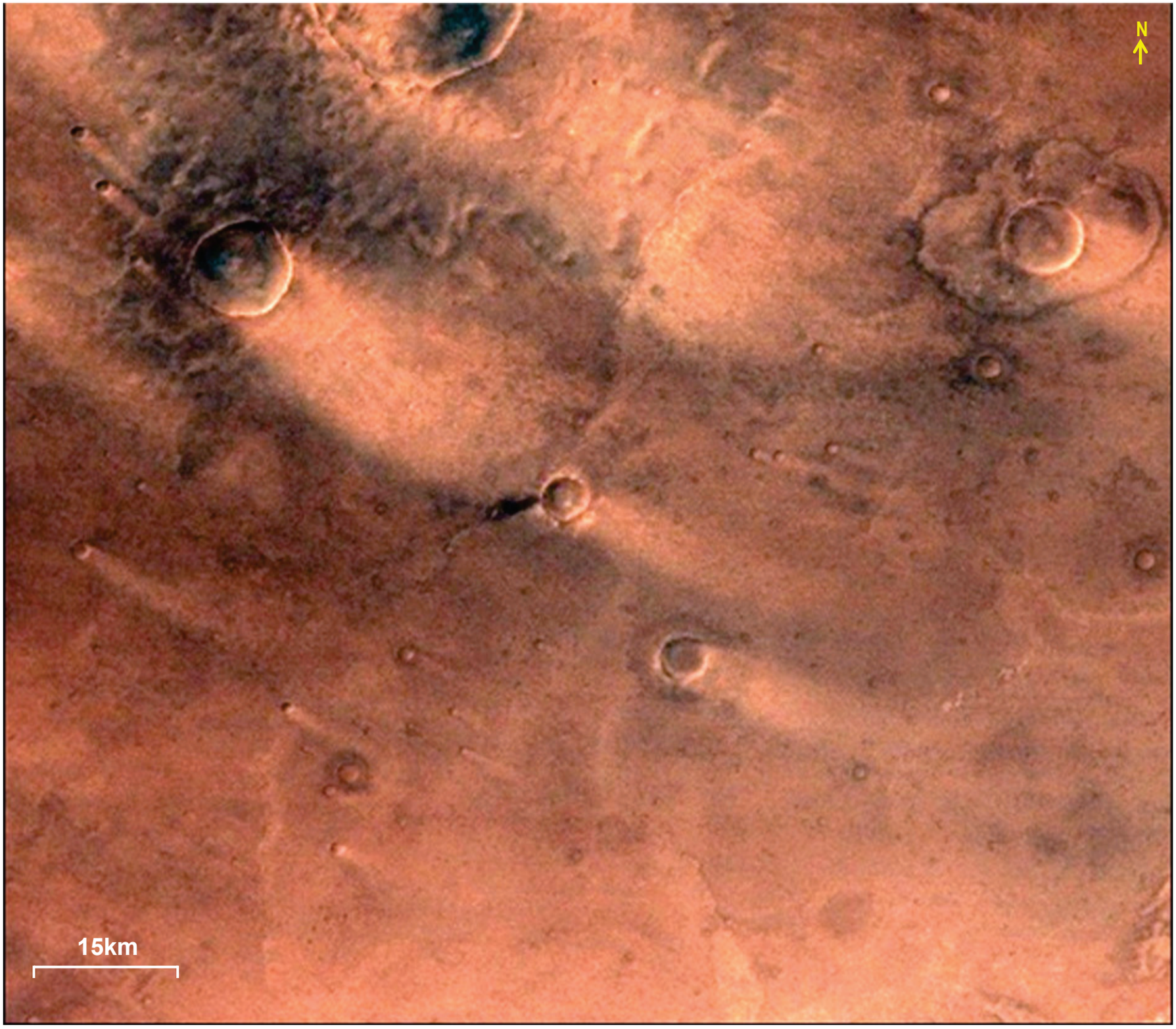
Image of Kinkora crater was taken by Mars Colour Camera (MCC) onboard Mars Orbiter Mission spacecraft on 16-02-2015 at a spatial resolution of 119 m from an altitude of 2286 km. Kinkora crater is located at the right portion of the image at 25^0S, 112^0 E. Wind streaks aligned along NW-SE direction are seen in this image. NE-SW aligned wrinkle ridge system to the west of Kinkora crater is also seen in this image.




N
Kinkora Crater
30 km

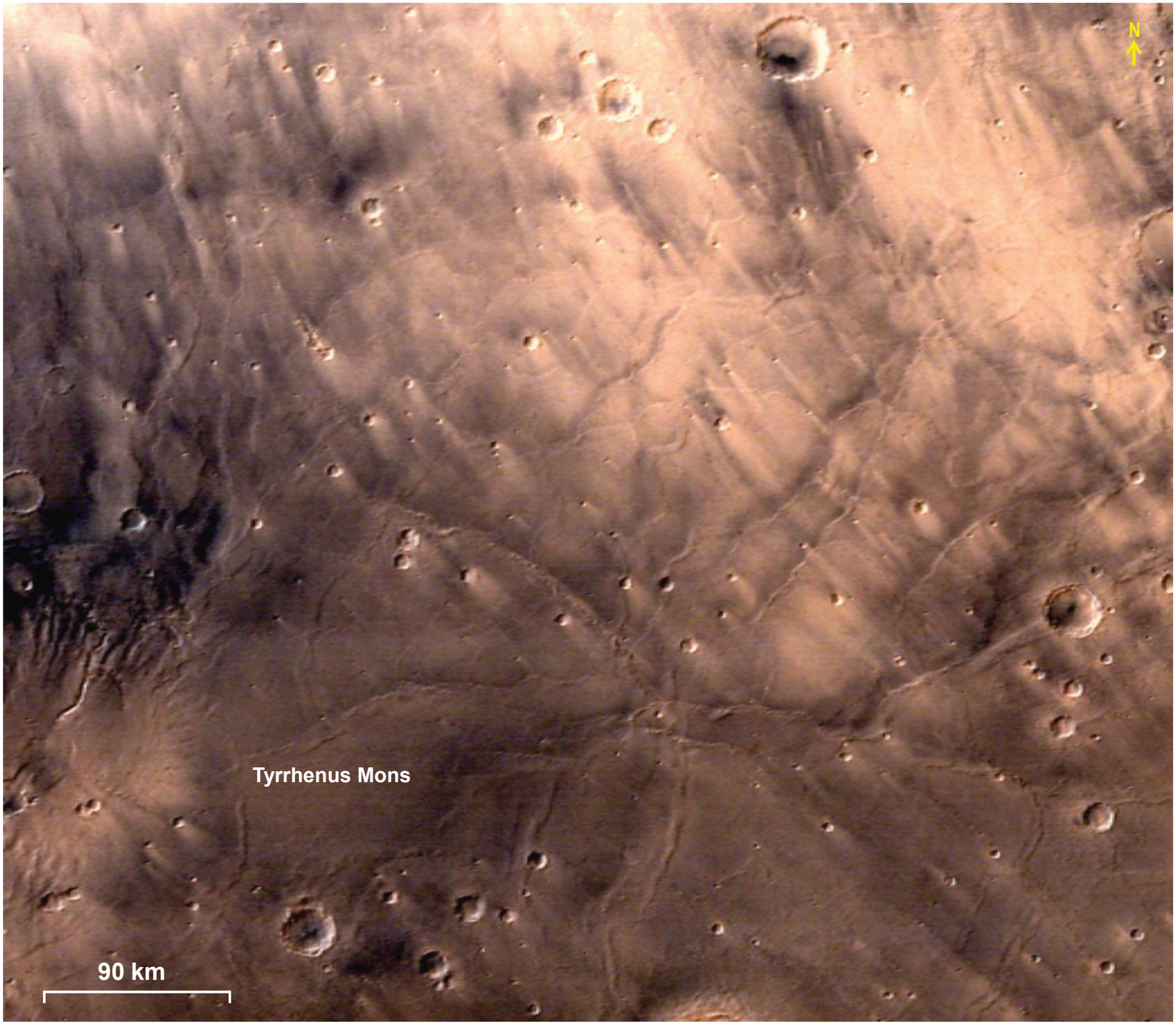
Wind Streaks in Terra Cimmeria region

Two types of wind streaks occur on surface of Mars, bright streaks and others are called dark streaks. They are associate with craters and other topographic obstacles. Bright streaks are thought to be deposits of dust, which are much more difficult to be removed by erosion. Image of bright wind streaks and impact crater in Terra Cimmeria region was taken by Mars Colour Camera (MCC) on 16-02-2015 at a spatial resolution of 52 m from an altitude of 1014 km. The direction of wind streaks provide an idea about the prevailing wind direction.


N
15km

Wind streaks near to Tyrrhenus Mons

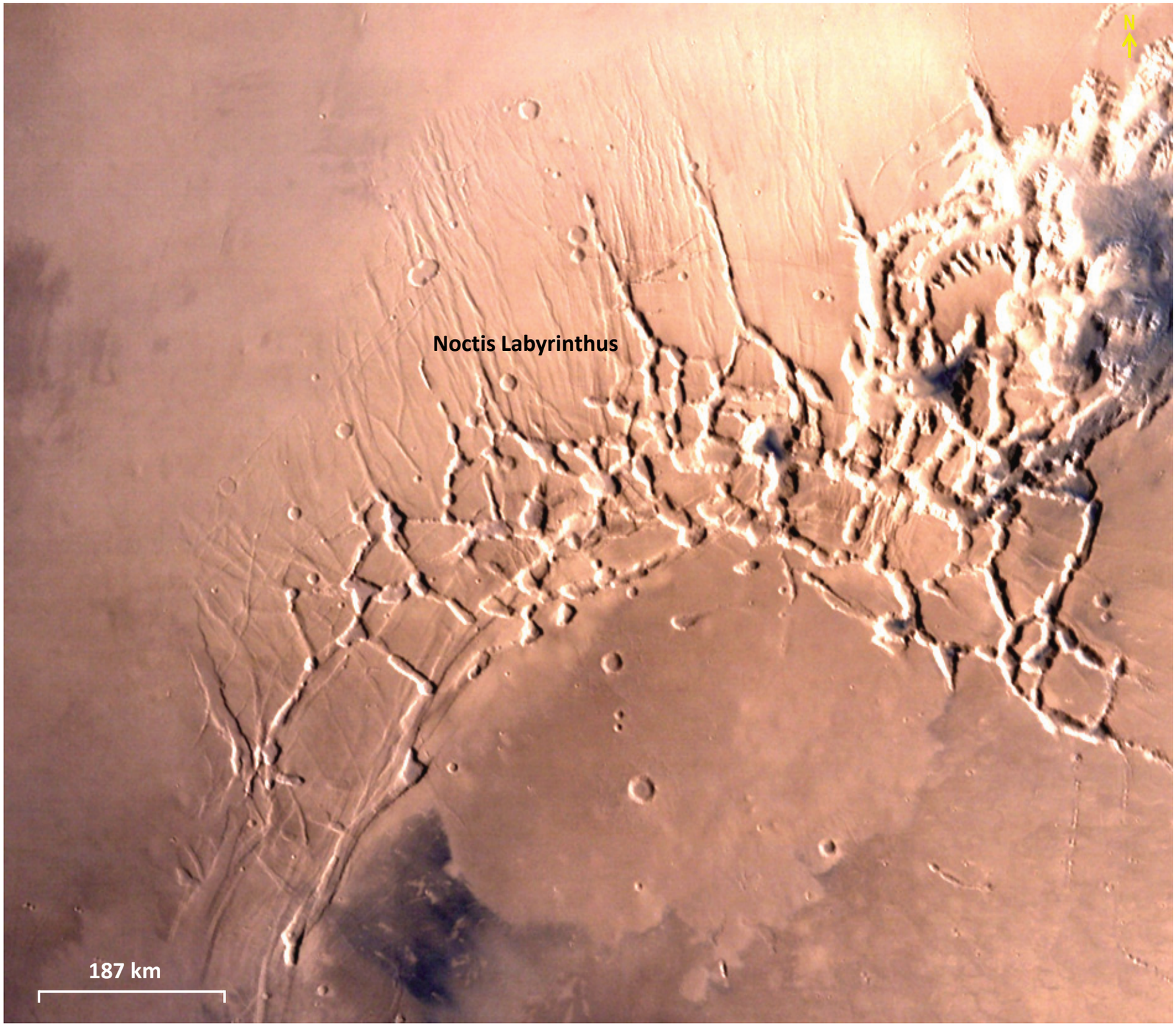
Some of the most prominent aeolian features on the surface of Mars are wind streaks. They appear in numerous images of the surface and are the result of wind erosion and deposition. As surface wind markers these streaks are very important in helping to understand the surface circulation patterns on Mars. Bright streaks are thought to be deposits caused by dust. They are difficult to removed by erosion, hence the bright streaks change much more slowly than dark streaks. Image of bright streaks and part of Tyrrhenus Mons crater in Hesperia Planum region was taken by Mars Colour Camera (MCC) on 29-11-2014 at a spatial resolution of 313 m from an altitude of 6028 km. They are located near Tyrrhenus Mons near ~21^{0}S, 113^0 E. Wind streaks are features caused by the interaction of wind and topographic landforms. The raised rims and bowls of impact craters causes a complex interaction such that the wind vortex in the lee of the crater can both scour away the surface dust and deposit it back in the center of the lee.


N
Tyrrhenus Mons
90 km

05 Tectonic Features

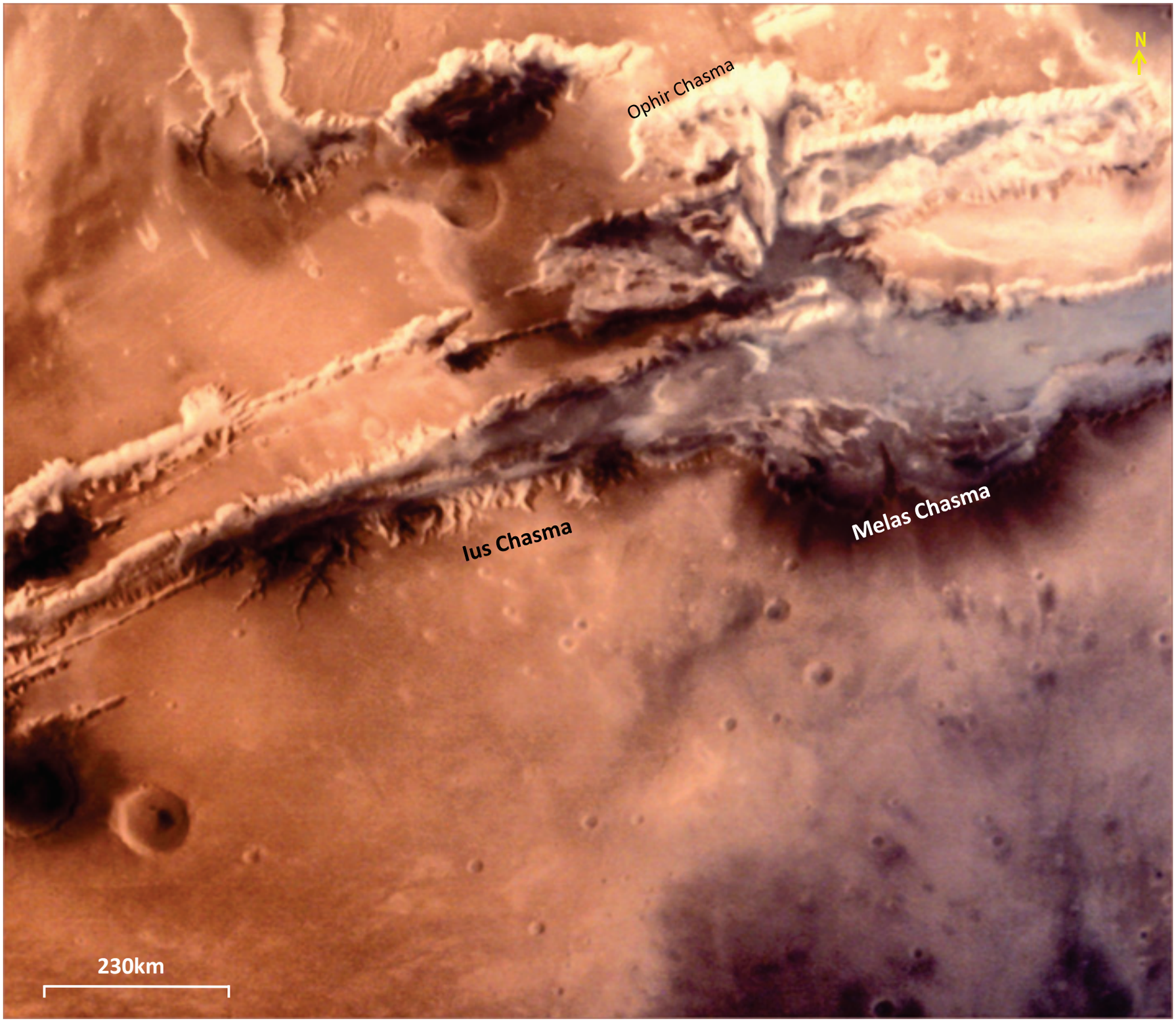
Noctis Labyrinthus

Image of part of Noctis Labyrinyhus region located near ~6^0S, 104^0 W was taken by Mars Colour Camera (MCC) on 20-01-2015, at a spatial resolution of 540 m from an altitude of 10392 km. Labyrinthus means complex intersecting valleys or ridges on Mars. It is present between Valles Marineris and the Tharsis region on Mars. This region of the Red Planet is characterised by a system of steep-walled canyons and valleys that give it the aspect of a naturally-formed maze or labyrinth. The valleys and canyons of the Noctis Labyrinthus were formed by faulting and many show the classic features of grabens, with the upland plain surface preserved on the valley floor.


N
Noctis Labyrinthus
187 km

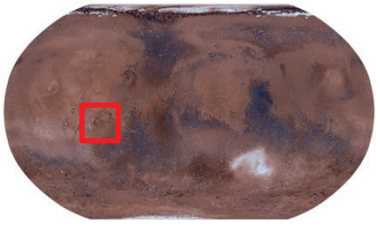
Part of Valles Marineris

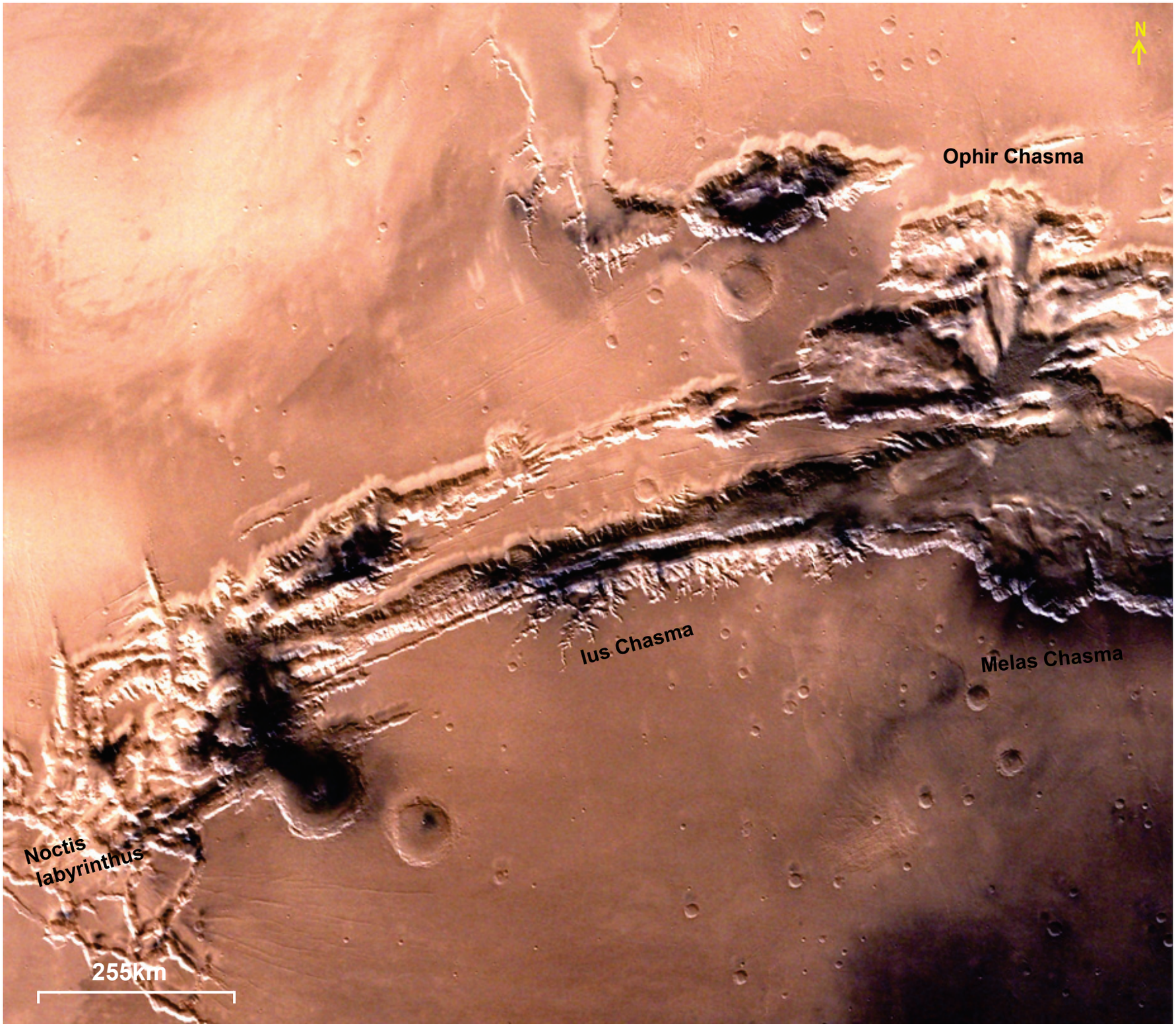
Image of part of Valles Marineris region located near ~7^0S, 74^0 W. was taken by Mars Colour Camera (MCC) on 5-02-2015, at a spatial resolution of 1159 m from an altitude of 22298 km. Different canyons in the Valles Marineris were seen in MCC image, such as Ophir Chasma, Ius Chasma and Melas Chasma. Ophir Chasma is the northern most depression of central Valles Marineris. It extends approximately 270 km in East–West direction and 90 km in North–South direction. Ius Chasma is a linear trough in western Valles Marineris, formed by horst and graben structures and mass wasting processes. Melas Chasma is located in the center of this canyon system on Mars.


N
Ophir Chasma
Melas Chasma
Ius Chasma
230km

Part of Valles Marineris

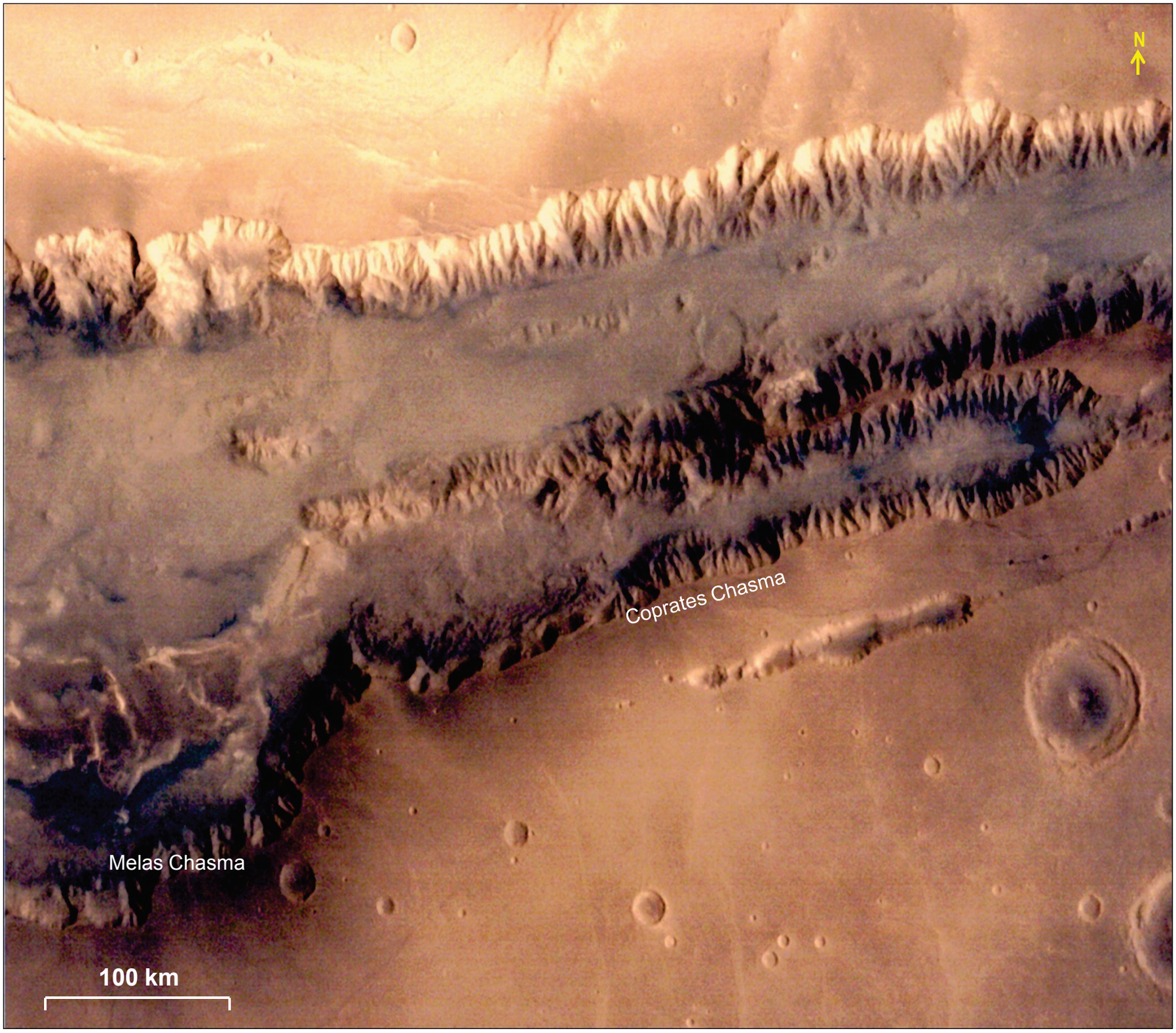
Image of Valles Marineris and adjoining regions of Mars was taken by Mars Colour Camera (MCC) on 10-11-2014 at a spatial resolution of 882 m from an altitude of 16970 km. Valles Marineris is largest canyon system about 4000 km and 200 km wide and 7 km deep. Dust trapped in the valley is seen as smoky haze. The image also shows Noctis Labyrinthus at bottom left corner of the image. The Noctis Labyrinthus, located at the western edge of the Valles Marineris Rift System, is a terrain composed of huge blocks which are heavily fractured.




N
Ophir Chasma
Ius Chasma
Melas Chasma
Noctis labyrinthus
255km

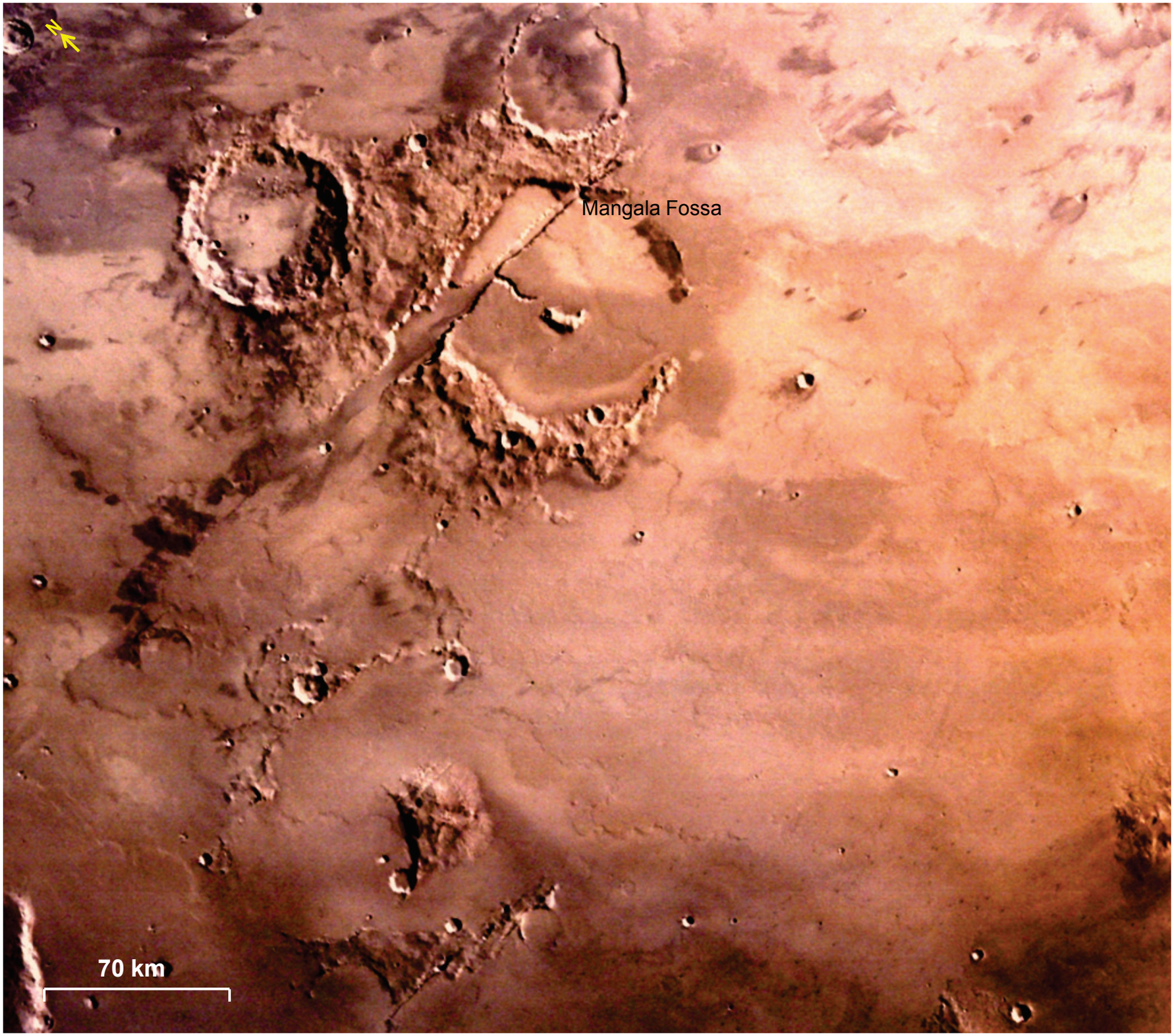
Higher resolution view of Valles Marineris

Image of the central portion of Valles Marineris region was taken by Mars Colour Camera (MCC) on 28-01-2015 at a spatial resolution of 300 m from an altitude of 5797 km. The region present in MCC image is located near ~12^0S, 64^0 W. Wall of the canyon are clearly seen in this image. At this time of Martian year valley is mostly filled by dust haze as seen in this image.


N
Coprates Chasma
Melas Chasma
100 km

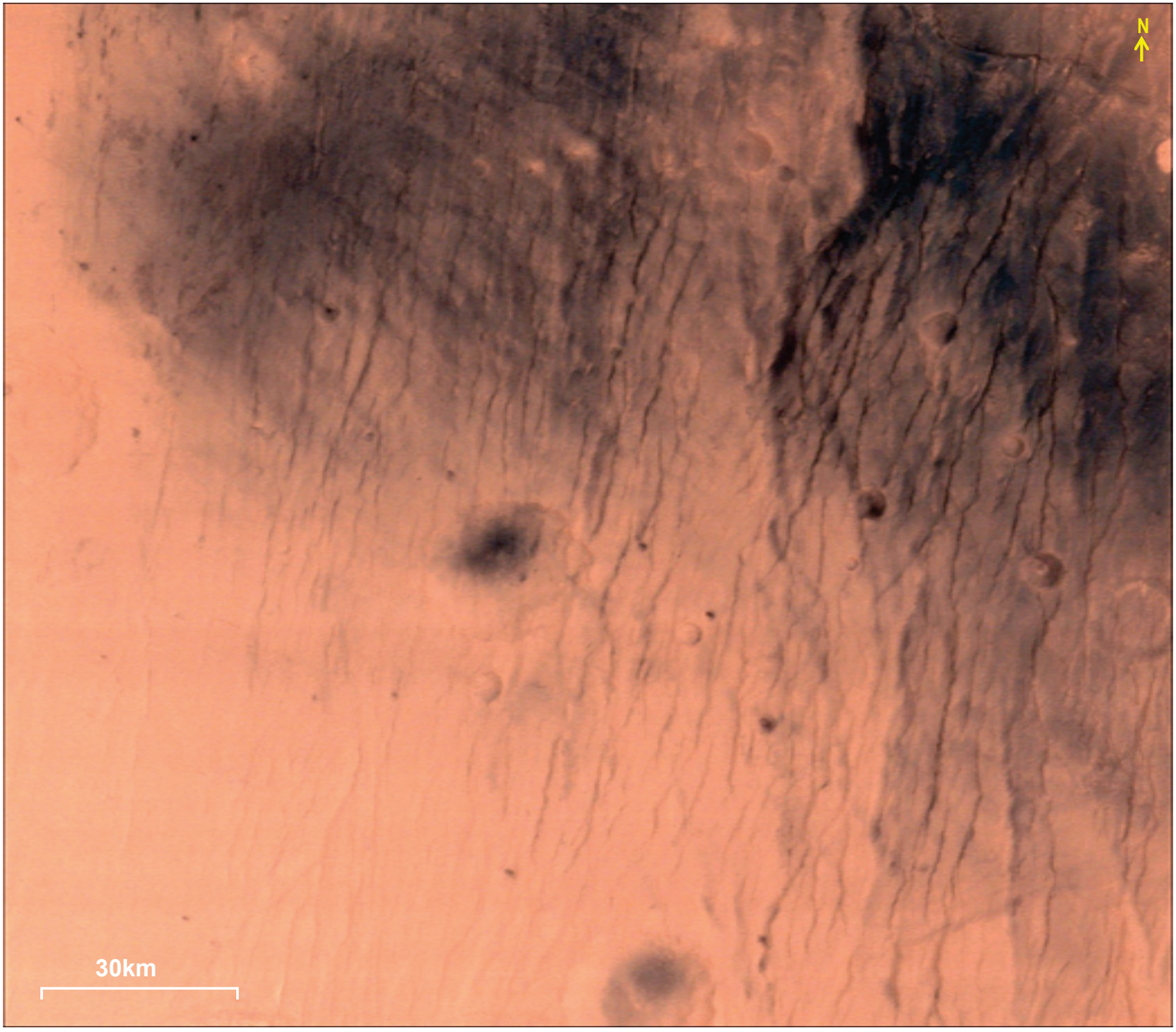
Mangala Fossa (Graben)

Mangala Fossa is a graben located near ~15^{0}S, 142^{0}W. Graben means fracture or trough. Grabens are downthrown areas relative to the surrounding rocks near fracture. Fossa, means a Long, narrow depression. Image of part of Mangala Fossa region of Mars was taken by Mars Colour Camera (MCC) on 2-02-2015 at a spatial resolution of 219 m from an altitude of 4211 km. NE-SW trending graben cutting across a larger crater located in northern part of image. Larger crater is having the diameter of 100 km.


N
Mangala Fossa
70 km

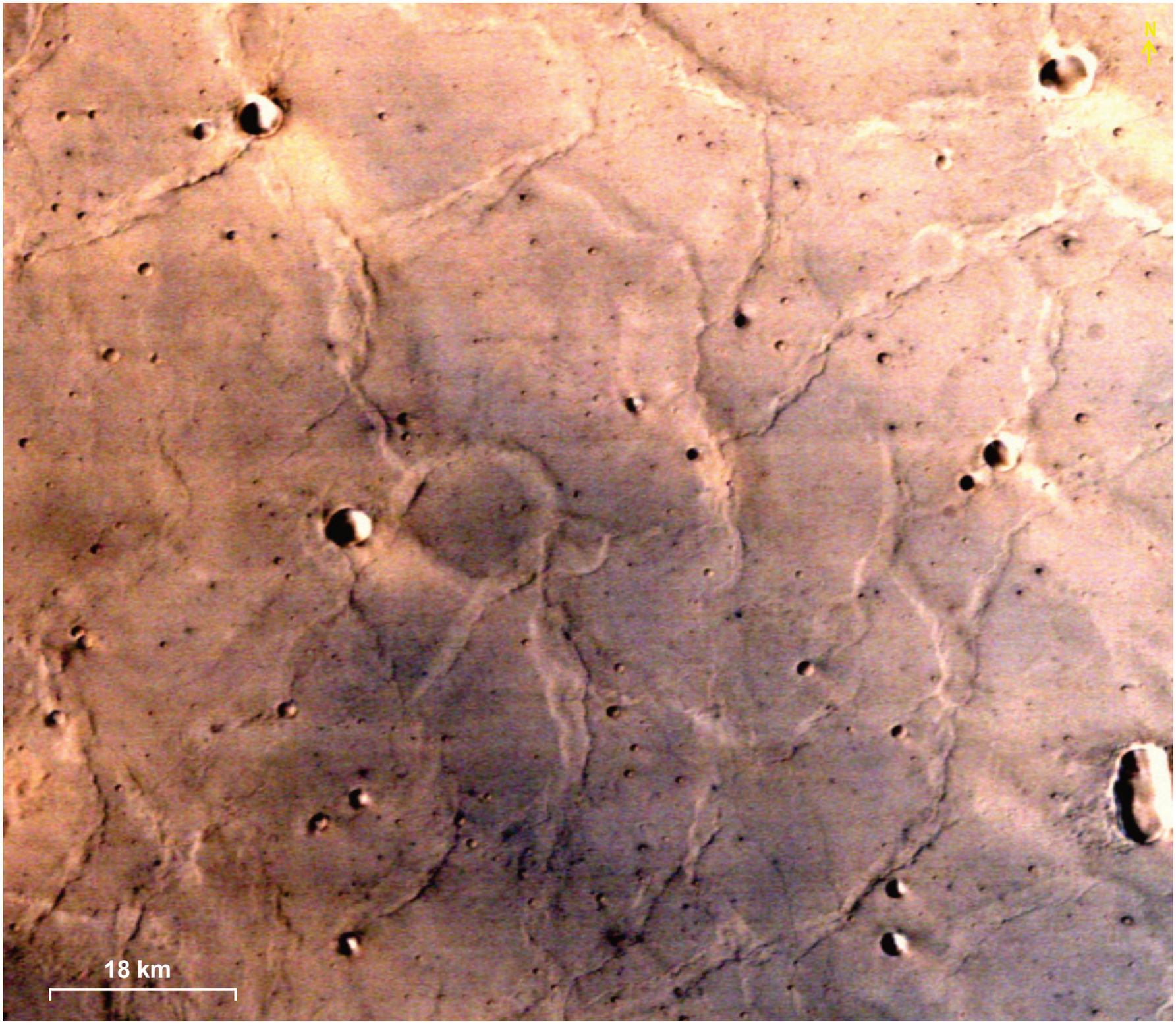
Fracture System

Image of fracture system in the region south of Noctis Labyrinthus located near ~28^0S, 108^0 W. The image was taken by Mars Colour Camera (MCC) on board Mars Orbiter Mission on 19-02-2015 at a spatial resolution of 74 m from a altitude of 1440 km.


N
30km

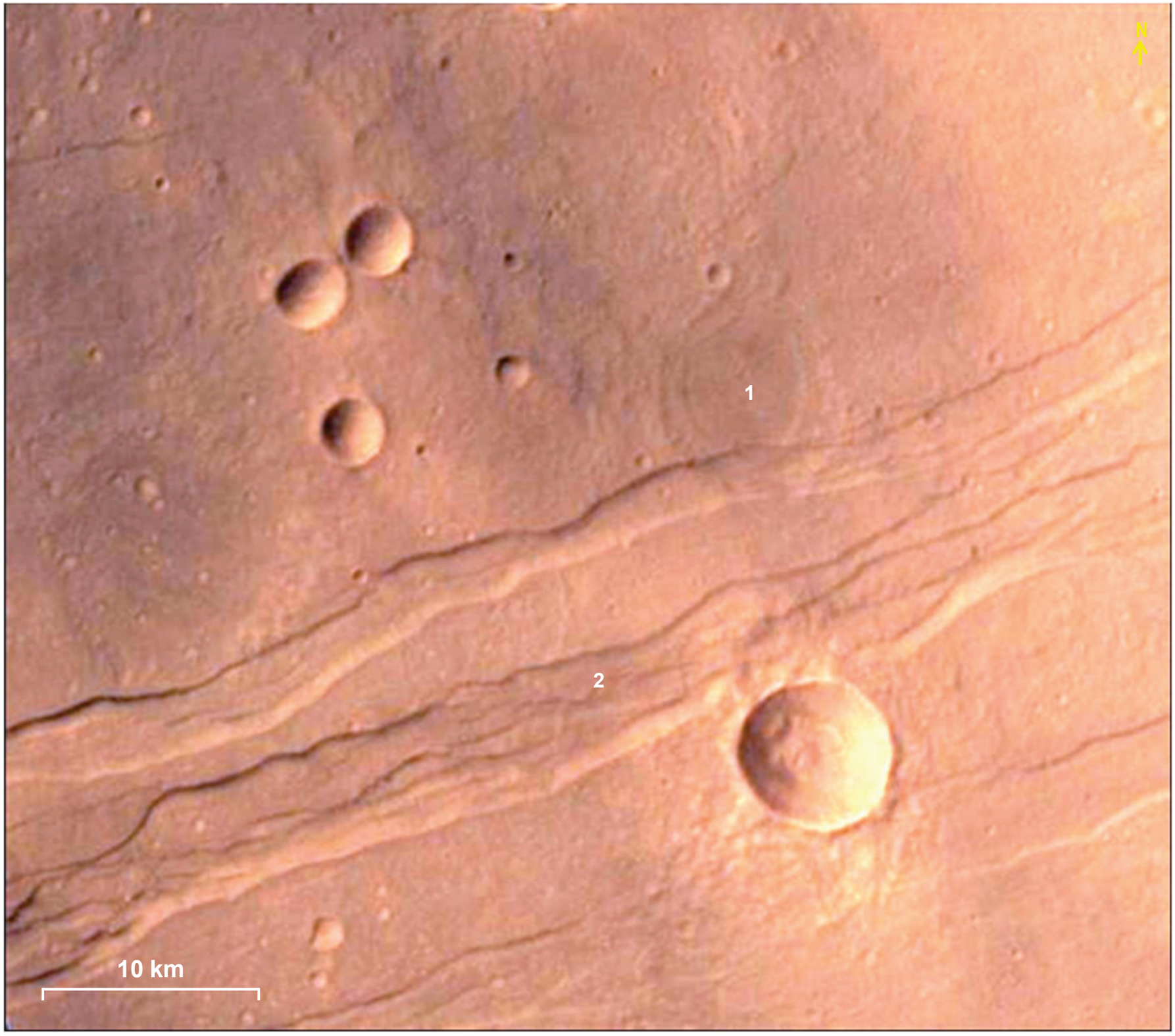
Interconnected Ridges

Image of interconnected ridges in Hesperia Planum region was taken by Mars Colour Camera (MCC) on 31-01-2015 at a spatial resolution of 58 m from an altitude of 1132 km. The region present in the MCC image is located near ~29^0S, 120^0 E. Wind streaks are also clearly seen in this image.


N
18 km

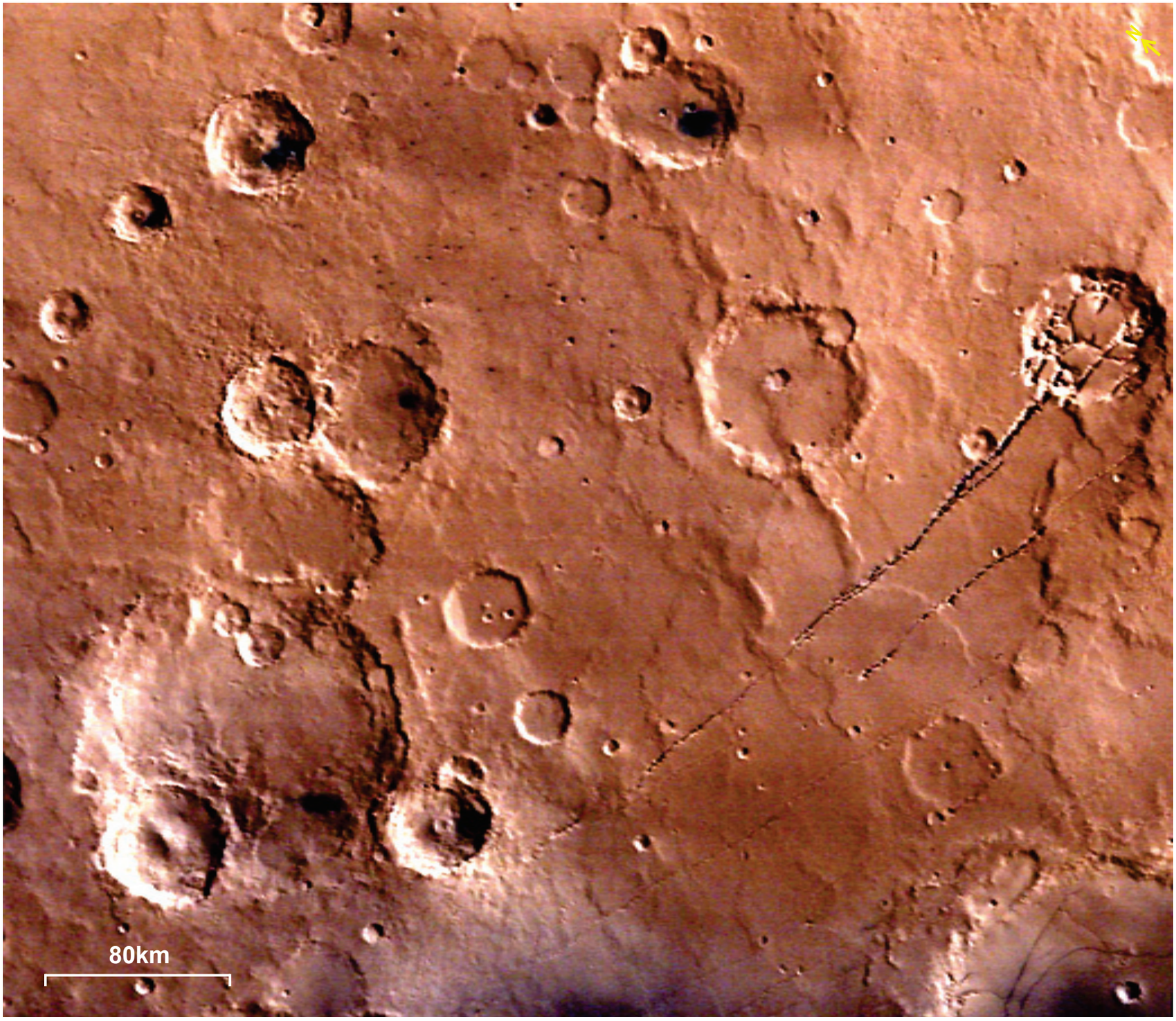
Crater bisected by fault

Image of crater located SE of Bernard crater in Terra Sirenum region on Mars was taken by Mars Colour Camera (MCC) on 13-03-2015 at a spatial resolution of 23 m from a altitude of 442 km. A concentric crater (1) super imposed over graben is also seen in this high resolution image. The relative position of this crater with respect to graben indicates that crater is younger than graben system. Larger crater having the diameter of 6 km. Three NE-SW trending grabens, and craters of various dimensions are clearly seen in this image. Part of regional graben system (2) of length 600 km is seen in this image.


N
1
2
10 km

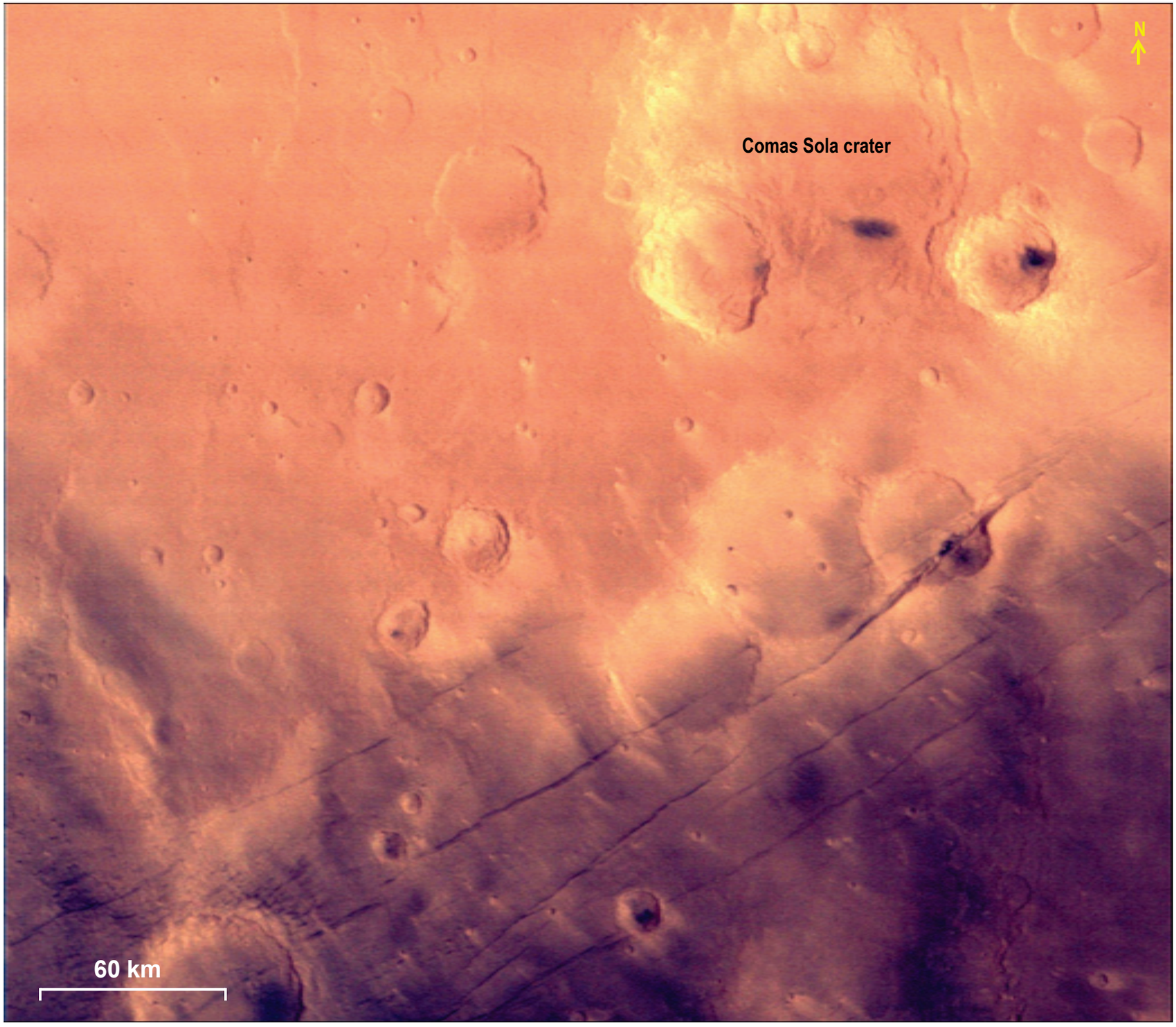
Mangala Fossa region

Image of craters bisected by fracture system and overlapping crater in Mangala Fossa region located near latitude ~19^0S, 159^0 W. The image of these fractures was taken by Mars Colour Camera (MCC) on board Mars Orbiter Mission on 11-02-2015 at a spatial resolution of 202 m from a altitude of 3900 km.


80km

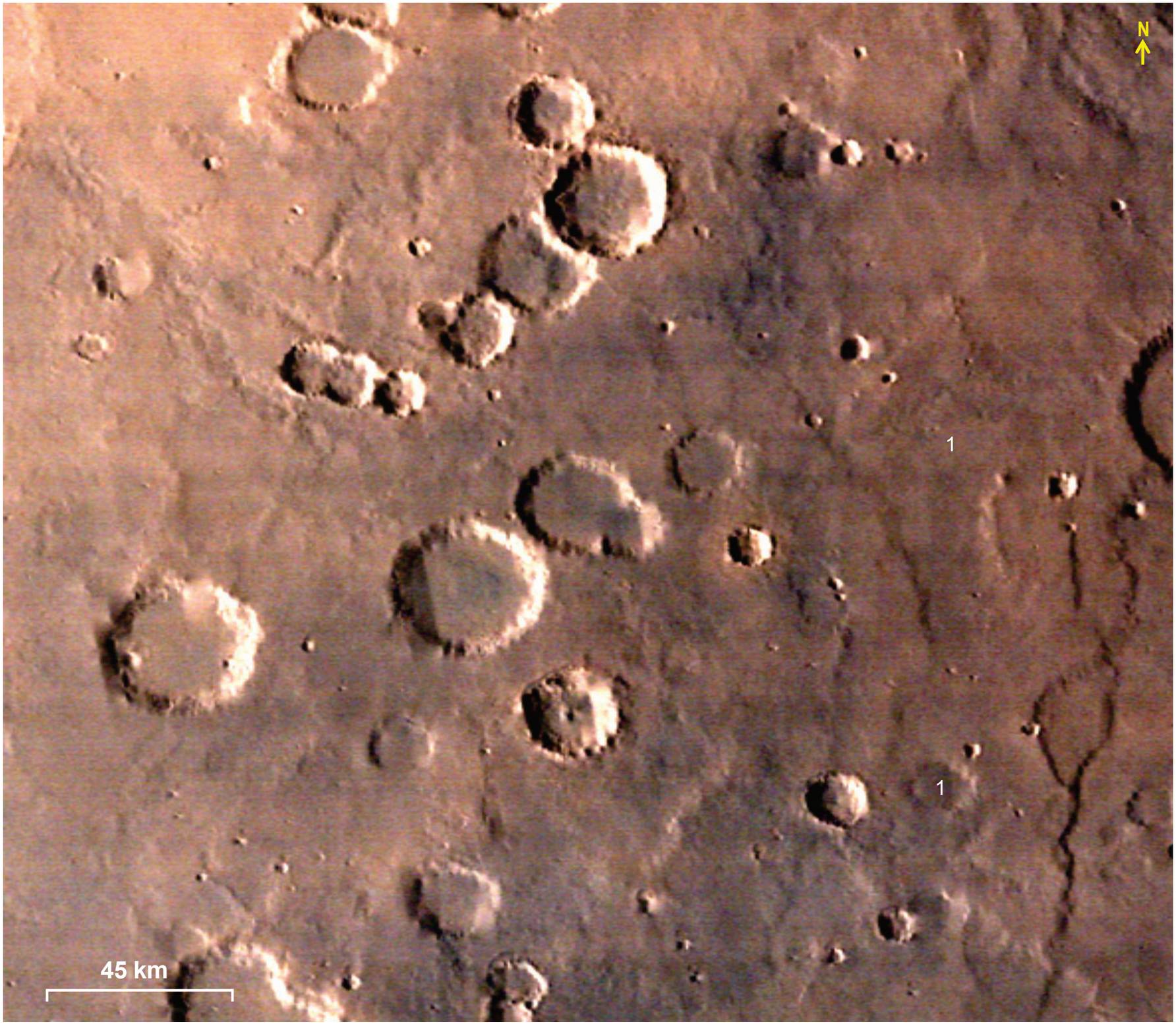
Fracture Lines Near Comas Sola crater

Image of fracture lines near Dejnev crater are seen in this image. This region located at ~21^0S, 168^0 W. Regional fractures of lengths 100-300 km are cutting across the region seen in this image. Comas Sola crater is located at north-eastern part of the image. Wind streaks are also clearly seen in this image. This Image was taken by Mars Colour Camera (MCC) on 03-02-2015 at a spatial resolution of 179 m from an altitude of 3453 km.


N
Comas Sola crater
60 km

Wrinkle Ridges

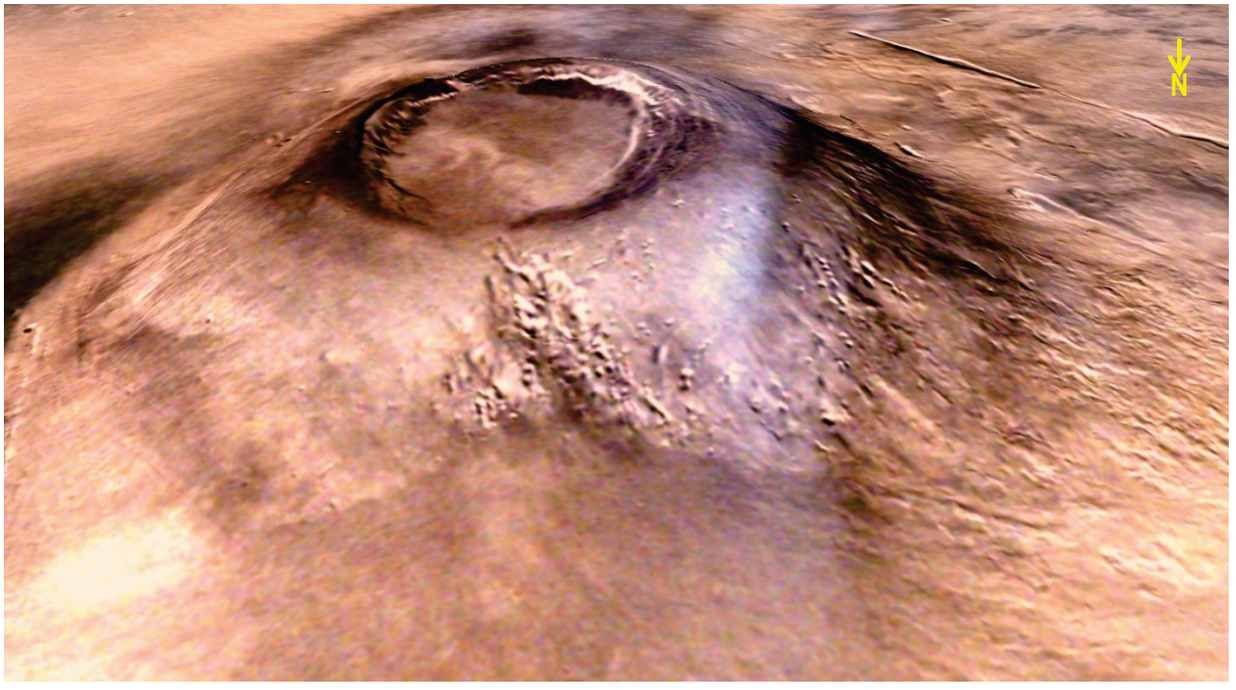
Image of Wrinkle Ridge in the region south of Novara crater was taken by Mars Colour Camera (MCC) on board Mars Orbiter Mission on 02-11-2014 at a spatial resolution of 128 m from a altitude of 2460 km. Wrinkle ridges (1) are seen at the right side of the image. Region shown in this image is located around 29^0S,10^0W on Mars.


N
1
1
45 km

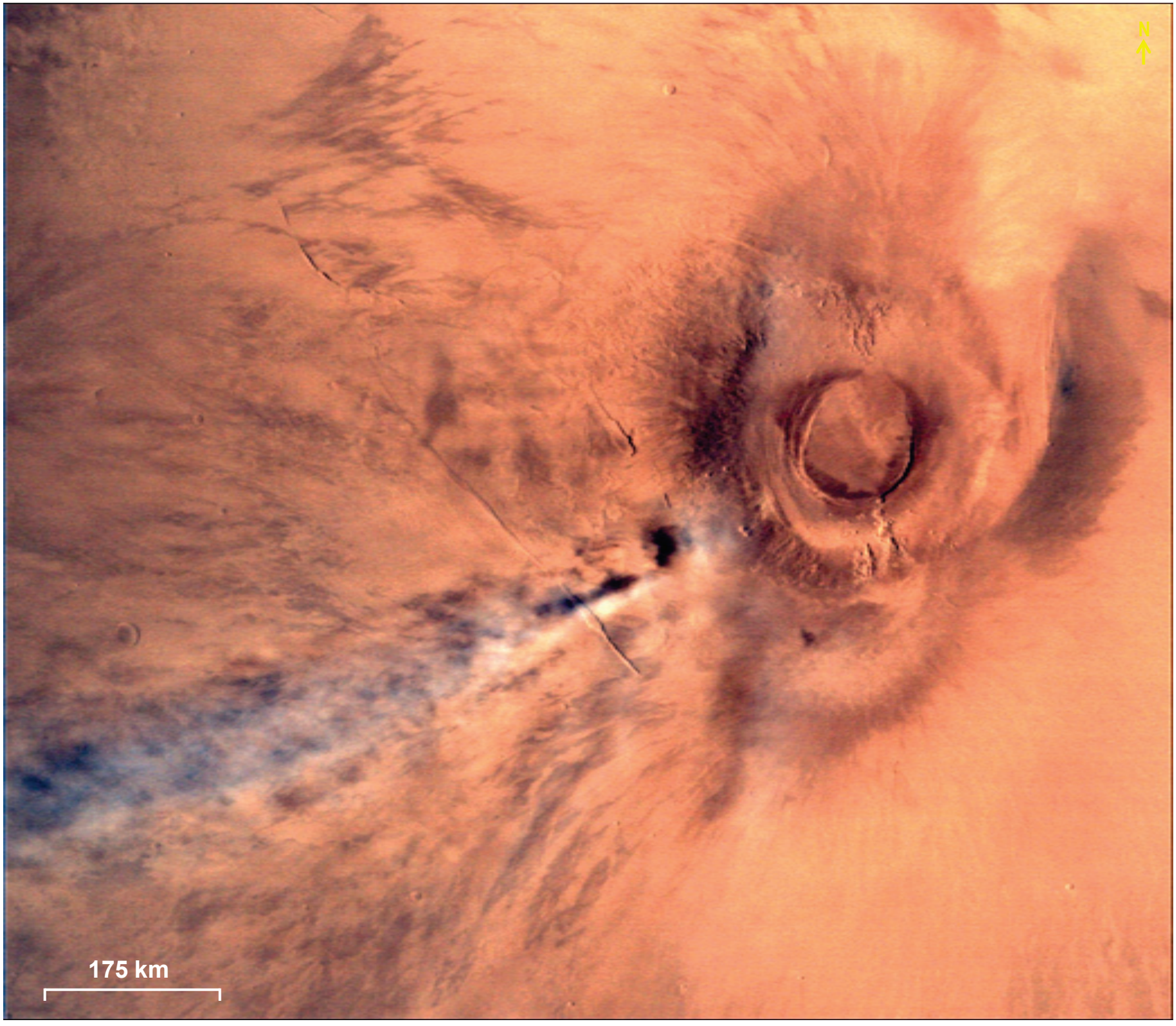
06 Volcanic features

Arsia Mons region

Arsia Mons is second highest volcano in the Tharsis Montes region having the height of ~17 km from surrounding plain regions. Arsia Mons is the southern most of three volcanoes of Tharsis Montes. Base of Mons is about ~435 km in diameter, and the summit caldera is ~110 km wide. Image of Arsia Mons region was taken by Mars Colour Camera (MCC) on 4-01-2015 at a spatial resolution of 556 m from an altitude of 10707 km. Water vapor clouds around Arsia Mons are seen on the left of volcanic mountain.

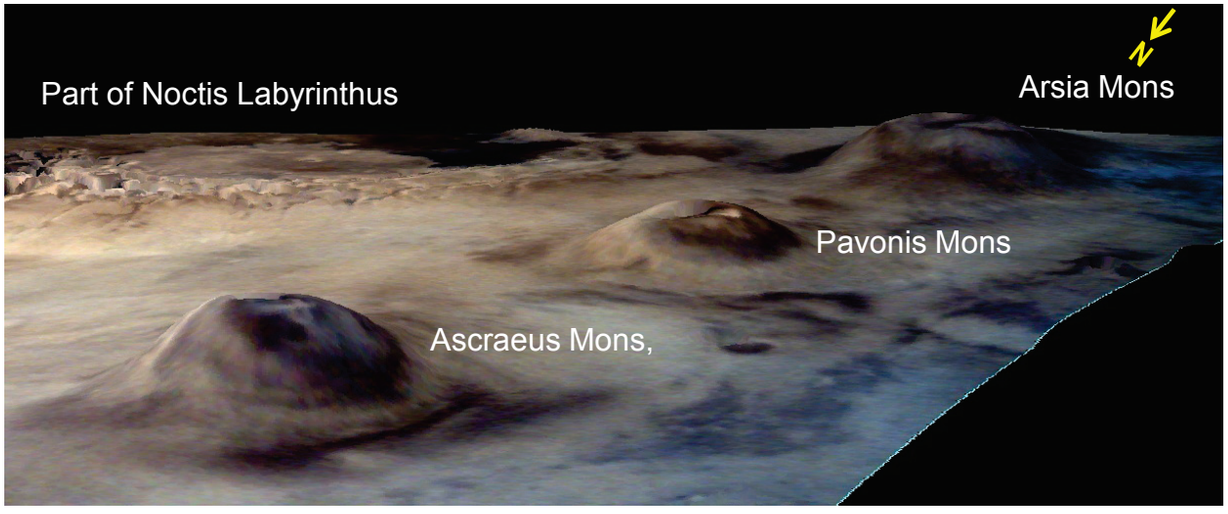


Three dimensional perspective view of Arsia Mons

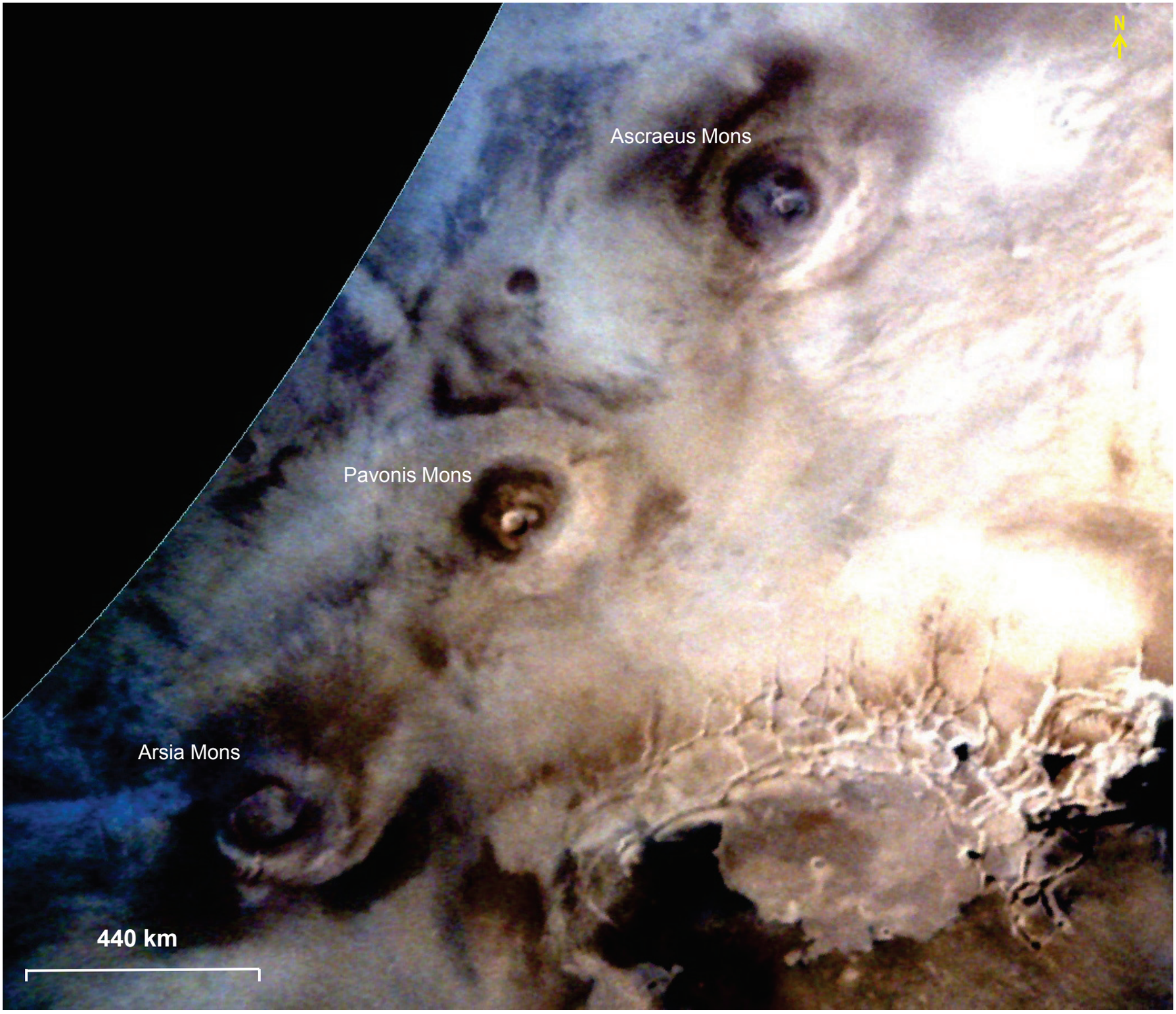

N
175 km

Tharsis Montes

Tharsis Montes located in the western hemisphere of the Mars. Tharsis volcanoes are Arsia Mons, Pavonis Mons and Ascraeus Mons. Tharsis Montes are product of volcanism and they are associated with tectonic processes which caused extensive crustal deformation in this area. Previous studies suggest that, Tharsis region is built on hot spot, similar to the island of Hawaii. Hot spot generates large quantities of magma in the lower crust that is released to the surface as basaltic lava. Mars lacks plate tectonics therefore the lava is able to build up in one region for billions of years to produce enormously large volcanic cones with giant heights. Image of Tharsis Monts region was taken by Mars Colour Camera (MCC) on 11-10-2014 at a spatial resolution of 1926 m from an altitude of 37695 km.

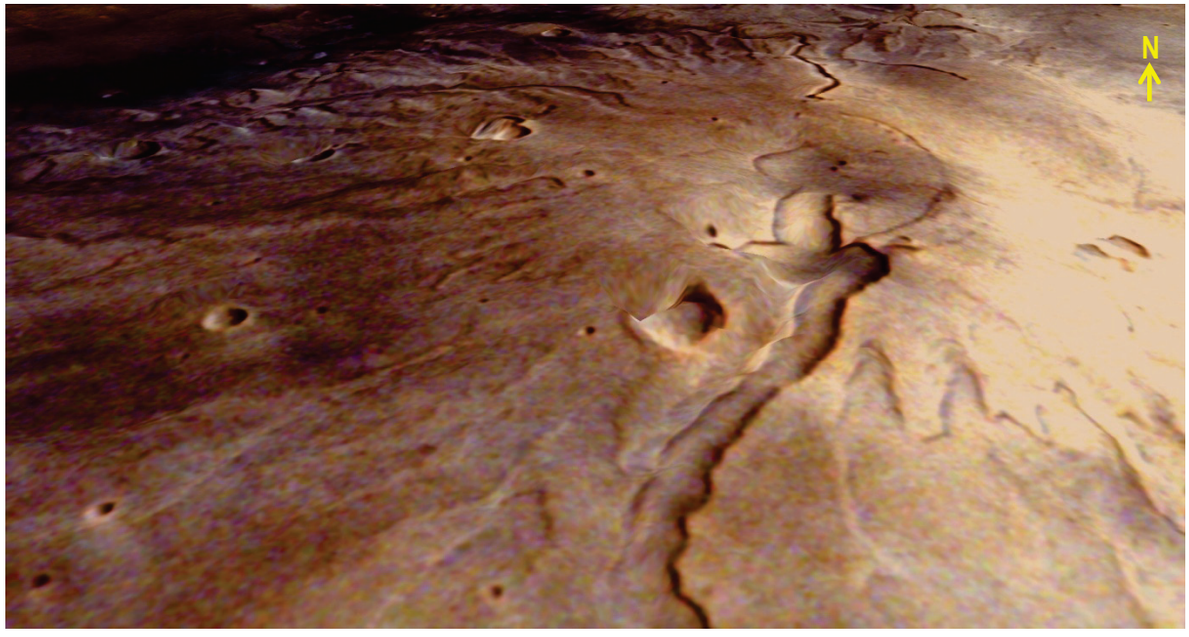


Three dimensional perspective view of Tharsis Montes

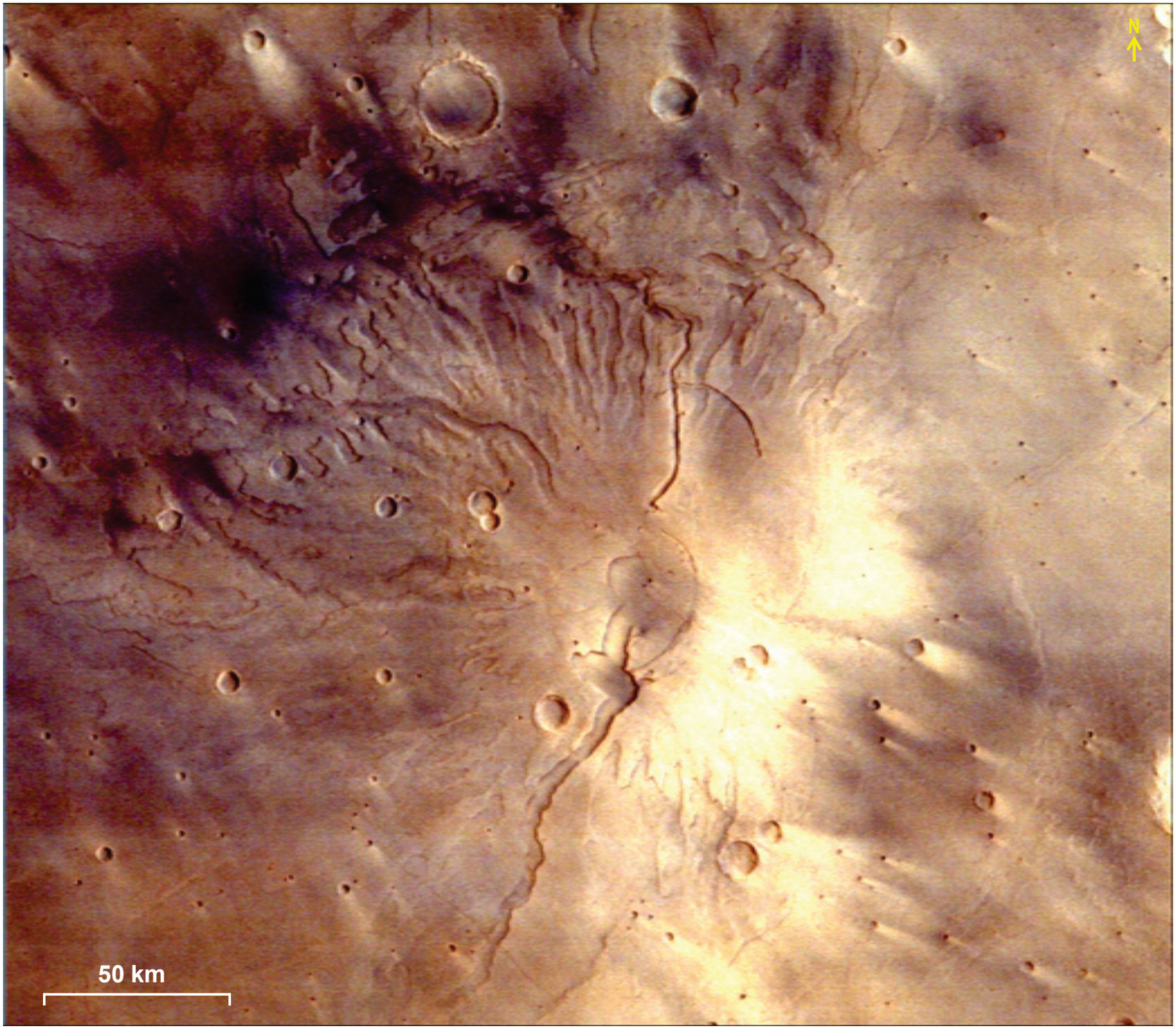

N
Ascraeus Mons
Pavonis Mons
Arsia Mons
440 km

Tyrrhenus Mons

Tyrrhenus Mons is a volcano present in the Hesperin planum, located at ~21^{0}S, 106^0 E on Mars. Tyrrhenus Mons is having base diameter ~269 km. Volcanism in Tyrrhenus Mons region occured around ~3.9 billion years ago. Concentric fractures systems seen in the MCC images are possibly formed by extensional stresses within the surface of Mars. The volcano displays a central complex. Formation of Tyrrhenus Mons has been attributed to large explosive eruptions in the Late Noachian Epoch that emplaced thick sequences of pyroclastic flow deposits around the volcano's summit. Image of Tyrrhenus Mons in Hesperia Planum region was taken by Mars Colour Camera (MCC) on 25-02-2015 at a spatial resolution of 166 m from an altitude of 3192 km. Impression of flow features and NE-SW trending fractures are clearly seen on Tyrrhenus Mons in MCC image. Impressions of wind streaks can also be seen in this image.

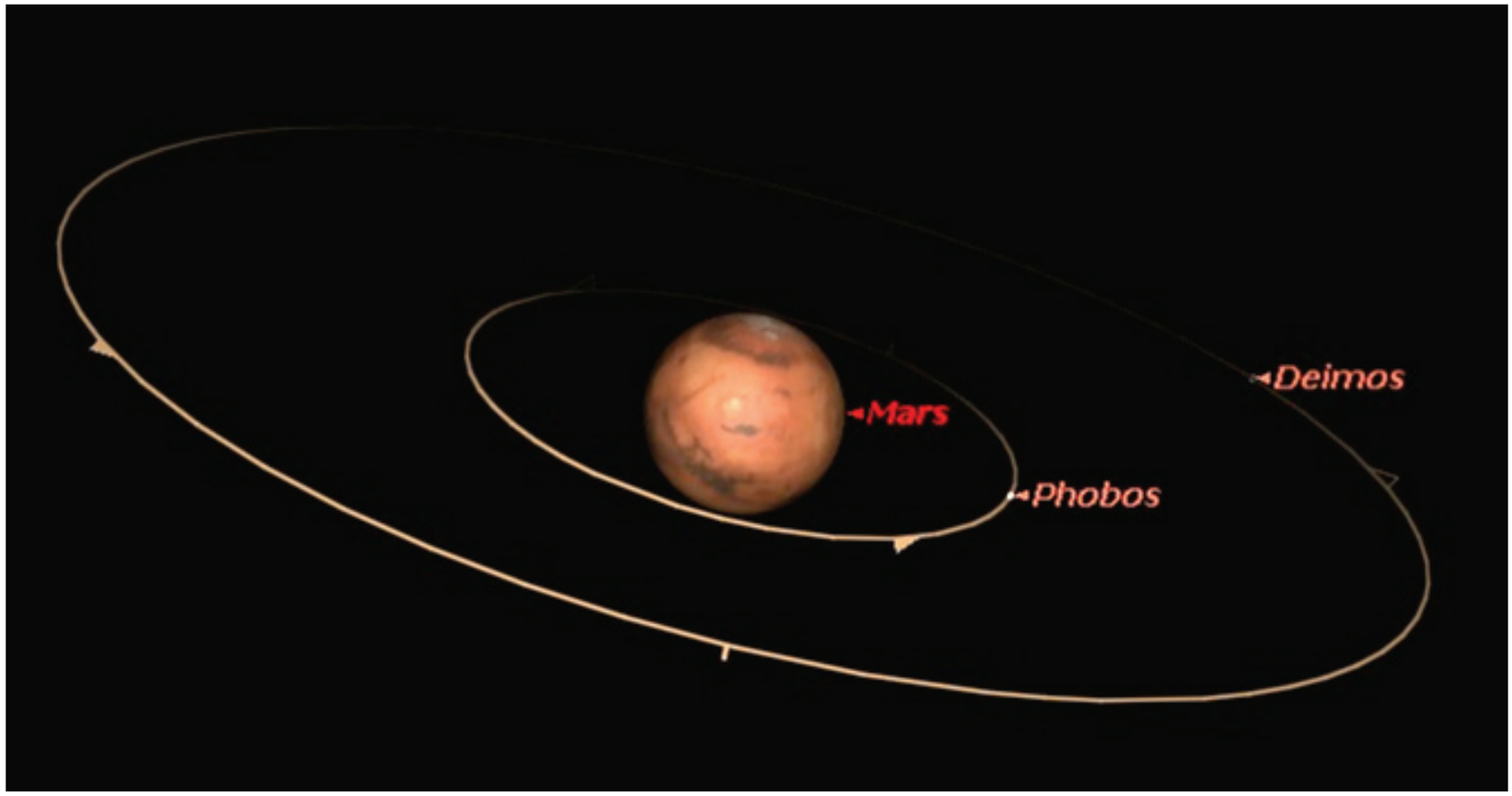


Three dimensional perspective view of Tyrrhenus Mons


N
50 km

07 Miscellaneous Results

Moons of Mars: Phobos and Deimos

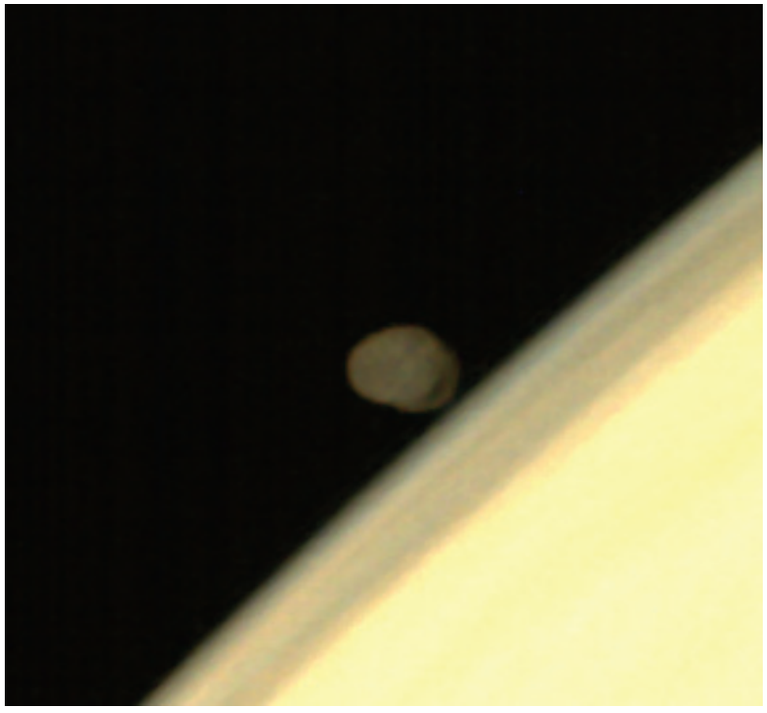


Moons of Mars : Phobos and Deimos

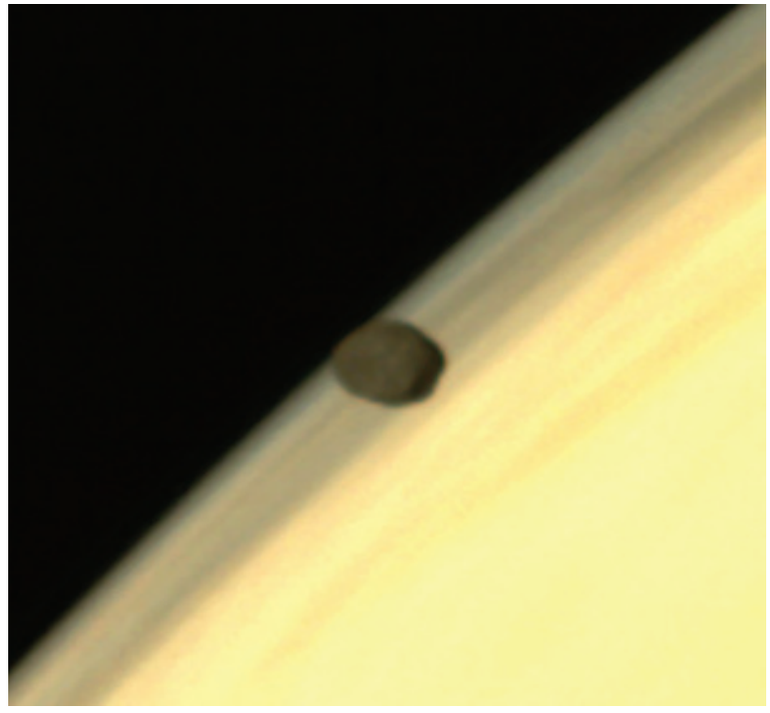
Phobos

Mars has two natural satellites, Phobos and Deimos having the mean radius of 11 km and 6.5 km, respectively. Phobos is the inner and larger one of the two natural satellites of Mars. Asaph Hall's an astronomer of the Naval Observatory in Washington discovered Phobos and Deimos in 1877. It is believed to be that these two satellites are originated from asteroids belt present between Mars and Jupiter.

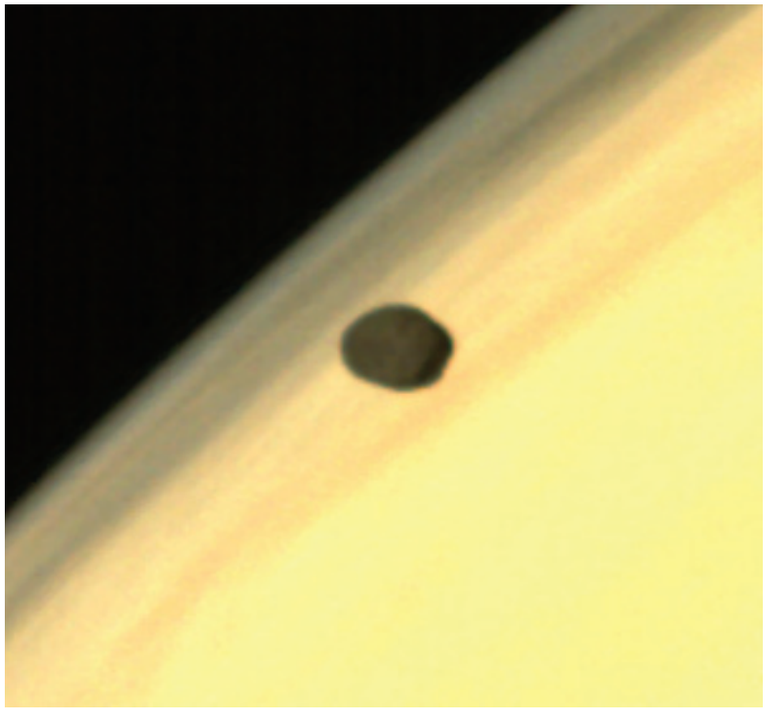
Phobos is a very irregular body and images of Phobos, its images was taken by Mars Colour Camera (MCC) on 14-10-2014 at a spatial resolution of 550 m. Phobos in the backdrop of Mars are seen in MCC images.



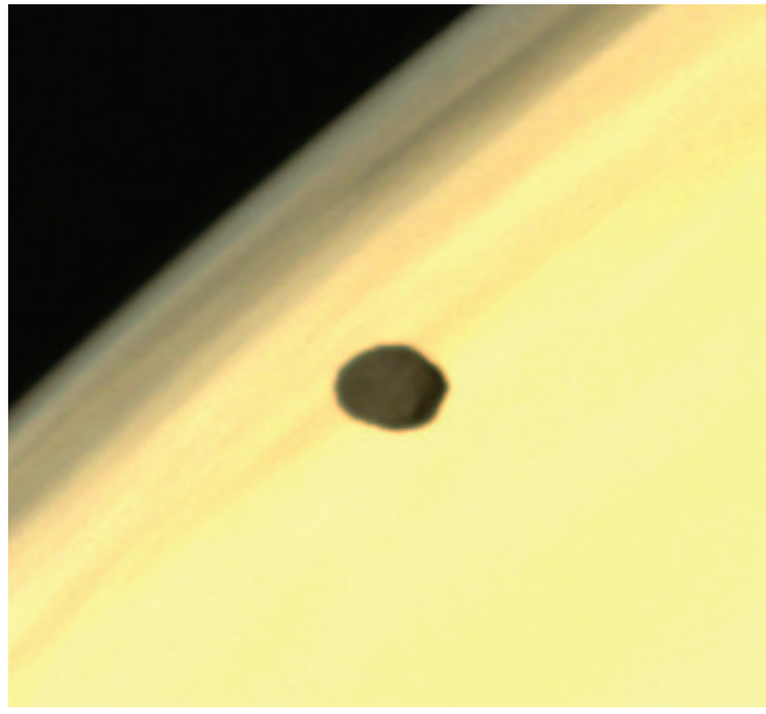
Phobos image at 11:25:35.85 GMT



Phobos image at 11:25:47.85 GMT



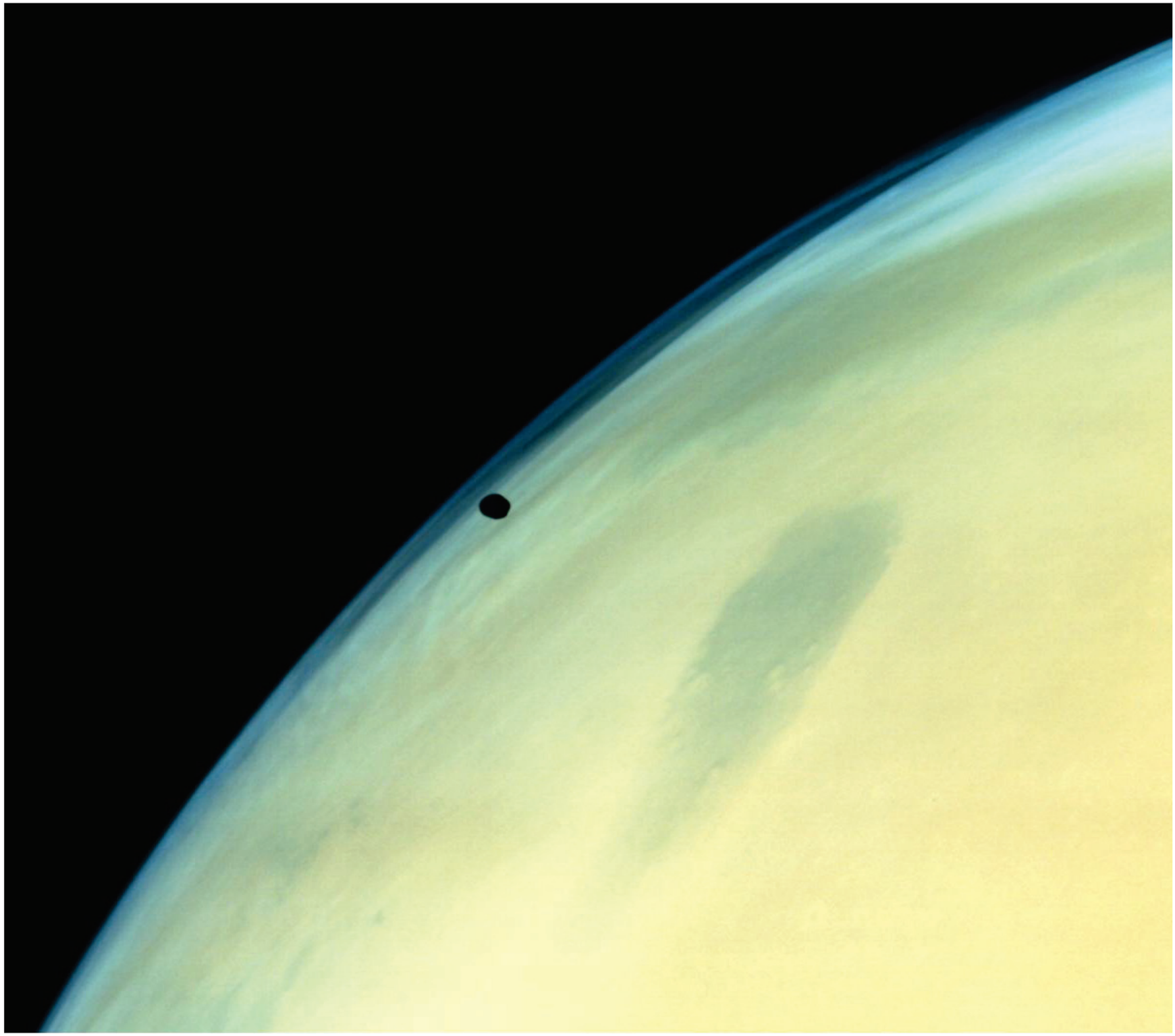
Phobos image at 11:25:59.85 GMT



Phobos image at 11:26:10.85 GMT

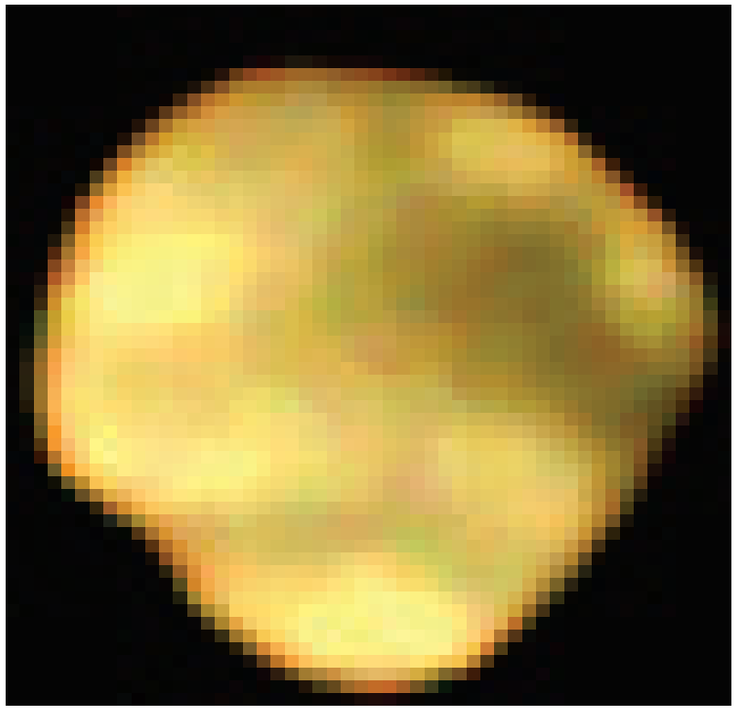
Transit of Phobos on Mars Surafce

Phobos is larger moon of Mars and its transit over Mars was captured by Mars Colour Camera (MCC) on 14-02-2015 at a spatial resolution of 550 m from an altitude of 16057 km from Mars. Phobos (dark body) is seen in the backdrop of Mars (bright colours). Phobos is heavily cratered and orbits Mars with a period of 7.3 hours, less than a Martian day.

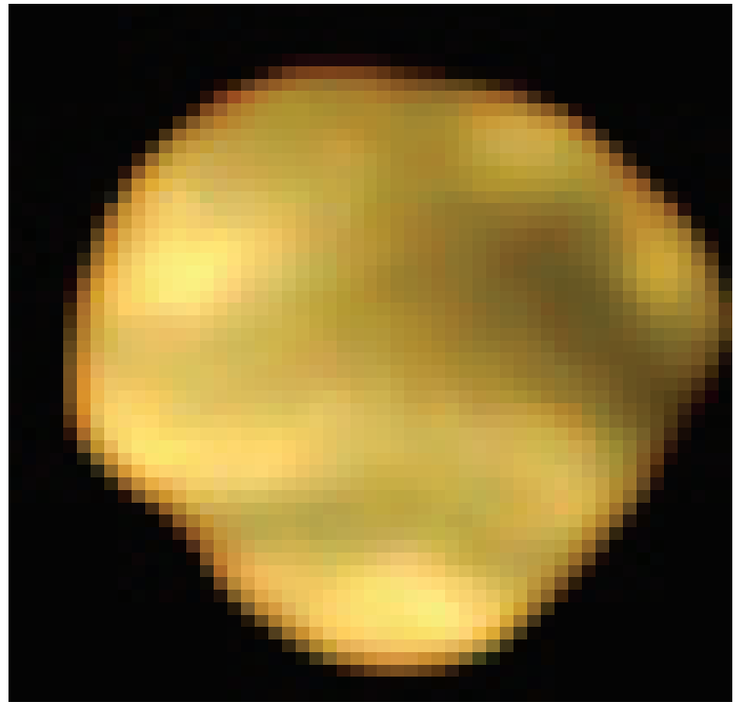


Deimos

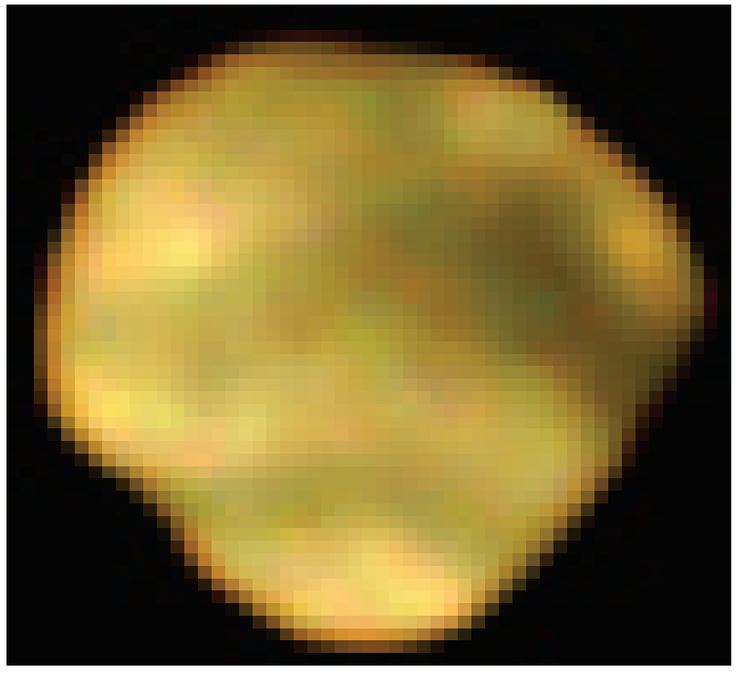
Images of Deimos, Moon of the Mars were taken by Mars Colour Camera (MCC) on 14-10-2014 at a spatial resolution of 230 m. The distance of Deimos from MOM was 4397 km. Deimos having the mean diameter of 14 km. Farside images of Deimos are taken first time by Mars Color Camera. Deimos is covered with a thick layer of dust therefore it has little surface details.



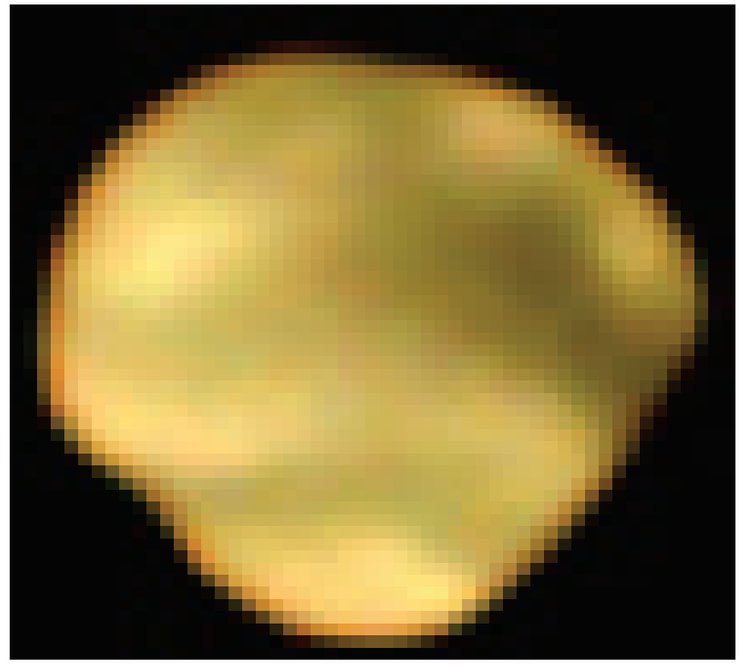
Deimos image at 13:05:36.54 GMT



Deimos image at 13:05:47.54 GMT



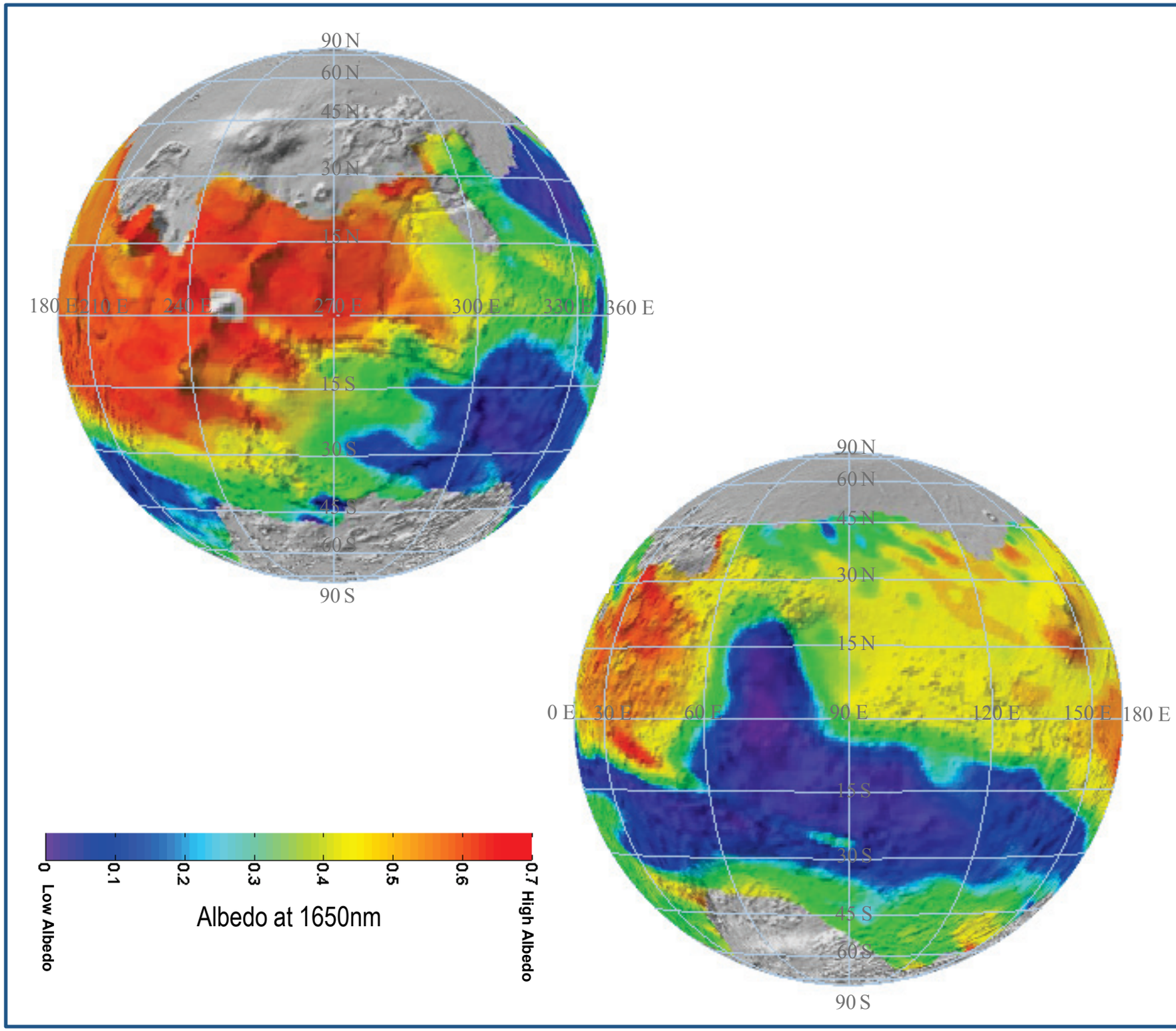
Deimos image at 13:05:59.54 GMT



Deimos image at 13:06:11.54 GMT

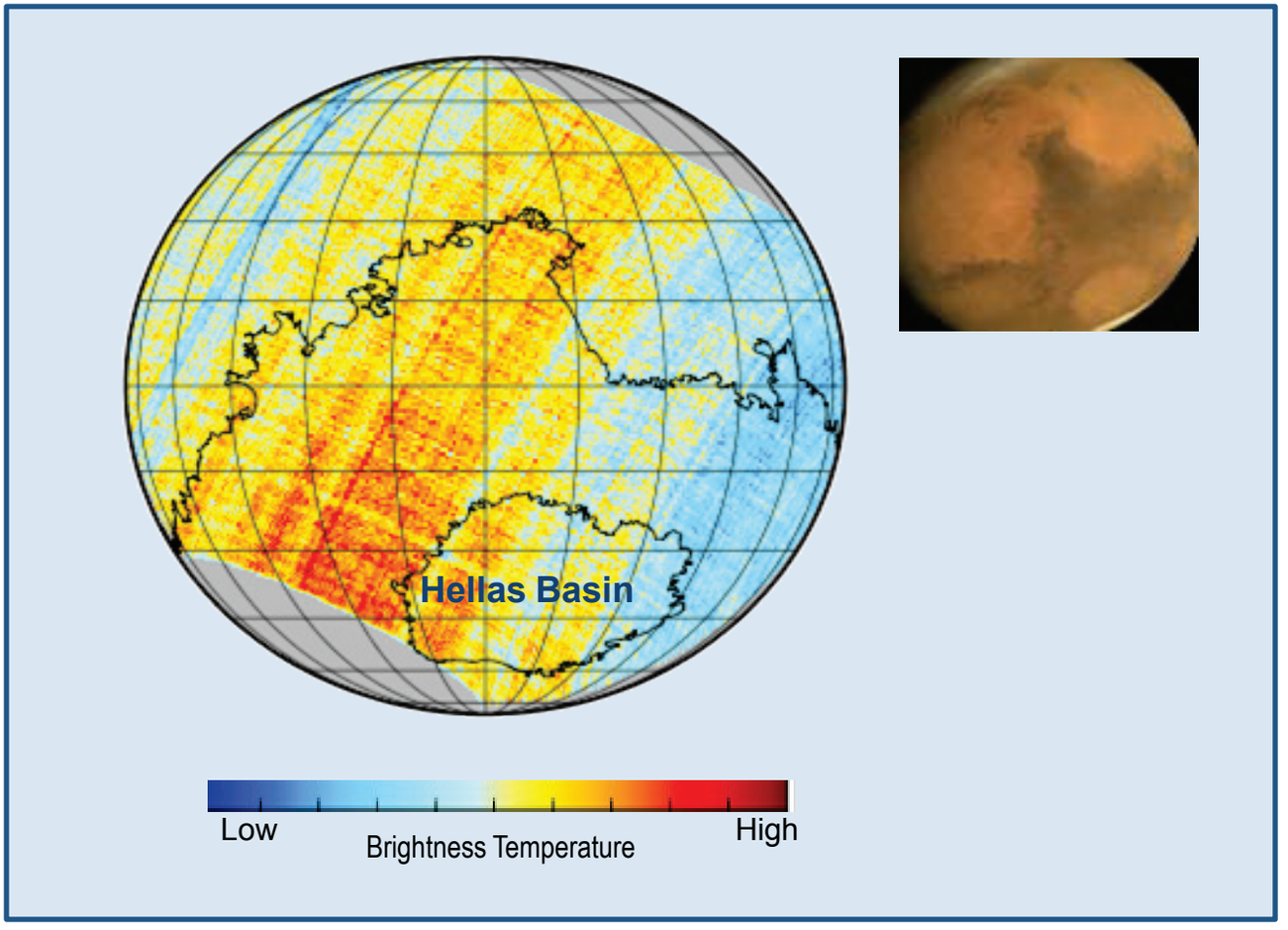
Global Albedo Map of Mars using Methane Sensor for Mars (MSM)

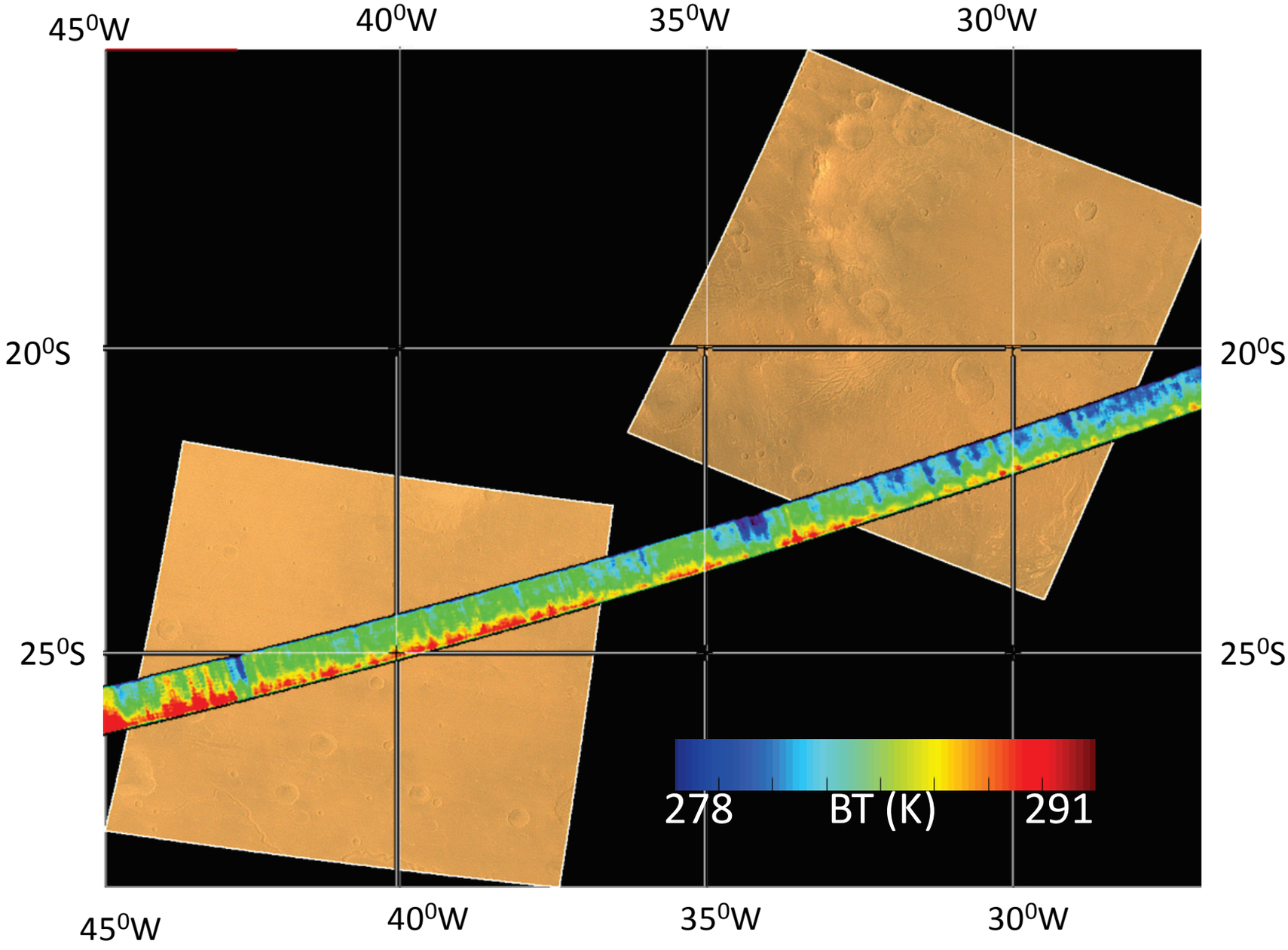
Global albedo maps of Mars in short wave infrared (SWIR) 1.6 μm wavelength has been made using the first five months of data provided by Methane Sensor for Mars (MSM). The bright regions (SWIR albedo greater than 0.4) are localized in Northern hemisphere with the highest albedo found over the Tharsis region. The low SWIR albedo regions (less than 0.2) are mainly localized in Syrtis Major Planum and Southern highlands, although low SWIR albedo regions such as Acidalia are also identified in the Northern hemisphere. These map provides information on the rock composition on the surface of Mars. The area shown in blue color indicates the presence basaltic composition while red indicates the sand covered regions of Mars.


90 N
60 N
45 N
30 N
15 N
180 E
210 E
240 E
270 E
300 E
330 E
360 E
15 S
30 S
45 S
60 S
90 S
0 E
30 E
60 E
90 E
120 E
150 E
180 E
0 Low Albedo
0.1
0.2
0.3
0.4
0.5
0.6
0.7 High Albedo
Albedo at 1650nm

Temperature Distribution on Mars using Thermal Infrared Imaging Spectrometer (TIS)

Thermal Infrared Imaging Spectrometer (TIS) detects emitted infrared radiation from Mars in 7-13 μm spectral region. This instrument is useful to study the spatial and temporal variation of surface temperature. Variability of Brightness Temperature (BT) observed from TIS instrument on 9 October 2014 (Ls=210^0) in 12.25 μm spectral band and Corresponding Mars Colour Camera (MCC) Image showing variation in surface albedo is shown below. This image is acquired from 52689 km altitude. Brightness Temperature depends on surface temperature and emissivity and is govern by Sun and sensor viewing geometry. Regions covered are Hellas basis, Syrtis Major and Parts of Arabia Terra. High albedo regions of Arabia terra and Isidis and low albedo region of Syrtis Major can be seen in the synchronous image acquired from Mars Colour Camera (MCC) onboard the MOM mission. The maximum brightness temperature was observed as 294K.





Brightness Temperature (BT) variability as observed from push broom imaging from TIS instrument near Holden Crater on 27 Feb. 2015 (Ls=299.2 Degrees) in 10.25 µm spectral band from the altitude of 386 km. TIS observations are draped on background of MCC data as ancillary source of information.

MCC image shows part of Eos Mensa region of Mars