Mars Express: 'Wrinkle ridges' and grabens in Tempe Terra

06 January 2012

Tempe Terra is located at the northeastern edge of the Tharsis volcanic region and forms the transition zone between the southern highlands and the northern lowlands. This area is characterised by a large variety of tectonic structures and is one of the most geologically diverse on Mars. These images from the High Resolution Stereo Camera (HRSC), operated by the German Aerospace Center (Deutsches Zentrum für Luft- und Raumfahrt; DLR) on board ESA's Mars Express spacecraft, which were acquired on 17 July 2011, show a large number of interesting geological phenomena.

The effects of different forces can be seen adjacent to one another. These have led to both extension of the Martian crust and crustal compression, which has created 'wrinkle ridges' (see image detail 1 in the overview image). The most striking result of the crustal extension is a linear graben running across the entire image and only broken by misalignment in a few places. This graben is up to a kilometre wide and is overlaid by a large impact crater some 12 kilometres across and its ejecta; inside the crater, the graben is covered by younger sediments (image detail 2).

The images show a section of the HRSC image strip located at 42 degrees north and 304 degrees east, obtained during orbit 9622 with a resolution of about 18 metres per pixel.

Landscape shaped by water as well as tectonic forces

To the north of the graben, in the right third of the image, the terrain falls away to the lowlands by over 1000 metres. The landscape here is marked by several extensive valley systems. Upslope, a number of smaller, dendritic valleys partially covered by impact craters can be made out (image detail 3). Many younger craters in the region south of the graben that still have well-preserved contours exhibit lobate, concentric structures in their interior that have been caused by a slow moving plastic material. These features, referred to by geologists as concentric crater fill, can be found in a number of places on Mars – including Phlegra Montes, the subject of last month’s images.

Prominent mesas are visible in the upper left section of the image, to the southwest (image detail 4). They reveal the original terrain level of the Martian southern highlands. Also conspicuous are the clearly structured ejecta of several impact craters. These partially cover the older flow and graben systems and therefore occurred later. Older, large impact craters (image detail 5) have been almost completely covered with sediment or filled with ejecta.

Tempe Terra was first described by Greek astronomer Eugenios Antoniadis (1870-1944, later known as Eugène Michel Antoniadi through his work in France). His observations of the Tempe Terra region with a powerful new telescope at the Paris Observatory in Meudon during the opposition of Mars in 1909 – described in detail in 1930 – disproved the theory circulating among astronomers that the 'canali' observed by Giovanni Schiaparelli in 1877 were artificial canals; Schiaparelli himself had serious doubts about this interpretation. As a tribute to both astronomers, who made important contributions to planetary cartography, craters on the Moon, Mars and Mercury bear their names. Tempe Terra was named after a valley to the north of Mount Olympus in Thessaly (Greece), where, according to mythology, Orpheus' wife Eurydice died after being bitten by a snake while fleeing from her tormenter, Aristaios.

The colour images were created from the nadir channel, the field of view of which is aligned perpendicular to the surface of Mars, and the colour channels; the oblique perspective views were generated from HRSC stereo channel data. The anaglyph, which creates a three-

dimensional impression of the landscape when viewed with red/blue or red/green glasses, was derived from the nadir channel and one stereo channel. The black-and-white picture is based on data acquired by the nadir channel, which has the highest resolution of all the channels. The colour-coded plan view is based on a digital terrain model of the region, from which the topography of the landscape can be derived. The image products shown here were created by the Planetary Sciences and Remote Sensing Department at the Institute of Geological Sciences of the Freie Universität Berlin.

The HRSC camera experiment on the European Space Agency's Mars Express mission is headed by Principal Investigator (PI) Professor Gerhard Neukum (Freie Universität Berlin), who was also responsible for the technical design of the camera. The science team consists of 40 co-investigators from 33 institutions in ten nations. The camera was developed at DLR under the leadership of the PI and it was built in cooperation with industrial partners EADS Astrium, Lewicki Microelectronic GmbH and Jena Optronik GmbH. The instrument is operated by the DLR Institute of Planetary Research in Berlin-Adlershof, through ESA/ESOC. The systematic processing of the HRSC image data is carried out at DLR. The images shown here were created by PI-group at the Institute of Geological Sciences of the Freie Universität Berlin.

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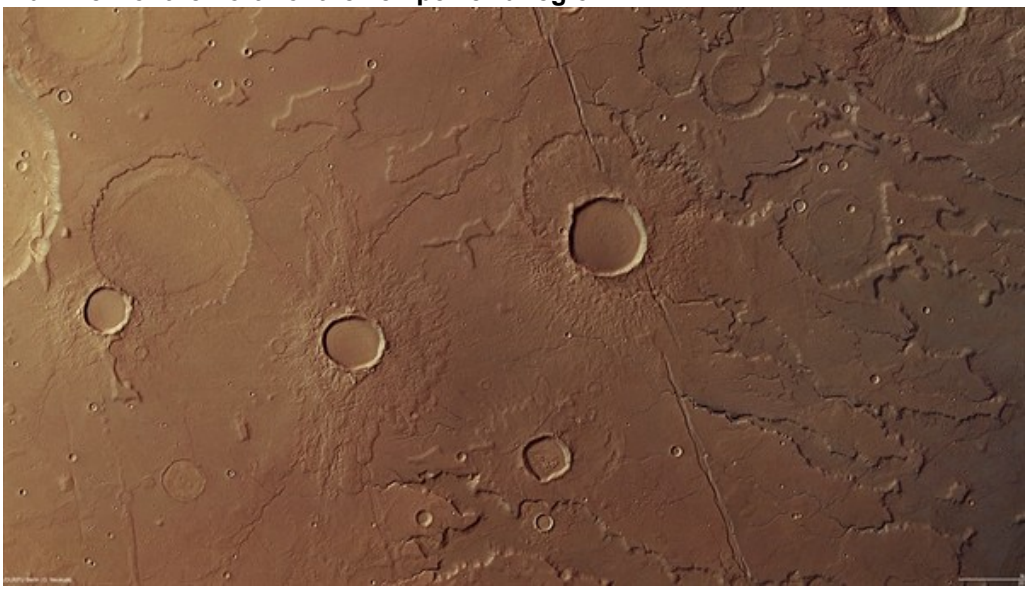
Plan view of the north of the Tempe Terra region



This colour view has been created using the nadir channel, which is directed vertically down onto the Martian surface, and the colour channels of the HRSC camera system on board ESA's Mars Express spacecraft; north is to the right in the image. The image covers an area of over 14,000 square kilometres, equivalent to an area roughly the size of the Bahamas. Tempe Terra is one of the most geologically interesting areas on Mars, because in this transition zone between the highlands and northern lowlands both tectonic forces and water and ice have made a wide range of changes to the landscape. Copyright note: As a joint undertaking by DLR, ESA and FU Berlin, the Mars Express HRSC images are published under a Creative Commons licence since December 2014: ESA/DLR/FU Berlin, CC BY-SA 3.0 IGO. This licence will also apply to all HRSC images released to date.

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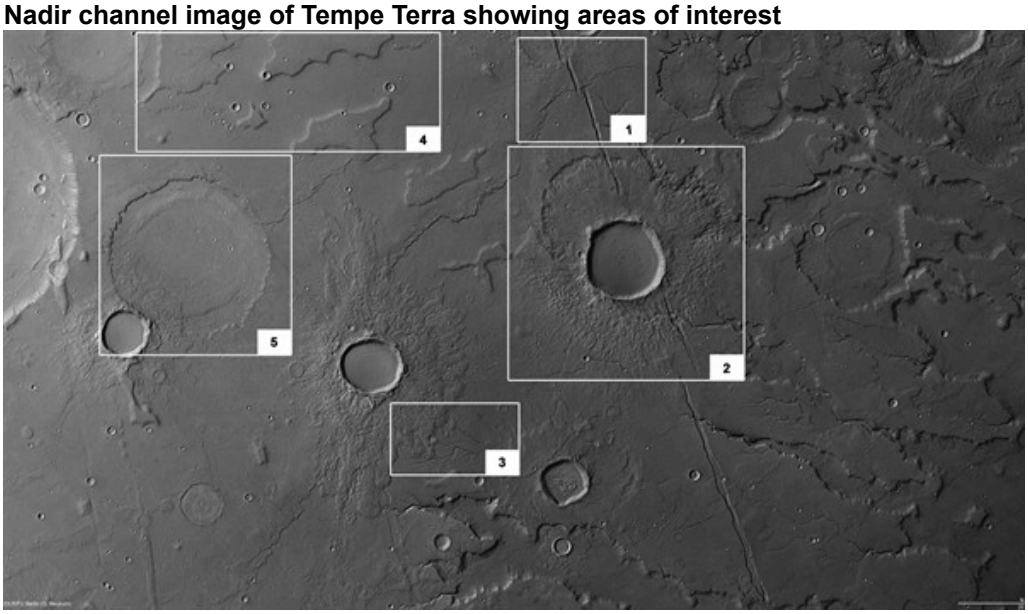
Nadir channel image of Tempe Terra showing areas of interest



The nadir channel, which points vertically down towards the planet’s surface, provides the highest image resolution in the HRSC camera system. During orbit 9622, ESA’s Mars Express spacecraft was about 425 kilometres above the surface, resulting in an image resolution of 18 metres per pixel. In the framed areas, conspicuous phenomena characteristic of the region are visible: a tectonic rift about a kilometre wide, caused by extension of the crust (box 1), which runs through the ejecta of an impact crater approximately 12 kilometres across (box 2). Dendritic valleys indicate that the landscape may have been shaped by flowing water (box 3). Mesas reveal the original terrain level of the southern highlands of Mars (box 4). Older large impact craters (box 5) have been almost completely covered with sediment deposited by flowing water or filled with impact ejecta. Copyright note: As a joint undertaking by DLR, ESA and FU Berlin, the Mars Express HRSC images are published under a Creative Commons licence since December 2014: ESA/DLR/FU Berlin, CC BY-SA 3.0 IGO. This licence will also apply to all HRSC images released to date.

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Oblique perspective view of Tempe Terra, from northwest to southeast

Realistic perspective views of the Martian surface can be generated from data acquired by the stereo and colour channels of the High Resolution Stereo Camera (HRSC) on board ESA's Mars Express spacecraft, which are oriented at an angle with respect to the planet's surface. This image shows the transition zone between the old highlands of Mars in the background, covered with numerous impact craters, and the northern lowlands in the foreground. A number of promontories that have not yet been worn away by erosion extend into the lowlands. Dendritic valleys indicate that flowing water has also contributed to the shaping of the landscape. The ejecta from an impact crater 12 kilometres across are intersected by a tectonic rift almost a kilometre wide, which is the result of tensile stress in the Martian crust. The interior of the crater has been filled in with a material the surface structure of which indicates that it had plastic properties. Copyright note: As a joint undertaking by DLR, ESA and FU Berlin, the Mars Express HRSC images are published under a Creative Commons licence since December 2014: ESA/DLR/FU Berlin, CC BY-SA 3.0 IGO. This licence will also apply to all HRSC images released to date.

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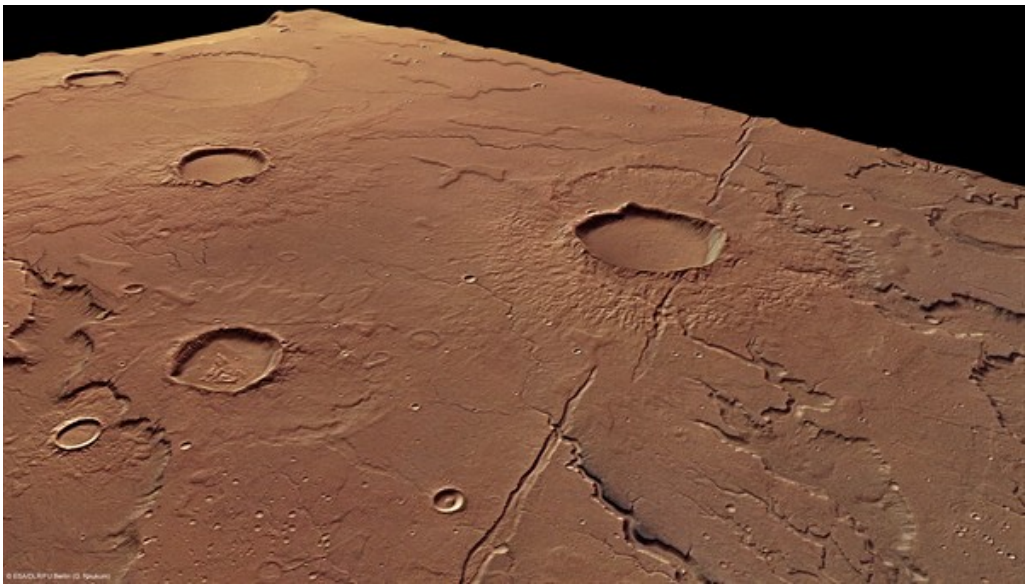
Oblique perspective view of a tectonic rift in Tempe Terra, looking from northeast to southwest



Realistic perspective views of the Martian surface can be generated from data acquired by the stereo and colour channels of the High Resolution Stereo Camera (HRSC) on ESA's Mars Express spacecraft, which are oriented at an angle with respect to the planet's surface. An impact crater nearly twelve kilometres across is intersected by a tectonic rift almost a kilometre wide, which is the result of tensile stress in the Martian crust. The interior of the crater has been filled in with a material the surface structure of which indicates that it had plastic properties. The transition zone from the Martian highlands to the northern lowlands can be seen in the right third of the image and at front left. Copyright note: As a joint undertaking by DLR, ESA and FU Berlin, the Mars Express HRSC images are published under a Creative Commons licence since December 2014: ESA/DLR/FU Berlin, CC BY-SA 3.0 IGO. This licence will also apply to all HRSC images released to date.

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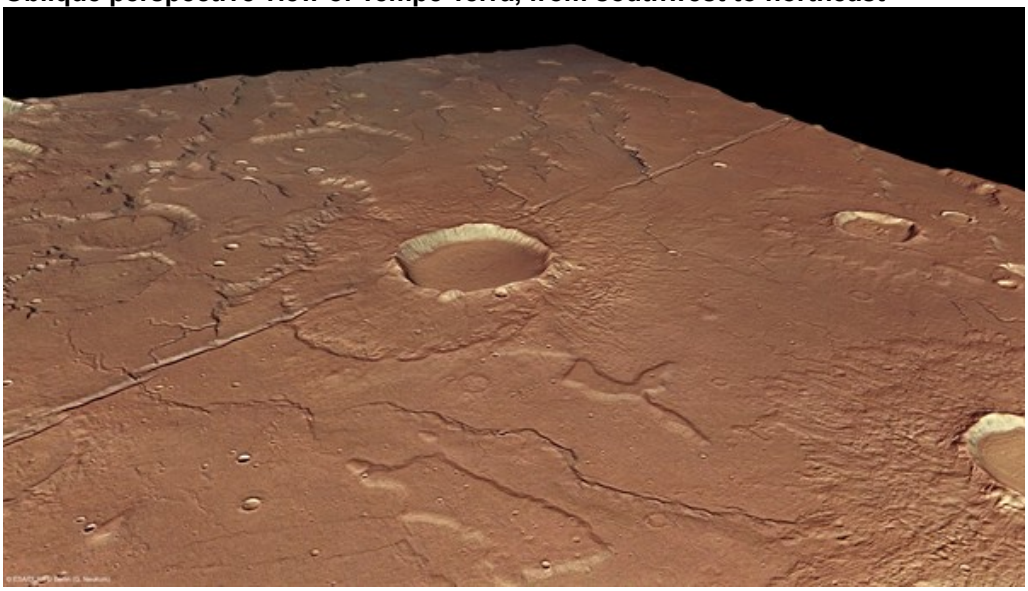
Oblique perspective view of Tempe Terra, from southwest to northeast



Realistic perspective views of the Martian surface can be generated from data acquired by the stereo and colour channels of the High Resolution Stereo Camera (HRSC) on ESA's Mars Express spacecraft, which are oriented at an angle with respect to the planet's surface. This image shows a view of the northern edge of Tempe Terra looking in the direction of the northern lowlands, which are visible in the background. Valleys up to a thousand metres deep have been dug into the Martian highlands by retrogressive erosion, leaving behind mesa-like promontories. In the centre of the image is an impact crater some 12 kilometres across with a striking ejecta blanket, intersected by a tectonic rift, or stress-induced fracture in the Martian crust. In the foreground, an irregular terrain edge – a 'wrinkle ridge', pushed upwards by compressive tectonic forces buckling the crust – can be seen. Copyright note: As a joint undertaking by DLR, ESA and FU Berlin, the Mars Express HRSC images are published under a Creative Commons licence since December 2014: ESA/DLR/FU Berlin, CC BY-SA 3.0 IGO. This licence will also apply to all HRSC images released to date.

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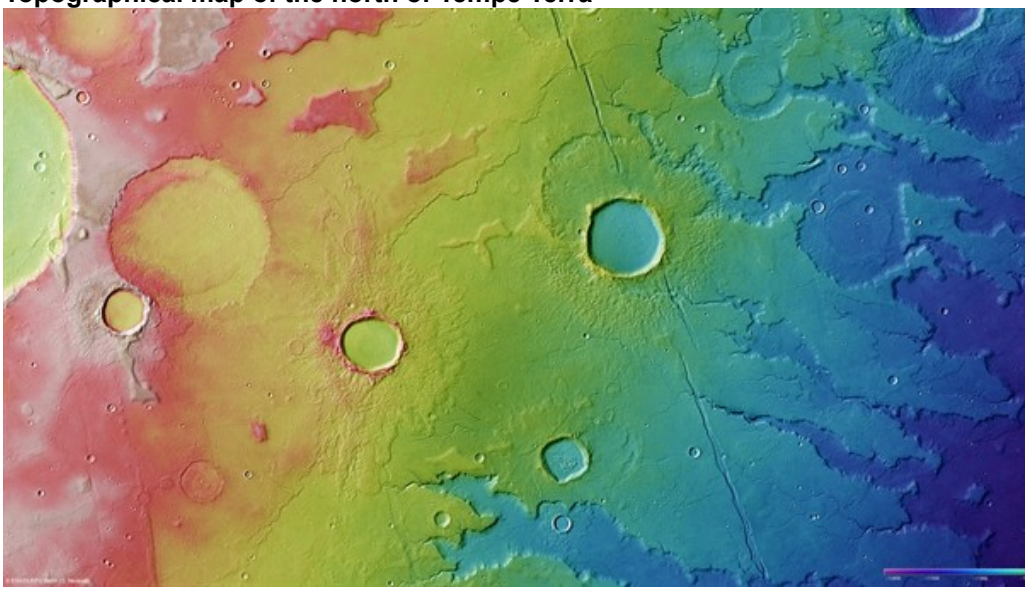
Topographical map of the north of Tempe Terra



Digital terrain models that illustrate the topography of the region using false colours can be derived using the HRSC stereo camera. The altitude can be read from the colour scale at the bottom right; north is to the right in the image. In the absence of ‘sea level’, the elevation data is referenced to an areoid - a modelled equipotential surface on which everything experiences the same gravitational attraction towards the centre of the planet. The colours make the transition from the highlands of Mars (pink, red, yellow and green) to the lowlands (blue) clearly visible. Individual promontories up to a thousand metres high that have not yet been worn away by erosion can be easily recognised, stretching into the northern plains, as well as mesas in the highlands that in turn rise up to around a thousand metres above the transition zone. Copyright note: As a joint undertaking by DLR, ESA and FU Berlin, the Mars Express HRSC images are published under a Creative Commons licence since December 2014: ESA/DLR/FU Berlin, CC BY-SA 3.0 IGO. This licence will also apply to all HRSC images released to date.

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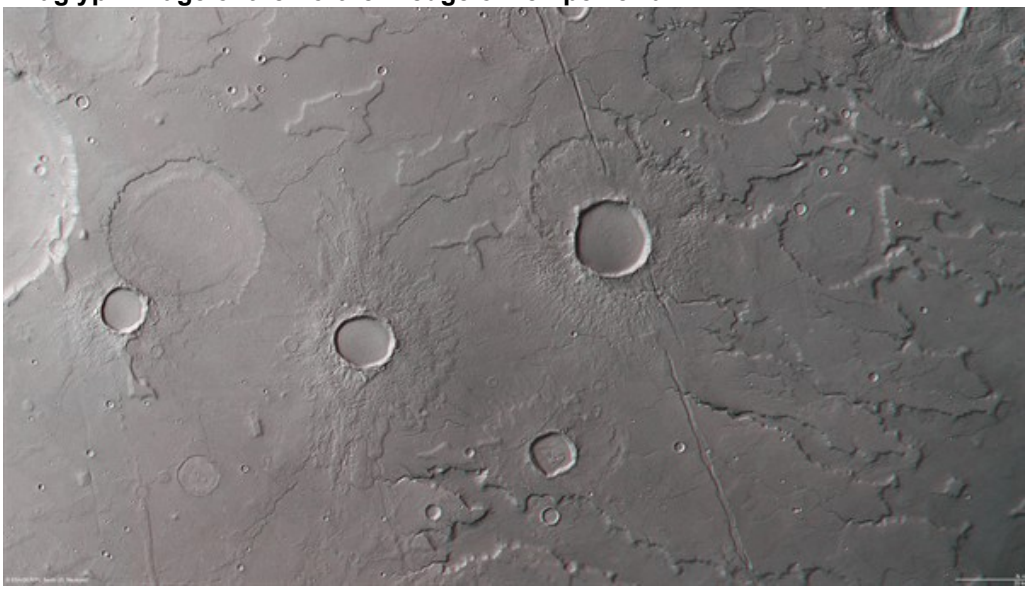
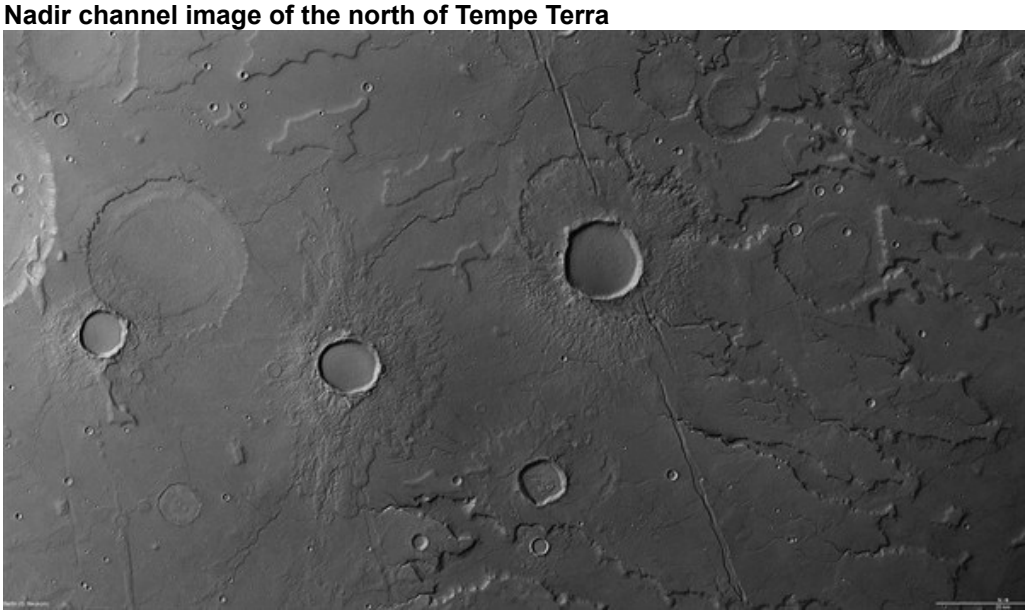
Anaglyph image of the northern edge of Tempe Terra



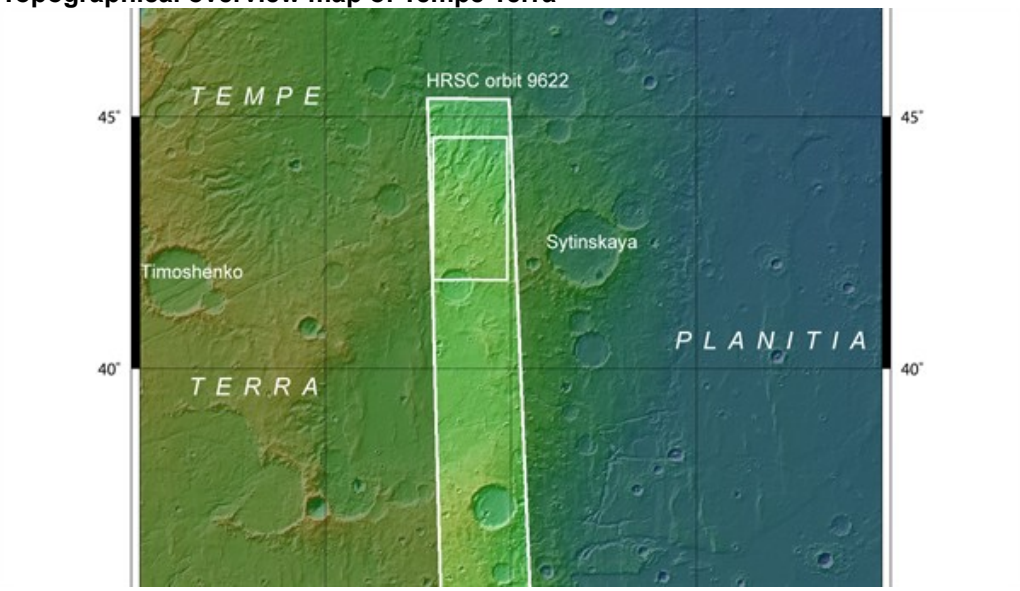
Anaglyph images can be created using data from the nadir channel of the High Resolution Stereo Camera (HRSC) camera system, the field of view of which is which is directed vertically down onto the Martian surface, and one of the four stereo channels, which are directed obliquely towards the surface. By using red/blue (cyan) or red/green glasses, a three-dimensional impression of the landscape is obtained; north is to the right in the image. On inspecting the northern edge of Tempe Terra in 3D, it becomes apparent that the area continually falls away from the south (left in the image) towards the northern lowlands. Small dendritic valleys indicate that flowing water must have played a role in the shaping of the landscape. A number of mesa-like promontories rise up to a thousand metres out of the plains. The circular rims of numerous impact craters and isolated mesas with irregular contours stand out strikingly in the south of the scene.

Nadir channel image of the north of Tempe Terra



The nadir channel, which points vertically down towards the planet’s surface, enabled HRSC image data to be captured with a resolution of 18 metres per pixel as Mars Express flew over the northeast of Tempe Terra during orbit 9622. These enable small-scale geological structures to be identified; north is to the right in the image. The image detail shown covers an area of over 14,000 square kilometres, equivalent to an area roughly the size of The Bahamas. Tempe Terra is one of the most geologically interesting areas on Mars, because in this transition zone between the highlands and northern lowlands both tectonic forces and water and ice have made a wide range of changes to the landscape.

Topographical overview map of Tempe Terra



Tempe Terra is located at the northeastern edge of the Tharsis volcanic region and forms the transition zone between the southern highlands and the northern lowlands. This area is characterised by a large variety of tectonic structures and is one of the most geologically diverse on Mars. The High Resolution Stereo Camera (HRSC) on board ESA's Mars Express spacecraft acquired an image strip of the northwest of Tempe Terra on 17 July 2011 during orbit 9622. The terrain shown in the images presented here is located in the small rectangular area near the north (top) of the image strip.

Credit: NASA/JPL (MOLA/FU Berlin).
