Explosive 'twin' craters on Mars

11 April 2013

Intense underground steam explosions that occurred during the crater formation process could be responsible for the central depressions present in these 'twin' craters, located on Thaumasia Planum, an elevated plateau that lies immediately to the south of Valles Marineris, the largest canyon in the Solar System. The images presented here were acquired by 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 on 4 January 2013.

The northernmost (right) of the large craters in images 1, 4 and 5 was named Arima, after a town on the island of Trinidad, in 2012; the southernmost (left) crater is unnamed. Both are just over 50 kilometres across and exhibit complex interior features. The southernmost crater is also presented as a perspective view, revealing its interior characteristics in more detail. Several staggered terraces can be seen between the upper edge of the crater wall, which is over 2000 metres high, and the flat floor. This terracing is frequently observed in craters of this size; after the asteroid impact, the ejecta forming the crater rim, which may be several kilometres high, are unstable and sink along lines of weakness within the crater that are parallel to and concentric with the crater wall.

Formation of central depressions

When a large asteroid strikes the surface of a planet, much of its kinetic energy is transformed into thermal energy. Water or ice trapped below the surface is rapidly heated; this can lead to violent steam explosions that create a hole in the centre of the crater, where most of the impact energy is concentrated. As a result, the rocky surface is weakened and collapses into the resulting cavity, or may even be blasted away entirely, leaving a hole surrounded by rocky debris in its place.

Although these two craters are similar in diameter, their central depressions differ in size and depth; this is most clearly evident in the false-colour topographic map (image 5). Perhaps more energy was delivered during the formation of the crater on the left, so that the subsurface ice was quickly evaporated, or more ice was present and caused an explosion of increased violence.

Small crater ejecta blankets also reveal influence of water

Many neighbouring smaller impact craters also reveal the presence of subsurface water or ice at the time of impact, as evidenced by their lobate rampart ejecta blankets. These debris deposits, which were excavated from the crater during its formation, have petal-like lobes around their edges. This feature results from the presence of liquid water in the ejected material, which allowed it to flow along the surface, thus giving the ejecta blanket the appearance of having flowed.

Impact craters like these offer windows into the past, in this case providing evidence for the Thaumasia Planum region having once hosted plentiful subsurface water or ice that was liberated during both small and large impact events.

Image processing and the HRSC experiment on the Mars Express mission

The images were acquired by the HRSC during Mars Express Orbit 11,467 on 4 January 2013. The image resolution is about 25 metres per pixel. The colour image (1/5) was captured using the nadir channel, which is directed vertically down onto the surface of Mars, and the colour channels of the HRSC; the perspective oblique view (2/5) was computed from data acquired by the HRSC stereo channels. The anaglyph image (4/5), 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 (5/5), 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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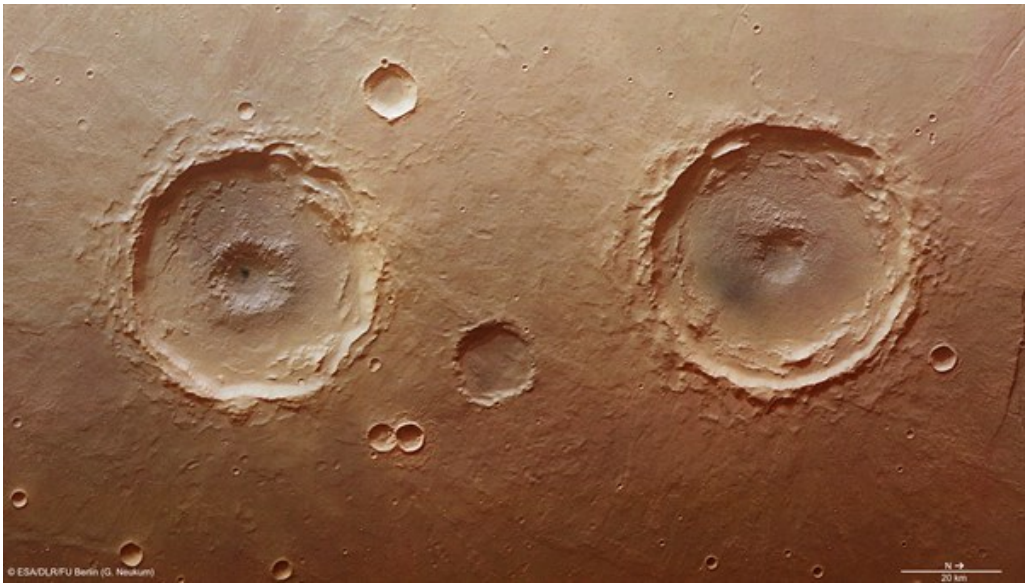
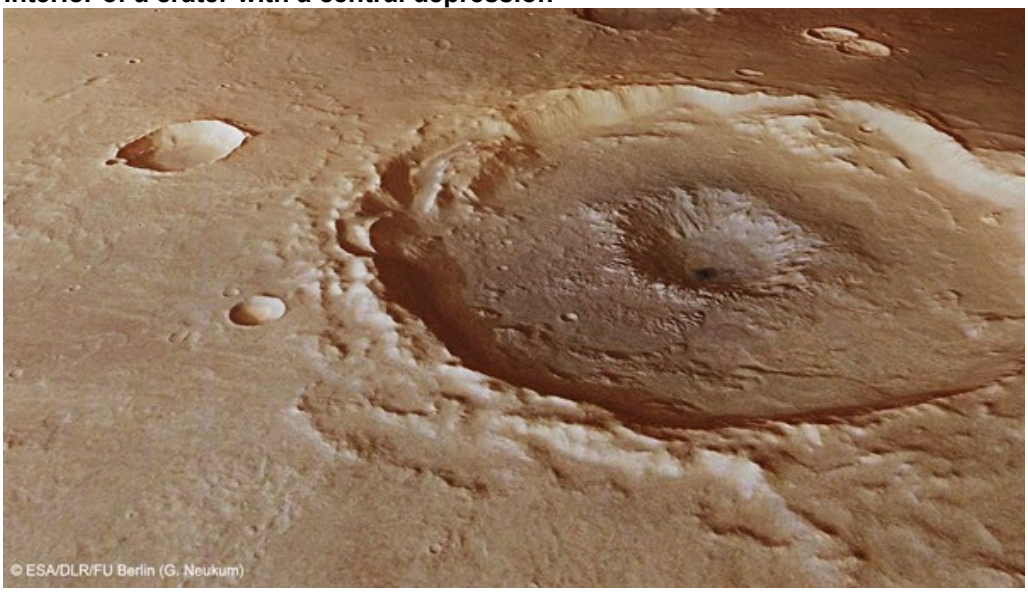
Arima Crater and its 'twin'



This colour plan view was created using data from the nadir channel, which is directed vertically down onto the Martian surface, and the colour channels of the High Resolution Stereo Camera (HRSC) on board ESA's Mars Express spacecraft. The data was acquired at approximately 17 degrees south and 296 degrees east during orbit 11,467 on 4 January 2013. The image shows two 50-kilometre craters located on Thaumasia Planum, just south of Valles Marineris. North is to the right of the image; the ground resolution is approximately 25 metres per pixel. The northern crater is named Arima, while the southern crater is unnamed. Both craters exhibit central depressions thought to have been caused by underground steam explosions during the impact events that formed them.

Credit: ESA/DLR/FU Berlin, CC BY-SA 3.0 IGO.

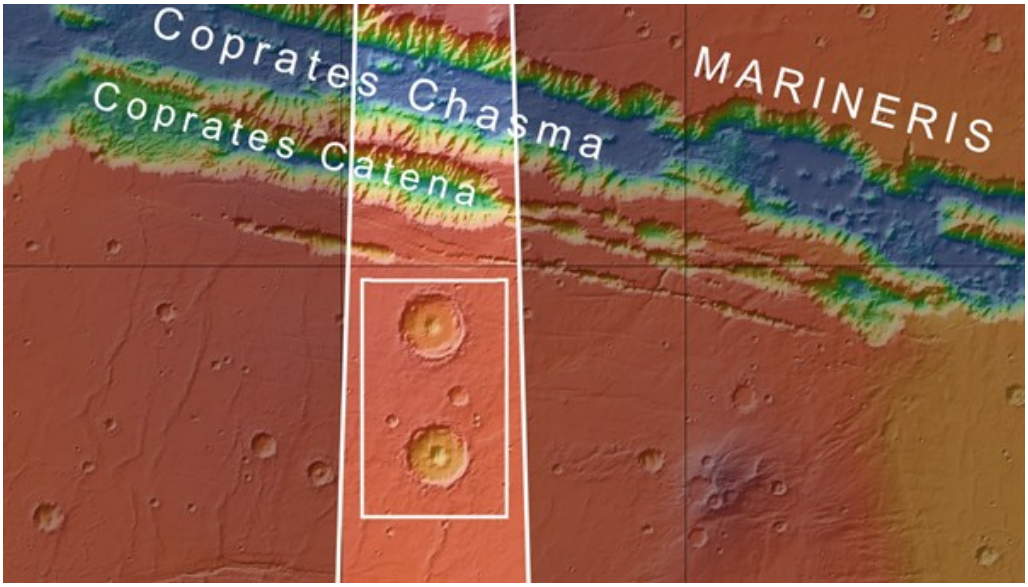
Interior of a crater with a central depression



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 shows a 50-kilometre crater in the Thaumasia Planum region. The image was generated from the HRSC data using digital terrain models. The image data was acquired on 4 January 2013 during orbit 11,467 and the image shows the central depression of this crater, which is thought to have been formed by a subsurface steam explosion as the thermal energy from the causative impact event rapidly vaporised water or ice lying below the surface.

Credit: ESA/DLR/FU Berlin, CC BY-SA 3.0 IGO.

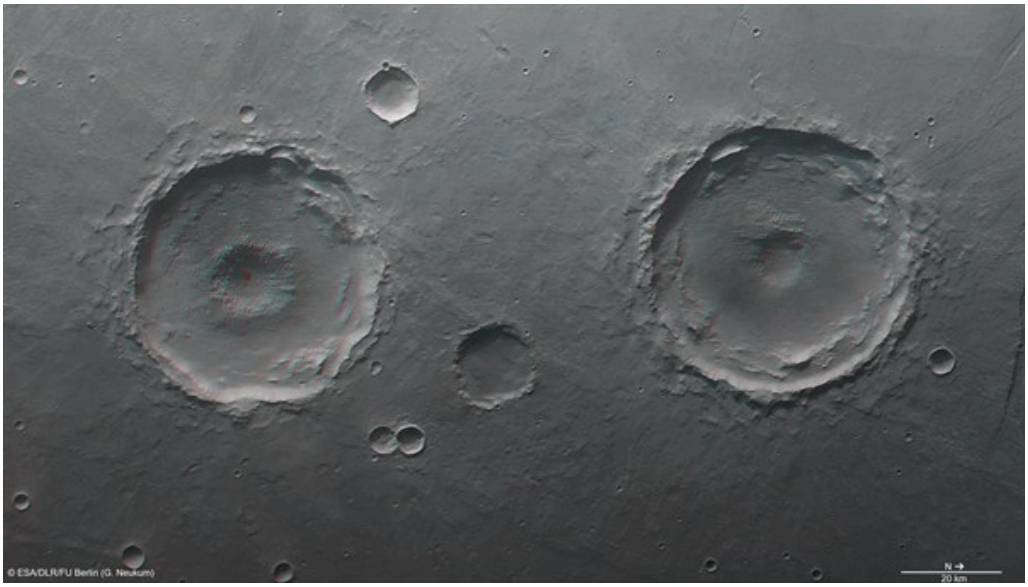
Arima and its 'twin' crater in context



The area imaged by Mars Express on 4 January 2013 during orbit 11,467 lies just south of the Coprates Catena region of Valles Marineris, in Thaumasia Planum. The small inner rectangle shows the region covered in this Mars Express High Resolution Stereo Camera (HRSC) image release highlighting two 50-kilometre craters, the northernmost of which is called Arima (the southernmost is unnamed).

Credit: NASA/MGS/MOLA Science Team.

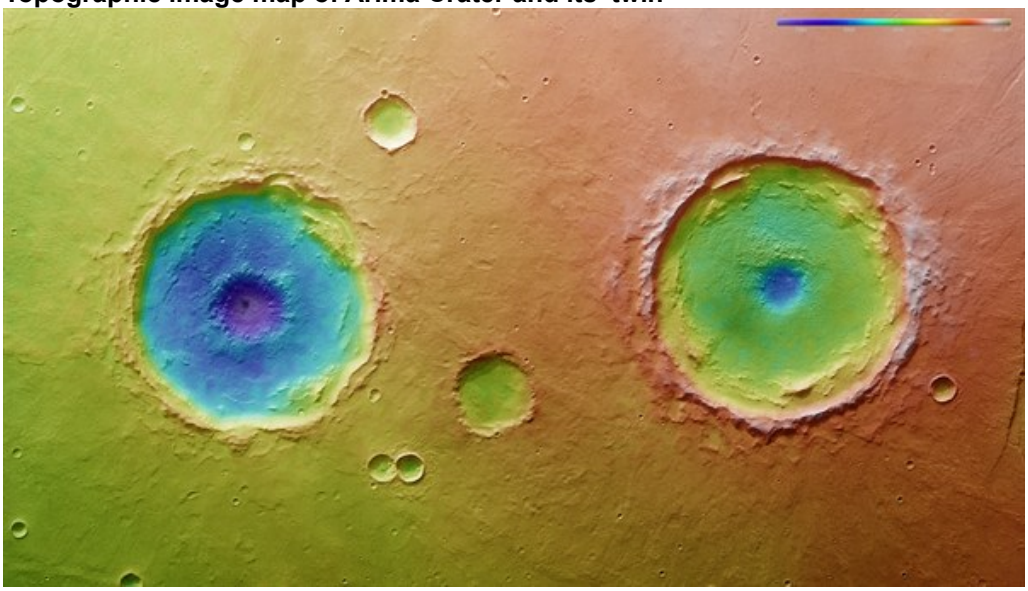
3D view of Arima Crater and its 'twin'



This image shows part of the Thaumasia Planum region imaged during orbit 11,467 on 4 January 2013 by ESA's Mars Express spacecraft using the High Resolution Stereo Camera (HRSC). Data from HRSC's nadir channel and one stereo channel have been combined to produce this anaglyph 3D image that can be viewed using stereoscopic glasses with red–green or red–blue filters. Centred at approximately 17 degrees south and 296 degrees east, the image has a ground resolution of about 25 metres per pixel. The image highlights Arima Crater (right) and its unnamed 'twin' crater to the left – and the central depressions of both craters. 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.

Credit: ESA/DLR/FU Berlin, CC BY-SA 3.0 IGO.

Topographic image map of Arima Crater and its 'twin'



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 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. This image shows part of Thaumasia Planum at approximately 17 degrees south and 296 degrees east. The image data was acquired during orbit 11,467 on 4 January 2013. The colour coding reveals the relative depth of the craters, in particular the depths of their central depressions, with the left-hand crater penetrating deeper into the subsurface than the right.

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