Landslides and lava flows on Olympus Mons

17 May 2013

On 23 January 2013 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, imaged the Sulci Gordii region. Sulci Gordii is located around 200 kilometres east of Olympus Mons, the highest volcano in the Solar System, and its impressive landscape was formed by enormous landslides, lava flows and tectonic forces associated with the volcanic activity of Olympus Mons. The section of Sulci Gordii shown in the main image (image 1) is about 150 kilometres by 80 kilometres.

Broken ring around the giant volcano

Sulci Gordii is an 'aureole' deposit – Latin for 'circle of light' – and is one of a number of such features that form a broken ring around the giant volcano, as hinted at in the context map (image 2). The aureoles tell the story of the catastrophic collapse of the lower flanks of Olympus Mons in its distant past. Today, it stands with steep cliff edges that rise two kilometres above the surrounding plains.

The collapse of the lower slopes was caused by a weakening of the rocky substratum beneath the volcano, probably due to the ingress of subsurface water. During the collapse, rocky debris slid down and out across hundreds of kilometres of the surrounding volcanic plains, giving rise to the rough surface of the aureole seen today. Similar debris flows are also seen on Earth, surrounding some volcanoes, including Mauna Loa in Hawaii, which, like Olympus Mons, is a smooth-sided 'shield' volcano built up from successive lava flows.

Traces of ancient lava flows

The smooth plains surrounding Sulci Gordii suggest that the massive landslide triggered by the collapse of the volcano's flanks was later partially buried by lava flows. Indeed, faint outlines of ancient lava flows can be seen by zooming into the upper centre-left portion of the main image (image 1). The characteristic corrugated appearance of the 'sulci' – a geological term used to describe roughly parallel hills and valleys on Mars – likely resulted during the landslide as material slid away from the volcano and became compressed or pulled apart as it travelled across the surface. Over time, erosion of weaker material between the peaks accentuated this effect.

The wavelike corrugations are best seen in the close-up perspective views (images 3, 4 and 5). A close up of these images reveals that the hills and ridges are also covered by fine wind-blown dust, and that many small-scale landslides occurred on the sides of the valleys between them. Similarly, subtle ripples in the Martian dust blanket can be seen on close inspection of the smooth plains. Here, thin undulating dunes have been shaped by the wind.

Numerous sinuous channels and jagged fracture networks also crisscross the scene, in particular at the southern (left) end of the main image (image 1) and in close-up in the perspective view (image 3). The channels range in length from around 50 kilometres to 300 kilometres and were probably formed by short-lived volcanic activity or tectonic tensile stresses, and possibly later widened by water. On the left side of the perspective view (image 3) is an impressive sight – a sinuous channel that is suddenly truncated by a tectonic fault. Another channel running across the centre foreground clearly has a complex fracturing history.

Tectonic forces have torn apart the Martian crust in rougher terrain that continues towards the north (top centre-right of the main image). The most obvious sign of this is the roughly 500 by

1000 metre, wedge-shaped block of terrain visible in the northeast of the colour-coded topographic map (image 7).

The scenery at Sulci Gordii reveals that, as on Earth, Mars has experienced dramatic volcano collapses where massive amounts of material are transported over hundreds of kilometres and subsequently shaped by the forces of wind, water and tectonics.

Image processing and the HRSC experiment on the Mars Express mission

The images were acquired by the HRSC on 23 January 2013 during Mars Express Orbit 11,531 at approximately 17 degrees north and 234 degrees east. The image resolution is about 31 metres per pixel. The colour image (image 1) was acquired using the nadir channel, which is directed vertically down onto the surface of Mars, and the colour channels of the HRSC; the perspective oblique views (images 3, 4 and 5) were computed from data acquired by the HRSC stereo channels. The anaglyph image (image 6), 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 aerial view, encoded in false colours (image 7), 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 board 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 10 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. The systematic processing of the HRSC image data is carried out at DLR. The images shown here were created by the Institute of Geological Sciences at Freie Universität Berlin in cooperation with the DLR Institute of Planetary Research, Berlin.

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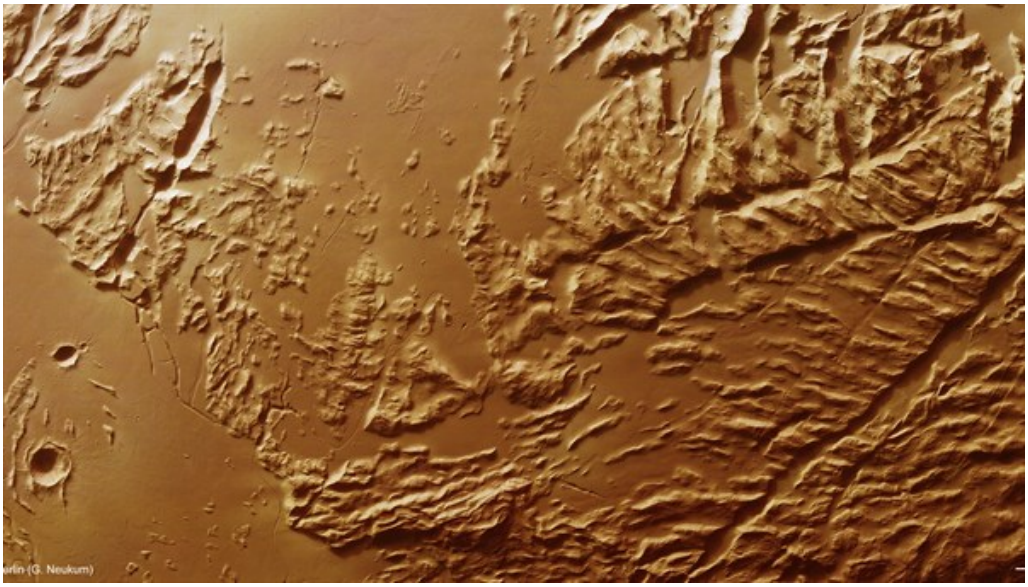
Sulci Gordii



This colour plan view of the Sulci Gordii region of Mars was created using data from the nadir channel, which is directed vertically down onto the planet's surface, and the colour channels of the High Resolution Stereo Camera. The image data was acquired on 23 January 2013 (orbit 11531), with a ground resolution of about 31 meters per pixel. Sulci Gordii lies at approximately 17 degrees north and 234 degrees east, about 200 kilometres east of Olympus Mons. The feature is an 'aureole' deposit resulting from a massive landslide that sloughed away from the flanks of Olympus Mons in its distant past. This complex scene is dominated by a series of roughly parallel ridges and valleys (called sulci), with lava or water-carved channels in the northernmost (left) portion of the image. Smooth, younger volcanic lava flows overlay parts of the sulci. 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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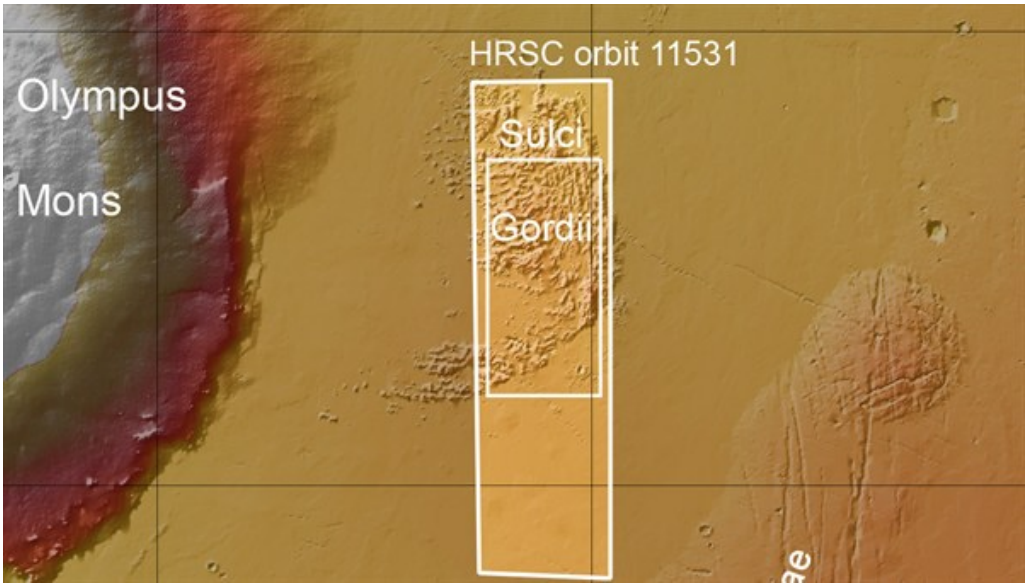
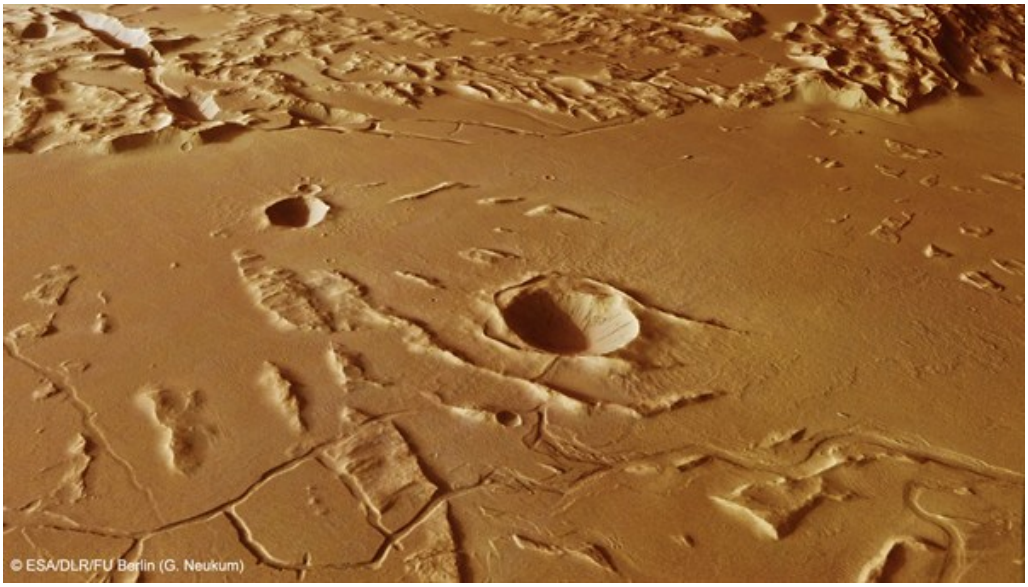
Sulci Gordii in context



Sulci Gordii was imaged by the High Resolution Stereo Camera on ESA's Mars Express on 23 January 2013 (orbit 11,531). Sulci Gordii lies at approximately 17 degrees north and 234 degrees east, about 200 kilometres east of Olympus Mons. Sulci Gordii is one of a number of similar features that form a broken ring around the volcano; they were formed during giant collapse and landslide events on the flanks of Olympus Mons. The other images presented here show the area contained within the inner box.

Credit: NASA/MGS/MOLA Science Team.

Channels and fractures in Sulci Gordii



Realistic perspective views of the surface of Mars 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 oblique angle with respect to the planet's surface. This image focuses on the southernmost portion of Sulci Gordii, which highlights jagged fractures and fault lines, as well as some sinuous channels that were likely created by short-lived volcanic activity and subsequently widened by water flows. In the foreground to the left, a channel that is abruptly truncated by a tectonic fault can be seen. Another channel in the centre foreground has also clearly undergone a complex fracturing history. To the upper right, a few rocky blocks appear like islands in a sea of ancient lava plains; the 'shoreline' at the top of the image is part of the ridge and valley system of Sulci Gordii. The image was created from data acquired by the High Resolution Stereo Camera (HRSC) on ESA's Mars Express spacecraft on 23 January 2013 (orbit 11,531), with a ground resolution of about 31 metres per pixel. Sulci Gordii lies at approximately 17 degrees north and 234 degrees east, about 200 kilometres east of Olympus Mons. 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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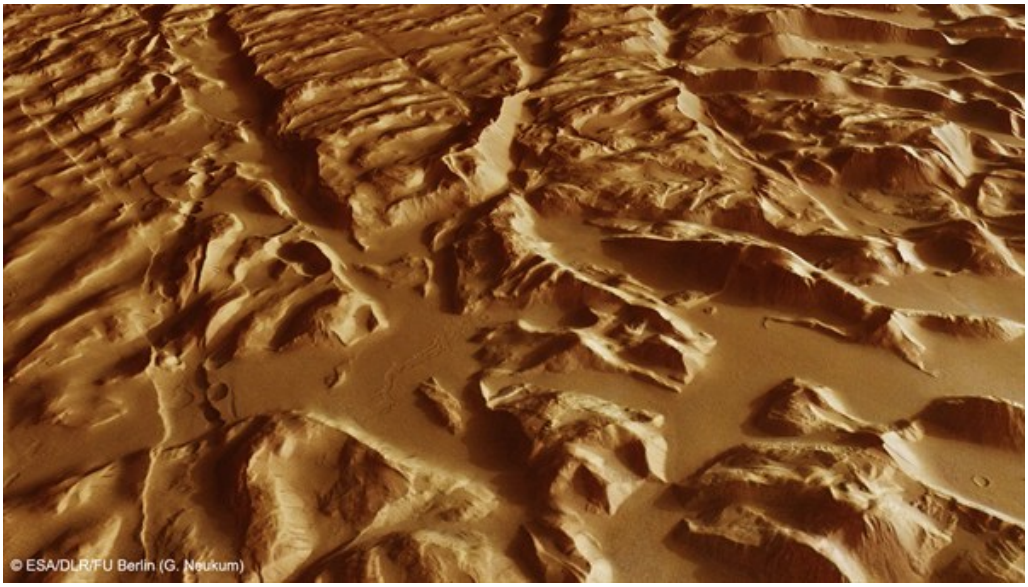
Inside Sulci Gordii



Realistic perspective views of the surface of Mars 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 oblique angle with respect to the planet's surface. This image offers a 'close-up' of the 'sulci' features that define Sulci Gordii. Sulci are roughly parallel sets of ridges and valleys likely formed through tectonic and erosion processes. A prominent fault line extends along the left side of the image, while smooth lava plains overlay parts of the sulci. Sulci Gordii is an aureole deposit resulting from the dramatic collapse of the flanks of Olympus Mons in its distant past. The image was created from data acquired by the High Resolution Stereo Camera (HRSC) on ESA's Mars Express spacecraft on 23 January 2013 (orbit 11,531), with a ground resolution of about 31 metres per pixel. Sulci Gordii lies at approximately 17 degrees north and 234 degrees east, about 200 kilometres east of Olympus Mons. 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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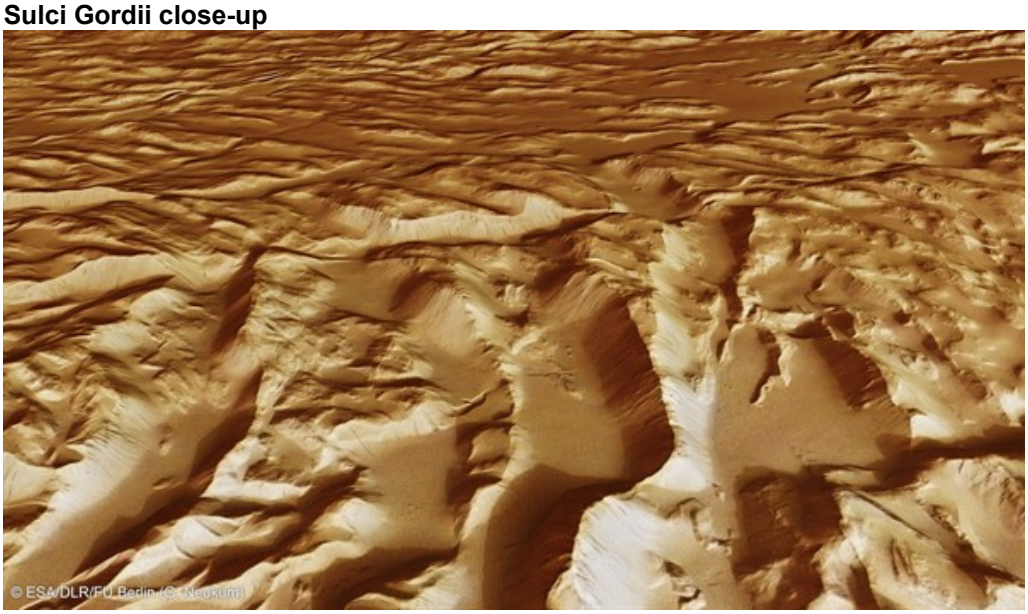
Sulci Gordii close-up



Realistic perspective views of the surface of Mars 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 oblique angle with respect to the planet's surface. This image focuses on a region on the western limb of Sulci Gordii (top centre-right on the colour plan view). Clearly in the foreground we can see the near-parallel characteristic of the ridges and valleys that define geological features called sulci. Close inspection of the ridges reveals dark streaks along their faces, evidence of numerous small landslides of rocky and dusty debris. Sulci Gordii is an aureole deposit resulting from the dramatic collapse of the flanks of Olympus Mons in its distant past. The image was created from data acquired by the High Resolution Stereo Camera (HRSC) on ESA's Mars Express spacecraft on 23 January 2013 (orbit 11,531), with a ground resolution of about 31 metres per pixel. Sulci Gordii lies at approximately 17 degrees north and 234 degrees east, about 200 kilometres east of Olympus Mons. 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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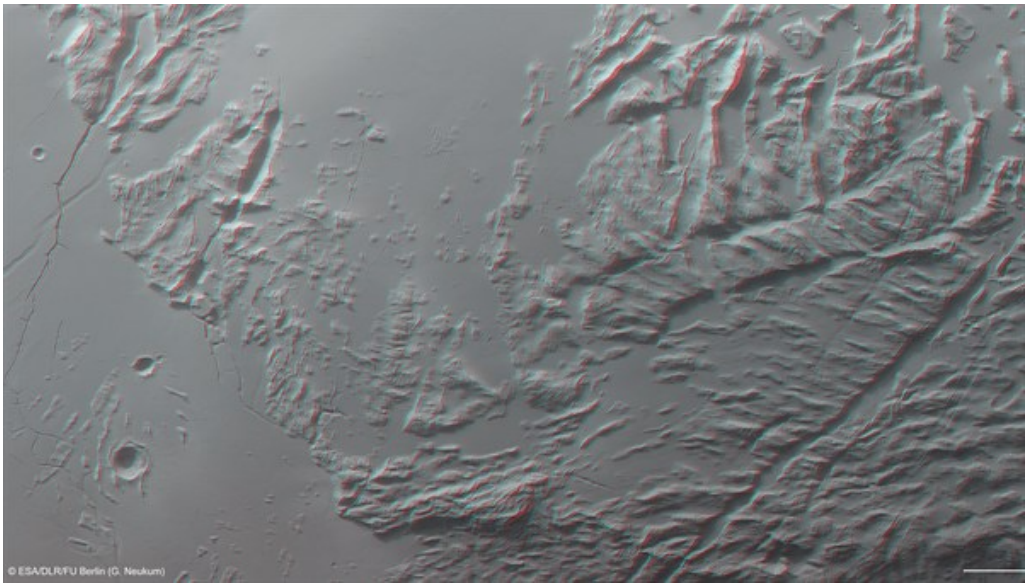
Sulci Gordii in 3D



Data from the nadir channel and one stereo channel of the High Resolution Stereo Camera on ESA's Mars Express have been combined to produce this anaglyph 3D image of Sulci Gordii that can be viewed using stereoscopic glasses with red–green or red–blue filters. Sulci Gordii is an aureole deposit resulting from the dramatic collapse of the flanks of Olympus Mons in its distant past. The image was created from data acquired on 23 January 2013 (orbit 11,531), with a ground resolution of about 31 metres per pixel. Sulci Gordii lies at approximately 17 degrees north and 234 degrees east, about 200 kilometres east of Olympus Mons. 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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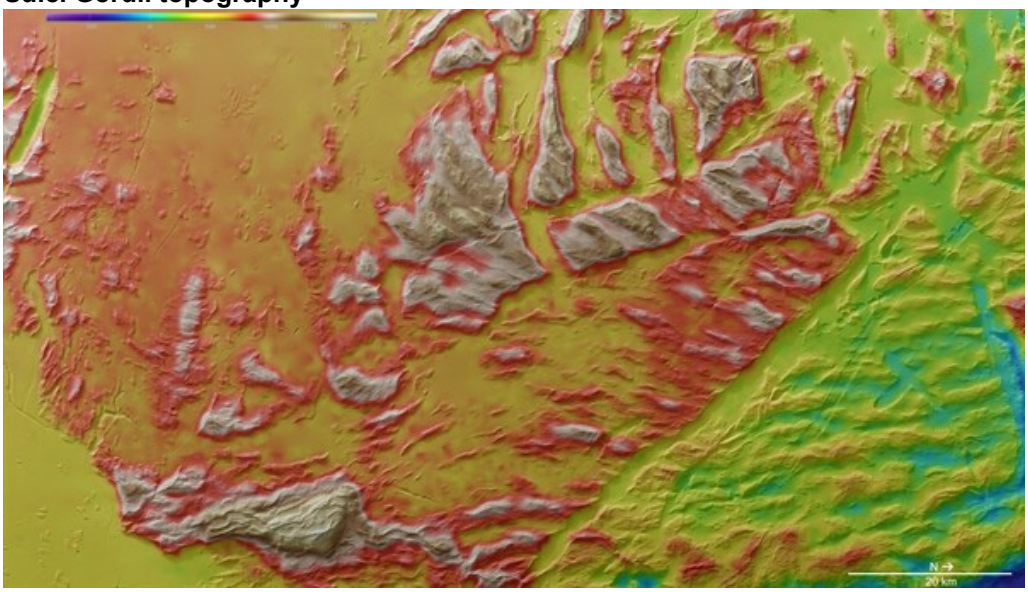
Sulci Gordii topography



Using the HRSC stereo camera, digital terrain models can be derived that illustrate the topography of the region using false colours. The altitude allocation can be read from a colour scale at top; 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. This image shows the Sulci Gordii region of Mars, which lies about 200 kilometres east of Olympus Mons. Sulci Gordii was imaged on 23 January 2013 (orbit 11,531), with a ground resolution of approximately 31 metres per pixel. 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/
