Valles Marineris – the largest canyon in the Solar System

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Mars is clearly much smaller than Earth, but it can still come up with impressive superlatives. Several landscape features have unquestionably enormous dimensions – at over 21 kilometres in height, Olympus Mons is the largest volcano in the Solar System; the Hellas impact basin is more than 2000 kilometres across and eight kilometres deep – but particularly spectacular is the Valles Marineris canyon system. This graben, up to 11 kilometres deep and 200 kilometres wide, stretches almost 4000 kilometres across the Martian highlands in an east-west direction along the equator. The Grand Canyon in the United States (almost two kilometres deep) would easily fit into one of the smaller valleys that run parallel to Valles Marineris.

The image presented shows a bird's-eye view of the central and eastern part of Valles Marineris, or to put it more precisely, from the perspective of ESA's Mars Express spacecraft, which repeatedly crosses the Martian equator from north to south or south to north. The High Resolution Stereo Camera (HRSC) on board Mars Express, which is operated by the German Aerospace Center (Deutsches Zentrum für Luft- und Raumfahrt; DLR), has been taking image strips of the valley system since 2004 as it passes overhead. The individual HRSC image strips are each between 50 and 200 kilometres wide, depending on Mars Express' orbit, so this view of Valles Marineris has only been made possible by creating a mosaic using 20 separate images.

How the image was created

The imaging principle of the HRSC enables digital terrain models to be derived from the camera’s nine separate imaging channels, four of which are stereo channels. This means that the altitude can be determined for each pixel. Perspective views of the surface of Mars can then be computer-generated using these models. To improve the presentation here, the altitudes have been exaggerated fourfold, so that the slopes and mountainsides appear steeper than they are in reality.

The colours in this image are slightly false as well. By increasing the contrast between the individual colour channels, many features of the terrain in this geologically extremely complex region that were not readily apparent can be made much more visible, as can differences in the surface composition.

Gigantic magma plumes breach the Martian crust

The formation of Valles Marineris is very likely associated with the Tharsis Region, which borders the canyon system to the west. Tharsis is a bulge over four kilometres high and several thousand kilometres across. This is where Olympus Mons, the highest volcano on Mars, and the volcanoes Arsia Mons, Pavonis Mons and Ascraeus Mons are located. There are also numerous signs of volcanism in Valles Marineris. Easily identifiable are layers in the kilometre-high slopes that were created by low-viscosity, basaltic lava, which has flowed across Mars on numerous occasions. The elevated regions around Valles Marineris are also made of these basalt layers.

Stresses built up during the formation of the Tharsis Bulge three to four billion years ago as a result of pressure from below, thought to have been caused by huge magma plume(s) that formed at great depths and, as a result of their lower density, rose through the plastic mantle until they reached the Martian crust. This led to stress fractures in the crust, huge sections of which subsequently sank thousands of metres between the walls of the fractured crust. Such

structures occur on Earth as well, albeit on a much smaller scale; the Upper Rhine Valley between Basel and Karlsruhe is one example of such a graben.

The characteristic shapes of fracture breaches have formed on the surface as a consequence of these stresses. The youngest of these stress fractures can be seen in the centre and along the lower edge of the image. The breaching of the crust and associated changes to the profile of the landscape has led to numerous and enormous ruptures and landslides along the edges of the terrain. Traces of these mass movements can be seen along the southern (bottom) and northern (upper centre) borders of Valles Marineris.

Water shaped the canyon as well

Later on, large volumes of water flowed through the valleys with great energy, changing the landscape of Valles Marineris and making the valley floor even deeper. These rivers flowed in an easterly direction, along the arm of the valley in the right half of the image, and poured into a system of outflow channels running northwards, ending in the lowlands in Mars' northern hemisphere.

Images acquired and measurements taken using the OMEGA spectrometer on board Mars Express show that the rocks have been mineralogically altered by the influence of water. There are layers and deposits of sulphates such as gypsum (calcium sulphate) or kieserite (magnesium sulphate) in numerous places in the Valles Marineris. These occur in water on Earth and contain water in their crystal structure (water of crystallisation). But these deposits were formed several hundred million or even billions of years ago; no water flows through Valles Marineris today.

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.

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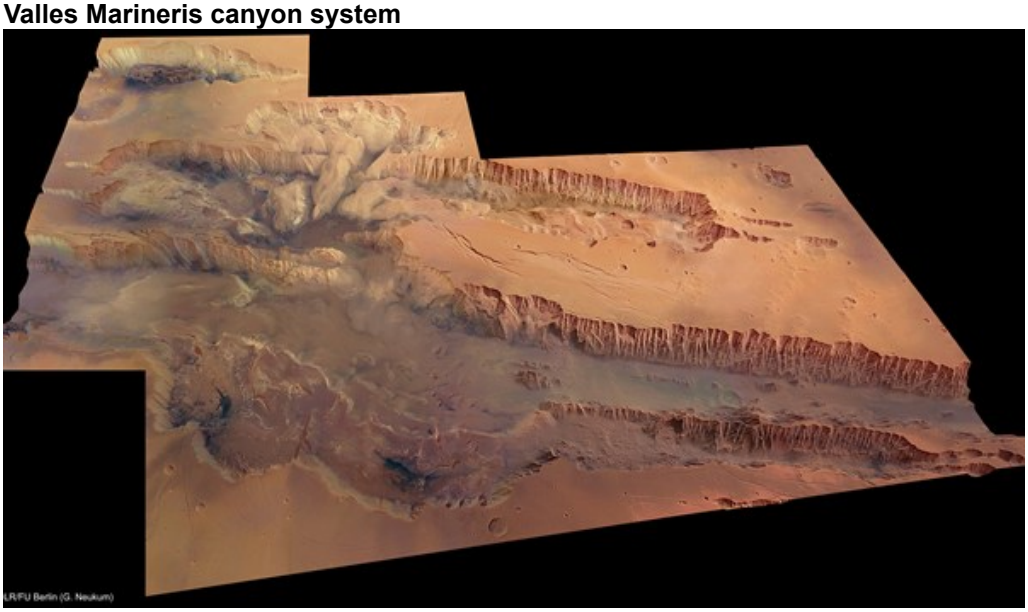
Valles Marineris canyon system



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