Glacial transportation of rubble and boulders through Reull Vallis

17 January 2013

As we look at the numerous graben and valleys that wind through the Martian highlands, it is not always clear which geological processes created them. Some valleys have very similar characteristics to those on Earth carved out by the flow of surface water; others possess a morphology where this is not so obvious. These images, 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, show the upper reaches of the Reull Vallis region, a valley that was, at times, shaped by the flow of glacial ice.

Reull Vallis is an outflow channel stretching over 1500 kilometres across the massifs of Promethei Terra, in the highlands of Mars' southern hemisphere, towards Hellas Planitia, an impact basin that, with a diameter of almost 2300 kilometres, is the largest impact structure on our planetary neighbour. The High Resolution Stereo Camera (HRSC) on Mars Express has been used numerous times to acquire images of Reull Vallis and the surrounding mountains (see images published on 8 December 2004). The images of the upper reaches of Reull Vallis shown here were acquired on 14 May 2012, during orbit 10,657, from an altitude of around 320 kilometres. They show details down to a size of 16 metres. The centre of the image is at 41 degrees south and 107 degrees east. The region shown here is around 15,000 square kilometres in size, and covers an area of 180 by 80 kilometres.

Using stereoscopic HRSC image data, from which digital terrain models can be derived, the topography of the surroundings of Reull Vallis and the profile of the graben-shaped valley can be deduced. Over one 80-kilometre stretch, the valley has a continuous width of around seven kilometres and is bound by steep, sharply contoured walls around 300 metres high. The box-shaped profile of Reull Vallis is conspicuous, very different from the familiar V- or U-shaped valleys here on Earth.

Material from the surroundings transported into the valley by ice

The bottom of Reull Vallis is covered with deposits, on the surface of which is an eye-catching pattern indicating the flow of the material and mostly running parallel to the edges of the valley, although in some places structures intertwined like braided hair are visible. This pattern was probably created by the flow of ice – a glacier on the surface of which a large volume of rubble and boulders has been transported down into the valley. On Earth, we see comparable phenomena known as rock glaciers in the Alpine and Polar regions. In these, the glacial ice is completely covered by boulders that have slid onto the ice from the valley walls.

Similar structures to those in the Reull valley are also found in the material filling nearby impact craters. This can be seen particularly well in two small craters northwest of the valley (upper right in the vertical overhead views and in one of the perspective views). The rocks certainly prevented the underlying ice from melting and – in the chilly temperatures prevalent on Mars – from sublimating (transitioning directly from a solid to a gaseous state) for much longer. However, at these 'temperate' Martian latitudes, there is a strong possibility that there is no longer any ice left under the sediments deposited by the glacier.

Terraces indicate an earlier water level in the sediments

Coming in from the north (right in the overhead view), a tributary valley flows into the main channel of Reull Vallis. Looking at the local environment in the topographical map, it can be seen that a side arm branches off further up the valley. Here, about 100 kilometres further southeast, it rejoins the main valley. To the north of Reull Vallis (in the right half of the overhead views), several of Promethei Terra's two to three thousand metre high massifs can be seen as well. Their somewhat smooth morphology indicates that erosion processes have been at work here for some time. Contours of extensive layers with tongue-shaped edges and occasionally smooth surfaces can be seen between the mountains; in some places they also have a pattern that follows the topography of their surroundings, as in the craters. These might also be sediments left behind by glacial ice. However, the smooth-surfaced layers could also be volcanic deposits.

Fairly evidently, a large volume of material have been carried away from the flanks of the mountains and transported into lower-lying regions, where it has tended to accumulate in impact craters. Also, the streaked pattern of the deposits in this crater that follows the circular crater rim is highly reminiscent of structures formed by glaciers on Earth. Stepped terraces on the inner walls of the craters could indicate the presence of a higher level of glacial ice covered by rubble and boulders, and that only when the ice and melt water disappeared did the sedimentary layer sink to where it is today.

Image processing and the HRSC experiment on Mars Express

The colour plan view (3/6) 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 (1/6 and 2/6) were computed from data acquired by the HRSC stereo channels. The anaglyph image (5/6), 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 colour-coded view (6/6) 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 45 co-investigators from 32 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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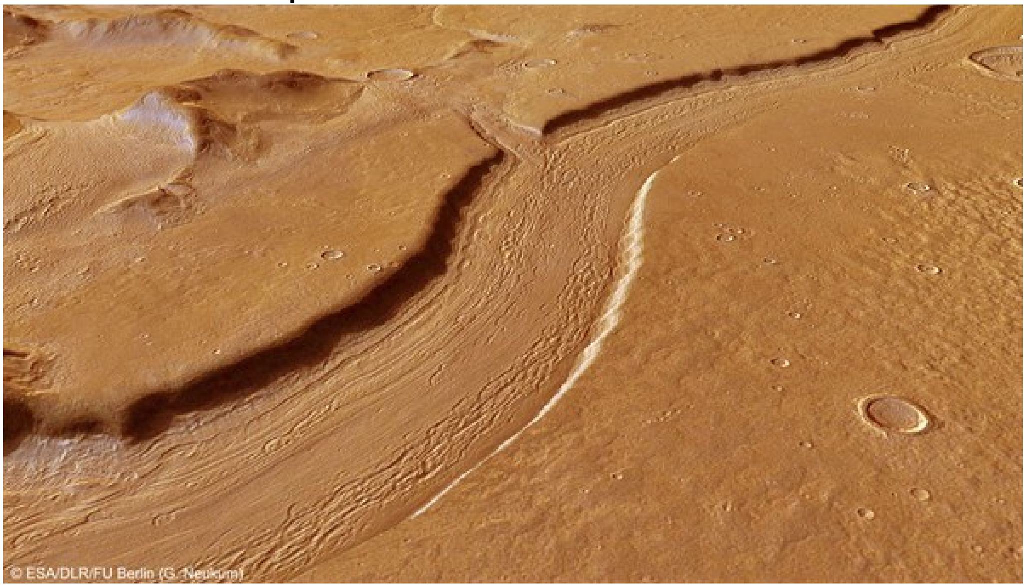
Rubble and boulder deposits in Reull Vallis



Ice flows have deposited rubble and boulders in the upper section of Reull Vallis outflow channel, some seven kilometres wide and 300 metres deep at this point, near to the Promethei Terra region that is. After the ice mass melted, a pattern was left in the sediments in which the movement of the glacier and its rocky cargo is clearly visible. A tributary valley flows into the main valley in the centre of the image. 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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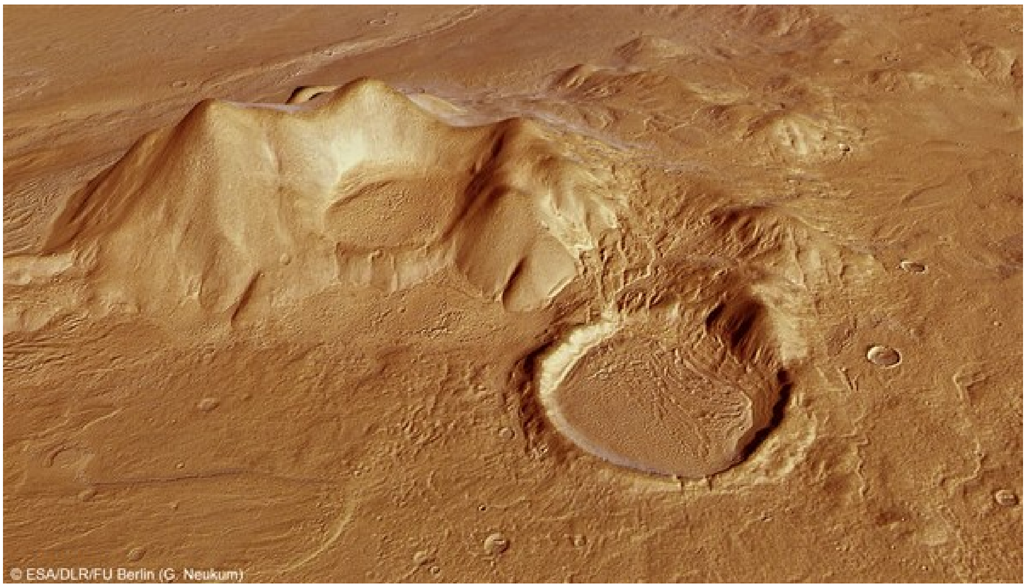
Sediment-filled craters in Promethei Terra



Glacial ice has had an effect on the landscape of not only Reull Vallis, but also in the mountains and craters of the adjacent Promethei Terra region. As with glaciers on Earth, ice masses start to flow and creep into lower lying regions, following the topography, under the pressure of their own weight and that of the boulders that have fallen onto them. After the ice disappeared, the sedimentary cargo was left behind. The pattern on the surface has been reproducing the flow movements ever since. 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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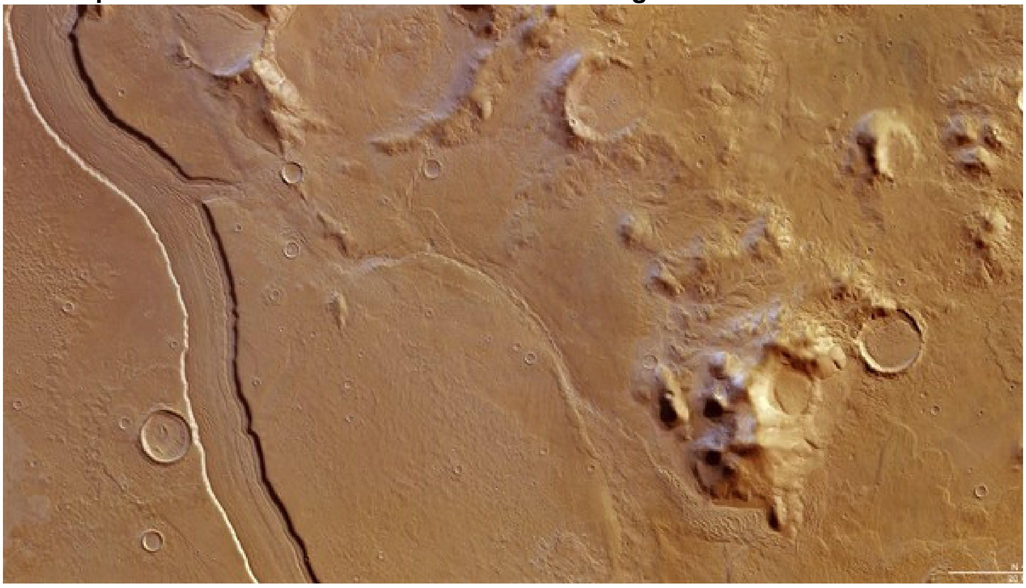
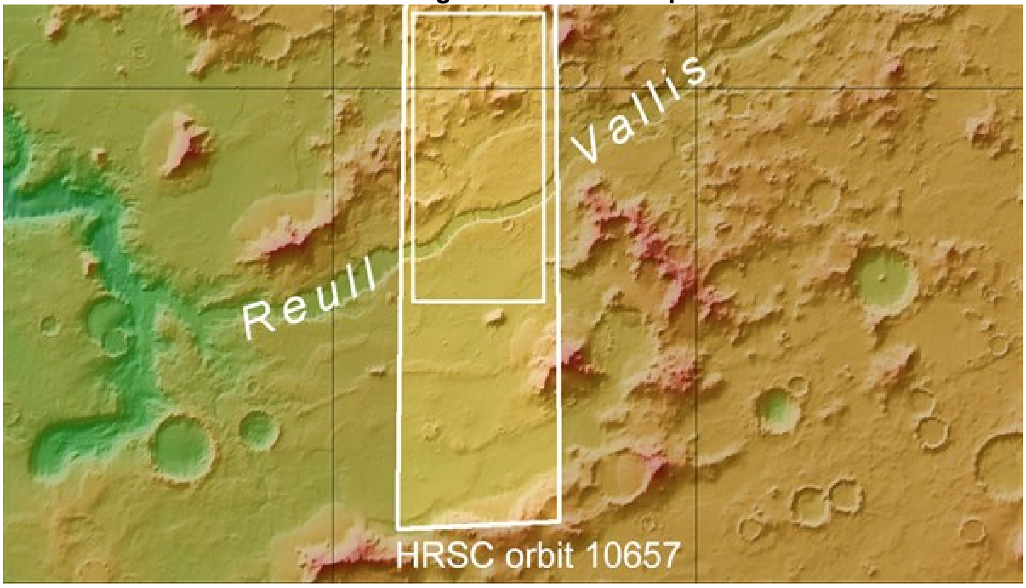
Colour plan view of Reull Vallis and its surroundings



With an almost continuous width of seven kilometres, Reull Vallis extends over a distance of 80 kilometres across Promethei Terra, a mountainous region on the edge of the huge Hellas impact basin in Mars' southern hemisphere. The conspicuous flow pattern in the valley can also be seen in several nearby impact craters. It presumably originates from ice flows that were covered with rubble and boulders and that left their sedimentary cargo behind there after melting.

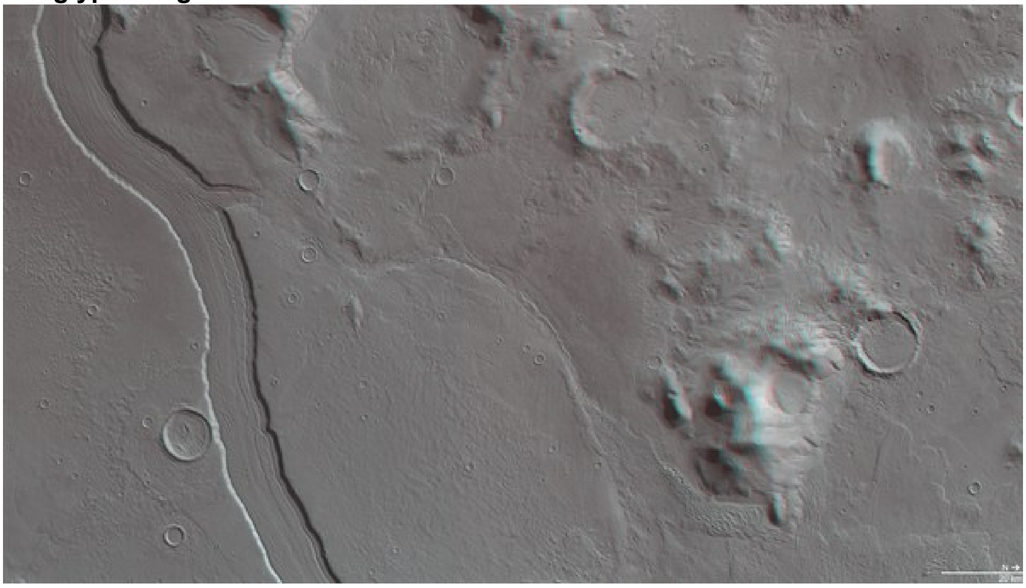
Reull Vallis on the northeastern edge of the Hellas impact basin



Reull Vallis extends across Promethei Terra, a mountainous region on the northeastern edge of the Hellas impact basin, for a distance of some 1500 kilometres – roughly corresponding to the length of the Rhine from its source in the Alps to its mouth. Like the Rhine, it undergoes a change in altitude of around 4000 metres as it does so. The HRSC stereo camera on Mars Express imaged the central section of Reull Vallis from an altitude of 320 kilometres during Orbit 10,657 on 14 May 2012. The landscape shown here lies in the region outlined by the smaller rectangle.

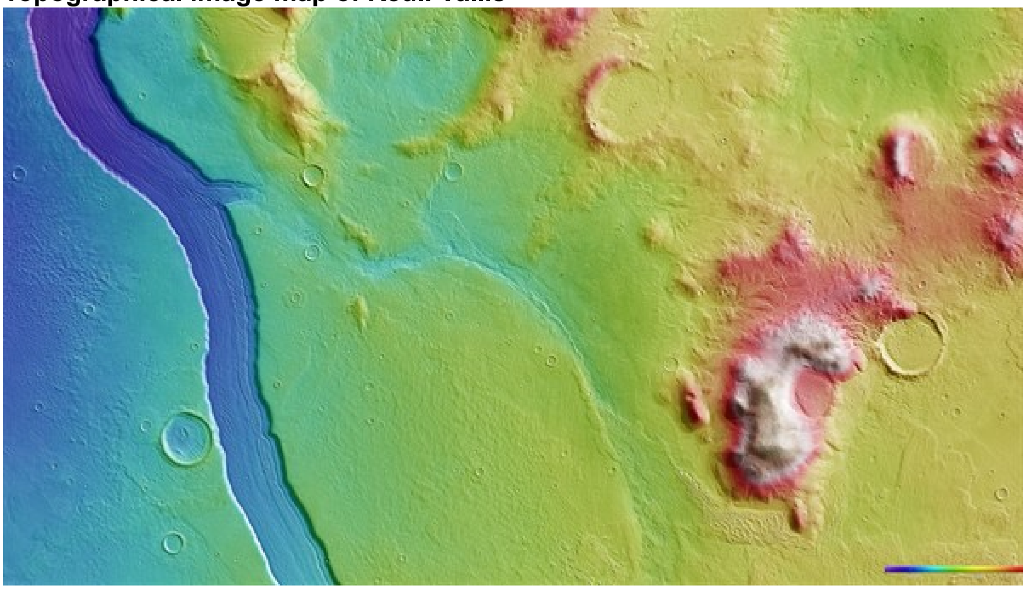
Credit: NASA/JPL (MOLA); FU Berlin.

Anaglyph image of Reull Vallis



Anaglyph images can be created from the nadir channel of the High Resolution Stereo Camera (HRSC), which looks vertically down at Mars, and one of the four stereo channels, which are directed obliquely towards the surface. Using red/blue (cyan) or red/green glasses gives a three-dimensional impression of the landscape. North is to the right in the image. The high resolution of 16 metres per pixel enables even small differences in altitude to be seen, for example in the deposits that the ice flow (glacier) have left behind in Reull Vallis, the striking valley system in the centre of the image, or in the surrounding mountains and 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.

Topographical image map of Reull Vallis



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 lower right; north is to the right in the image. In the spurs in the Promethei Terra highland region (right), individual mountains rise up to 2000 metres above the surroundings. Reull Vallis forms a striking incision around 300 metres deep. Clearly visible is a tributary valley running through the centre of the image and ending in Reull Vallis. 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.