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Mars Express - Pit chains on the Tharsis volcanic bulge

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In the Tharsis volcanic region, almost the size of Europe, the Martian highlands have arched up into a shield several thousand metres in height as a consequence of volcanic processes. Quite a few unusual topographic features can be observed there. Over the past year, 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, has acquired images of a series of linear fractures alongside chains of craters with depths of up to 1500 metres. Mars researchers remain divided about the origin of these crater chains.

These geological formations, referred to as 'pit crater chains', are visible in several places of the Martian highlands. Although such strings of separate, circular pit craters have constantly been forming along faults or cracks in the brittle Martian crust, the processes leading to their formation might be of completely different natures. These chains frequently occur on the flanks of shallow shield volcanoes, the bases of which have a very large diameter. When a lava flow cools and solidifies on its surface, its interior remains liquid and continues to flow as if inside a pipe, creating a subterranean cavity. Once the volcanic activity ceases, a tunnel or drained lava tube can be left behind underground. Over time, separate sections along the rocky roof of the tube collapse, leaving circular depressions on the surface. Such lava tunnels exist on Earth as well; in Hawaii, for example.

Their formation could also involve purely mechanical processes unrelated to volcanism; as the Martian crust is stretched apart, linear extension fractures are formed, giving rise to circular depressions along their course, where the surface material has 'sagged' downwards. Evidence that the Martian crust has been stretched in this region is provided by the linear faults – isolated blocks of terrain have collapsed into gaps created by the crustal extension, forming the now striking 'terraces'. The presence of extensional tectonics is also expressed in the name Tractus Catena (Latin for 'drawn-out chain').

A third possibility is the effect of groundwater; a similar phenomenon can be observed in karst regions on Earth – for example the sinkholes, called 'dolines', in the Swabian Jura, in south west Germany. The carbonic acid in the groundwater has dissolved the limestone, forming subterranean caverns. Over time, sizeable cavities form, and their ceilings cave in under their own weight. Although there is no limestone on Mars, other solution processes could lead to the formation of similar cavities; here, as with lava tubes, parts of the tunnel ceiling ultimately collapse, generating a row of sinkholes.

Subsurface cavities are a major theme of Martian exploration

The existence of water, and its relationship with subsurface cavities, is of great interest – particularly in the search for microbial life on Mars as well as for manned space travel and the colonisation of our planetary neighbour in the distant future. These caves could provide protection from radiation. Microorganisms could survive in such caverns, as they would be protected from the inhospitable conditions at the Martian surface, where the very thin atmosphere is not capable of providing protection against UV and other harmful cosmic radiation.

Image processing and the HRSC experiment on Mars Express

These HRSC images were acquired on 22 June 2011 during Mars Express' orbit 9538, from an altitude of a little over 400 kilometres. The image resolution is about 20 metres per pixel. The images show a section at 23 degrees north and 257 degrees east.

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 image 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 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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Colour overhead view of Tractus Catena

This colour view has been created using the nadir channel, which is directed vertically down onto the Martian surface, and the HRSC camera system colour channels on ESA's Mars Express spacecraft; north is to the right in the image. The image section shown covers an area of almost 20,000 square kilometres, roughly twice the size of Crete. Besides the monotone ochre typical of Mars, separate, small dark areas can be made out, especially in the vicinity of natural obstacles, such as the prominent fault structures or on the rims of impact craters. These are dune fields made of dark dust and sand, presumably of volcanic origin, transported here over a great distance by the wind. 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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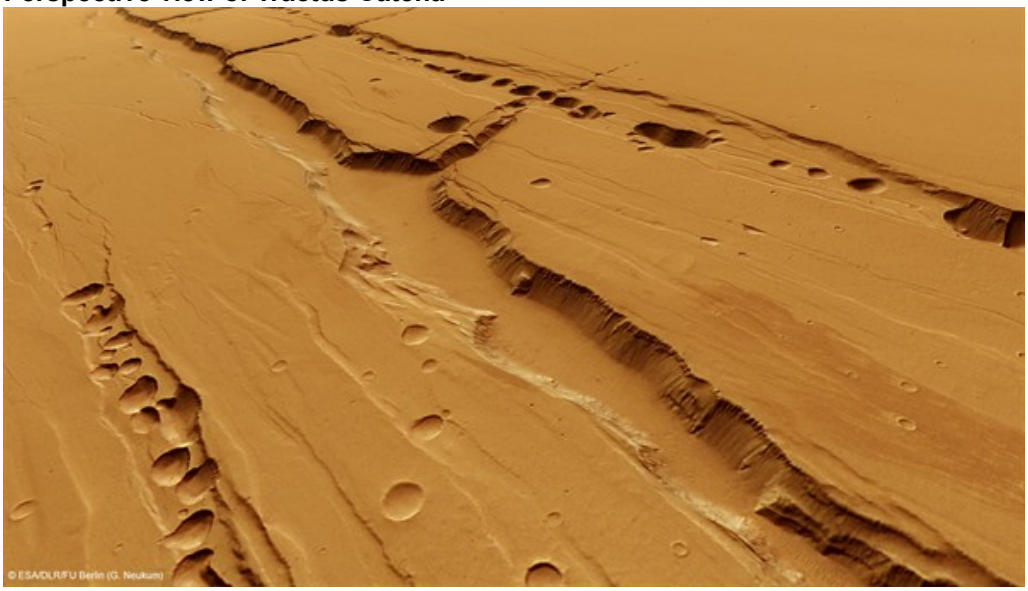
Perspective view of Tractus Catena



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. In this image, the view runs from the northeast, over the fractures of Tractus Catena, to the northern section of the Tharsis Bulge. Multiple chains of crater-like depressions up to 1500 metres deep that have formed along the major fault lines are clearly visible. The origin of these pit crater chains, which are mostly observed along stress fractures, is still unclear. Volcanic processes may be one cause, but the role of water in underground cavities might also be a factor. 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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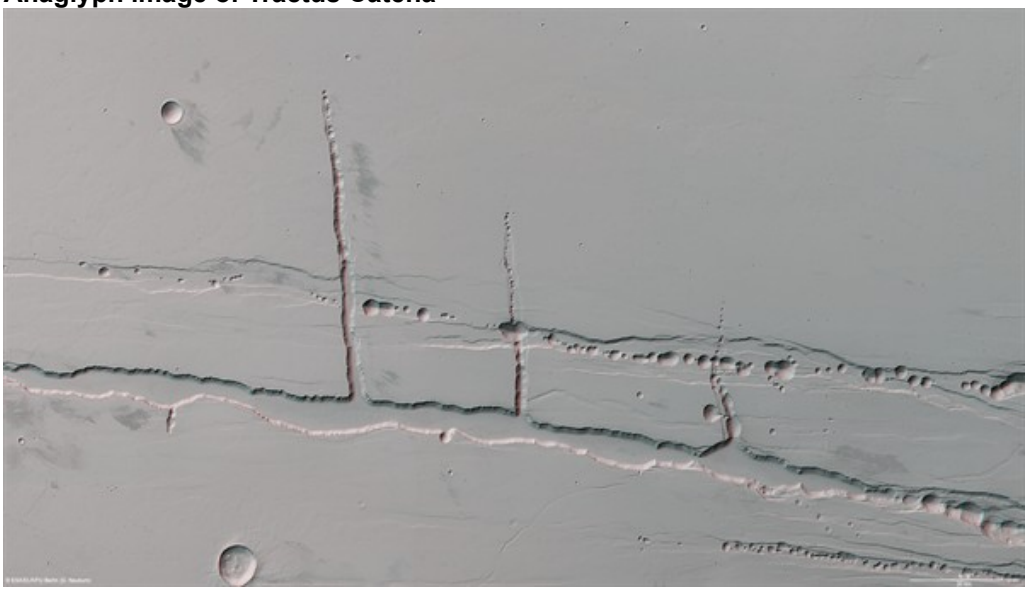
Anaglyph image of Tractus Catena



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 can be obtained; north is to the right in the image. 3D glasses make it easy to see how the craters abruptly plunge into the depths with no evident rim – substantially different from impact craters. Because of the linear fractures, isolated dune fields can be seen. The flatness of the Tharsis highlands makes other faults running from west to east and the two grabens oriented from north to south strikingly clear. 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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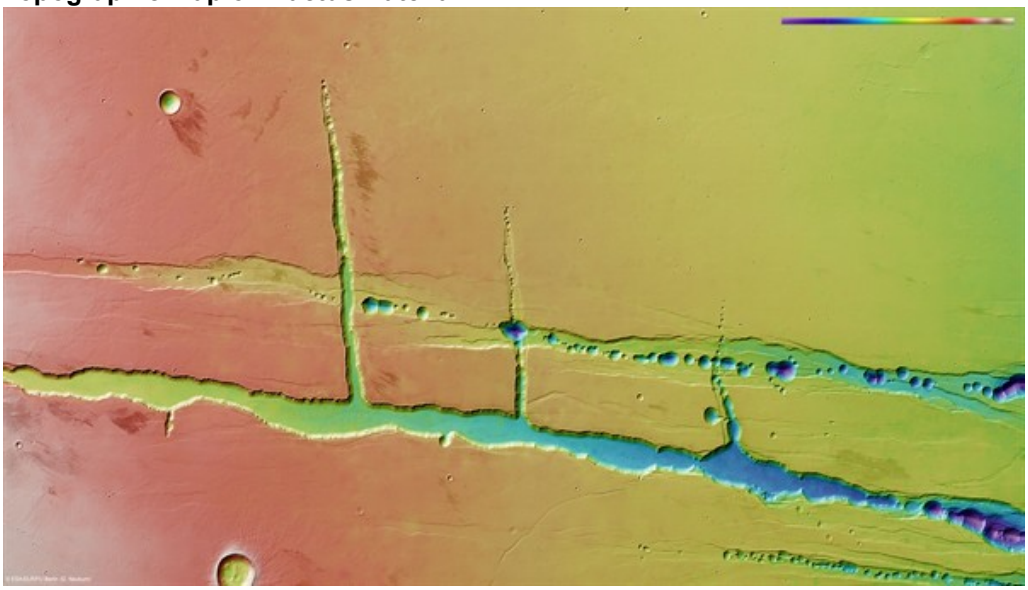
Topographic map of Tractus Catena



Using the HRSC stereo camera, digital terrain models can be derived that illustrate the topography of the region using false colours. The elevation can be read from a colour scale at the upper 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 Tharsis plateau slopes gently towards the north, which is from left to right in the image. The two main faults, stress fractures running linearly from south to north, have a rather similar negative south-north gradient. Numerous, round, crater-like depressions, aligned like a string of pearls and between

1000 and 1500 metres deep, are visible in the northern part of the faults. The origin of these pit crater chains is not yet fully understood. 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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HRSC nadir image of Tractus Catena

The nadir channel, which is directed vertically down onto the surface, has the highest resolution of the HRSC camera system. In this case, as Mars Express flew over the northern Tharsis highlands at an altitude of slightly over 400 kilometres, the resulting resolution is 20 metres per pixel. This enables small-scale geological structures to be identified; north is to the right in the image. The image section shown covers an area of roughly 190 by 100 kilometres. Numerous, circular crater-like depressions aligned with one another resembling a string of pearls – a pit crater chain – are visible along two main fault lines parallel to one another. The high image resolution enables the structures on the rims of the stress fractures and the separate pits to be made out very easily. Various geological processes are being discussed as the origin of the pit crater chains. 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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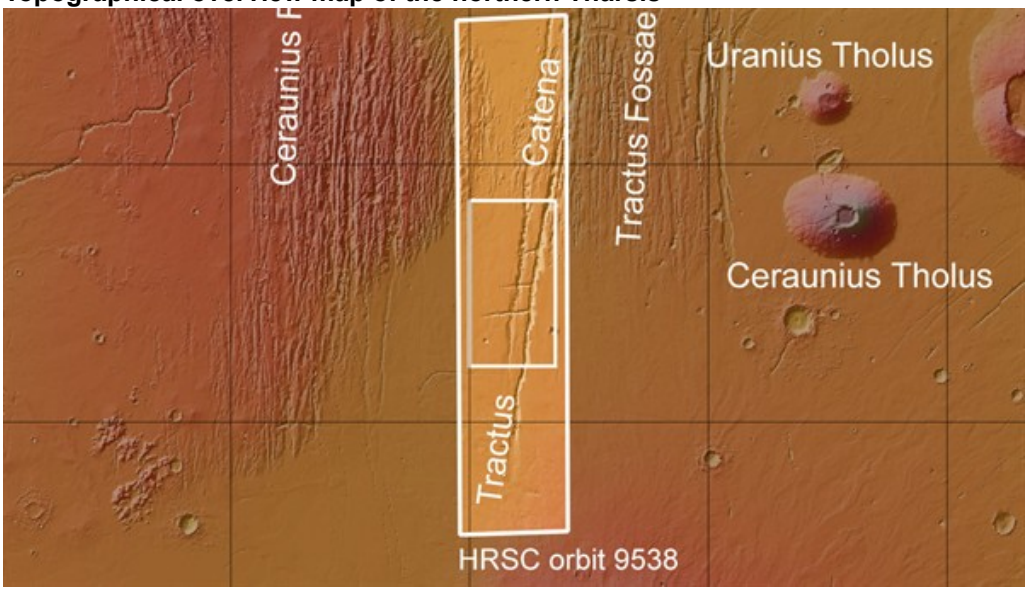
Topographical overview map of the northern Tharsis



The Tharsis region, about the size of Europe, is one of the most striking volcanic regions on Mars. Here, the Martian crust here has been pushed up several thousand metres above the surrounding highlands. Some of the largest volcanoes on the planet, such as the almost 20,000-metre high Ascraeus Mons, are prominent peaks. In the vicinity of these gently sloping shield volcanoes, numerous structures that have been formed by stresses in the Martian crust can be seen; these take the form of surface collapses resulting from stress fractures. ESA's Mars Express spacecraft acquired images of the region north of Ascraeus Mons on 22 June 2011 using the HRSC camera system from an altitude of slightly over 400 kilometres; linear stress fractures are visible in the images. An unusual alignment of pit chains – the Tractus Catena pit crater chain – can be seen along the fractures. The images selected for publication here show the smaller, inner rectangle.

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

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