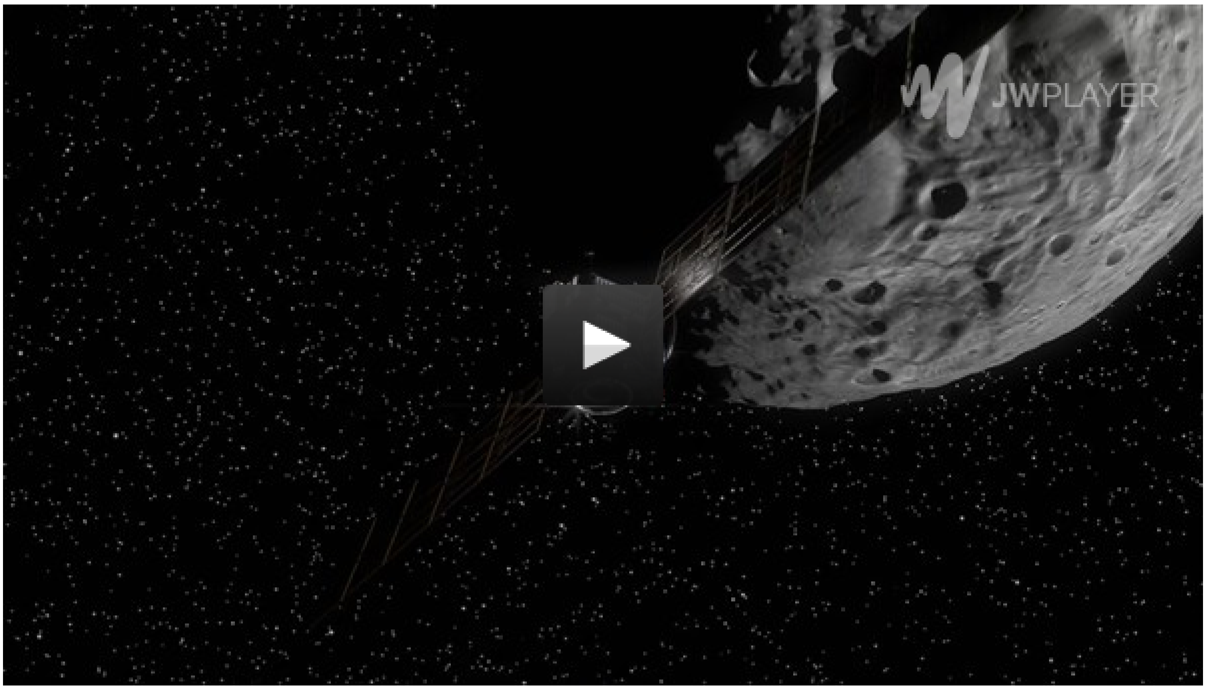
Vesta – a planet-like asteroid

10 May 2012

Even though it doesn't quite qualify as a 'proper' planet, the second most massive asteroid in the Solar System, Vesta – which has a diameter of approximately 530 kilometres – exhibits numerous planetary characteristics. This is just one of the many significant results of NASA's Dawn mission, published in the journal Science on 11 May 2012. The Dawn spacecraft has been orbiting Vesta since 16 July 2011. The German Aerospace Center (Deutsches Zentrum für Luft- und Raumfahrt; DLR) is involved in the mission.

"Vesta is more like the Moon than other asteroids," explains Ralf Jaumann, from the DLR Institute of Planetary Research in Berlin-Adlershof. "Its internal structure, range of geological surface features, heterogeneous composition and, above all, the alteration of the surface due to material mass movement suggest a dynamic, long lasting, planet-like evolution." Jaumann heads the Dawn science team at DLR. The planetary geologist is one of the principal authors of a series of articles being published in Science by the US/German/Italian research group. For these, the DLR planetary researchers have been analysing images from a camera system that was jointly developed for Dawn by the Max Planck Institute for Solar System Research and DLR, under the sponsorship of the DLR Space Administration.

Mega impacts with global effects



Animation: Virtual flight over asteroid Vesta (Credit: NASA/JPL-Caltech/UCLA/MPS/DLR/IDA)

"Since we began systematic mapping on 6 August 2011, this camera has delivered perfect high-resolution images of Vesta," says Jaumann. "One completely unexpected discovery has been a number of troughs several hundred kilometres long that sometimes run parallel to the equator and sometimes at an angle to it, as if carved with a gigantic plough. Then, beneath the already suspected huge impact basin near the south pole, we also discovered traces of an equally large but even older collision." The researchers working with Jaumann are certain that these two mega impacts are the cause of the troughs on Vesta's equator. In the midst of the larger basin, there is a central massif over 20 kilometres high.

The DLR Institute of Planetary Research is well known for its expertise in surveying bodies in the Solar System. The scientists have used stereo image data to generate three-dimensional global terrain models of Vesta that have contributed considerably to our understanding of its internal structure and surface features. The terrain models, which are accurate to 15 metres, and the maps derived from them, form the basis of the detailed research of Vesta conducted by the international Dawn science team. Dawn should help answer fundamental questions about the early development of the planets.

"It is probable that Vesta was once even bigger than it is today," explains Chris Russell, Principal Investigator of the Dawn mission, from the University of California in Los Angeles. “Enormous fragments were blasted off this protoplanet by collisions. Nevertheless, Vesta was big enough to ‘differentiate’ – that is, to form a metallic core surrounded by a rocky mantle.” This had been suspected previously and has now been confirmed by mineralogical analyses of the surface of Vesta. Observations with the specialised German camera and measurements taken with the US/Italian spectrometers on board Dawn indicate the same composition as that of rare meteorites found on Earth.

Vesta is the ‘mother’ of a family of asteroids

‘HED’ meteorites – named after the initials of three classes of rocky meteorite, Howardites, Eucrites and Diogenites – also originate from a differentiated asteroid mother body and have had a ‘hot’ past, meaning that they were at least partly molten when they formed. Two large bodies impacted with Vesta in its south hemisphere, blasting off many thousands of cubic kilometres of rock fragments. Referred to as Vestoids, these now follow Vesta’s orbital path. “Two impact basins that almost completely overlap were left behind and are now named after priestesses of the Roman goddess Vesta – Rheasilvia and Veneneia,” explains Russell. “Fragments of Vesta and the Vestoids were flung into space as HED meteorites, and pieces landed on the Earth.”

The fact that Vesta had been heavily impacted twice became apparent in the topographical maps generated by the DLR researchers. “Vesta has had to endure a lot in its history,” says Jaumann. “Veneneia, the older basin, is almost as large as Rheasilvia and has a diameter of 400 kilometres. The greatly disturbed topography and extremely steep mountain and crater walls show that the asteroid consists of solid rock beneath its topmost layer of dust.”
The gigantic impacts shocked Vesta to the core. Several dozen enormous troughs running along the equator are proof of these asteroid-quakes. “We could establish a significant geometric connection to the centres of the impact basins Rheasilvia and Veneneia. The simultaneous formation of basins several hundred kilometres wide and global structures shows that all of Vesta was shocked to breaking point by the cosmic collisions,” says Ralf Jaumann about the analysis of the results.

But Vesta still holds a few mysteries; no structures clearly indicating volcanism have been identified on the surface, even though it is expected in theory. “The reason for this may be that the surface is covered by a thick layer of debris and dust – the regolith – that has been gradually generated by meteorite impacts, covering up traces of earlier volcanism,” Jaumann suggests. Some areas with conspicuously dark material might in fact indicate volcanism, but this might also be a carbon-rich substance carried there by comets or asteroids. Until Dawn’s departure for dwarf planet Ceres at the end of August 2012, the scientists still have time to unlock Vesta's secrets.

The mission

The Dawn mission to Vesta and Ceres is managed by NASA's Jet Propulsion Laboratory (JPL) in Pasadena, which is a division of the California Institute of Technology, for NASA's Science Mission Directorate in Washington DC. The University of California, Los Angeles, is responsible for overall Dawn mission science. The camera system on the spacecraft was developed and built under the leadership of the Max Planck Institute for Solar System Research in Katlenburg-Lindau, Germany, with significant contributions from the German Aerospace Center (DLR) Institute of Planetary Research in Berlin and the Institute of Computer and Communication Network Engineering in Braunschweig. The Framing Camera project is funded by the Max Planck Society, DLR, and NASA/JPL.

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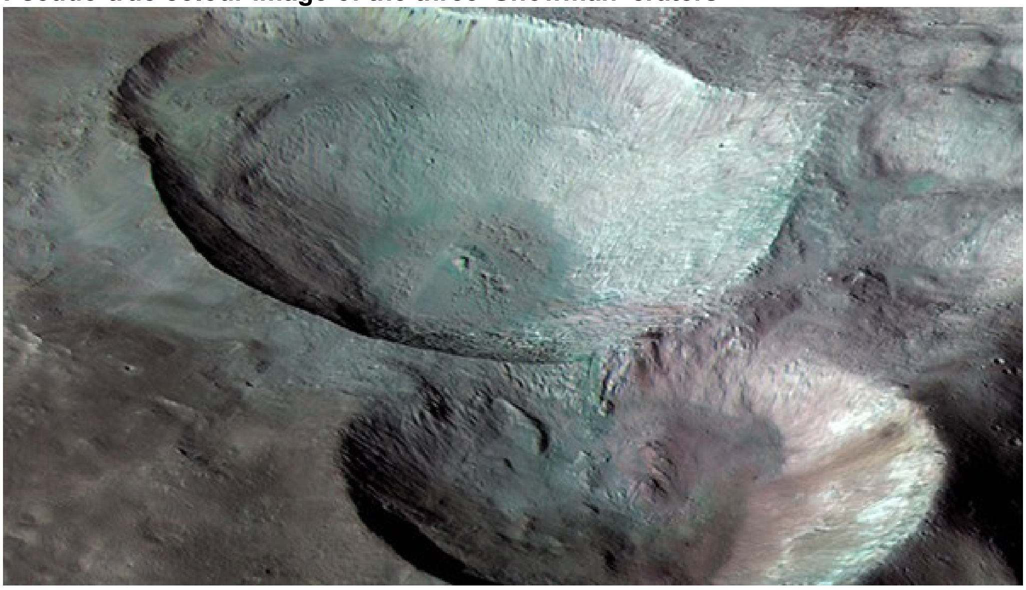
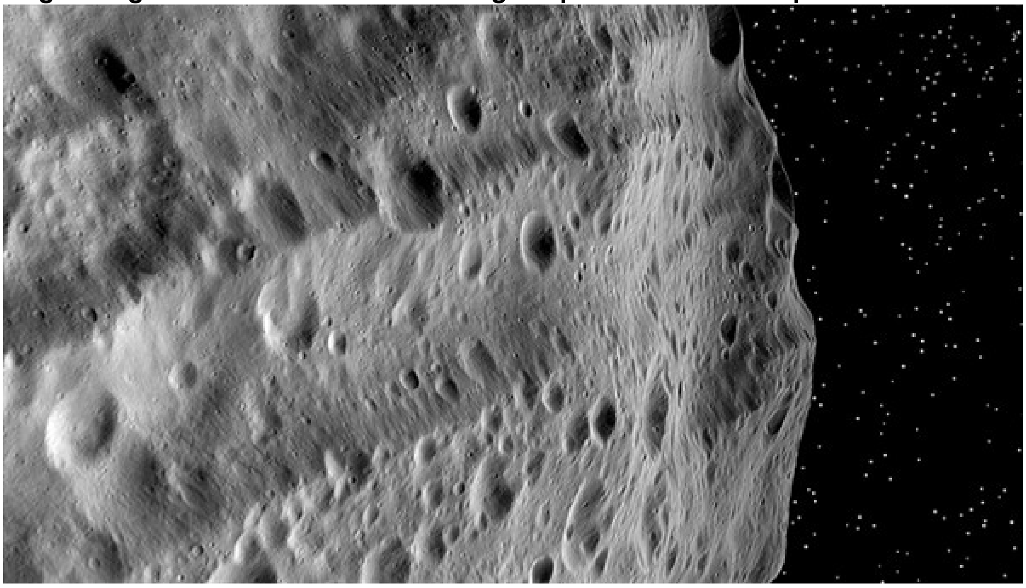
Pseudo-true colour image of the three 'Snowman' craters



Three impact craters of different sizes, arranged in the shape of a snowman, make up one of the most striking features on Vesta. In this view the three 'snowballs' are upside down, so that the shadows make the features easily recognisable. North is to the lower right in the image, which has a resolution of 70 metres per pixel. The image is composed of many individual photographs taken during the high-altitude mapping orbit, at about 680 kilometres above Vesta's surface. The largest of the three craters, Marcia, has a diameter of 60 kilometres. The central crater, which is about 50 kilometres in diameter, is named Calpurnia, and the lower crater, named Minucia, has a diameter of about 22 kilometres. Marcia and Calpurnia are possibly the result of an impact by doublet asteroids, whereas Minucia was formed by a later impact. To derive the colour information, images acquired by the German camera system on the Dawn spacecraft in two near-infrared channels (917 nanometres and 749 nanometres) and an ultraviolet channel (438 nanometres) were combined to create what is referred to as a pseudo-true colour image. The true colours of the surface of Vesta appear somewhat different, but the subtle changes in material properties across the craters and impact ejecta can be detected. In both Marcia and Calpurnia, landslides can be seen; also, dark material has been exposed below the rim of Marcia.

Credit: NASA/JPL-Caltech/UCLA/MPS/DLR/IDA.

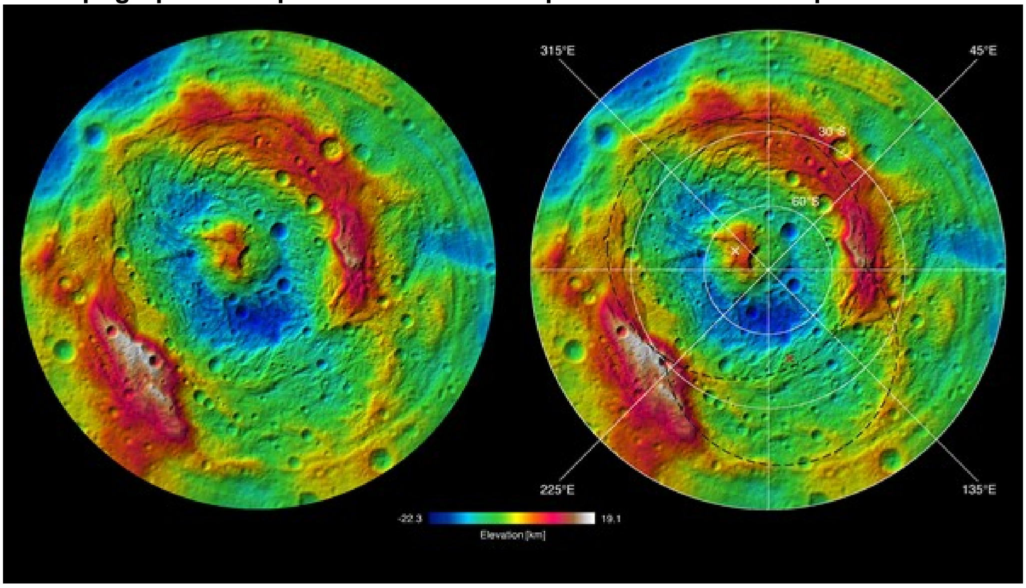
Huge troughs on Vesta – a result of mega impacts at the south pole



As NASA's Dawn spacecraft sent the first images of Vesta back to Earth in July 2011, scientists immediately noticed numerous troughs, as if carved with a gigantic plough. This image shows two troughs in the Divalia Fossa system, running parallel to the lower edge of the image. The majority of these troughs extend along the equator, but a second group – inclined with respect to the equator – have been identified in the northern hemisphere. These parallel trenches are usually several hundred kilometres long, up to 15 kilometres wide and more than one kilometre in depth. They are the result of two large asteroid impacts at the South Pole, demonstrating that impact events that occurred hundreds of kilometres apart caused shocks throughout Vesta and altered its surface.

Credit: NASA/JPL-Caltech/UCLA/MPS/DLR/IDA.

The topographical map reveals a double impact at Vesta's south pole



Observations with the Hubble Space Telescope hinted that the south pole of the approximately 500-kilometre asteroid Vesta was somewhat flattened. With the images acquired by the Dawn spacecraft, it became obvious that there is a huge impact basin, with a diameter of 500 kilometres. It has been named Rheasilvia, after one of the Vestal Virgins of ancient Rome. DLR has computed topographical maps of asteroid's surface from stereoscopic image data; these reveal the extent of this cosmic collision (red and white – elevated areas; green and blue – low regions). The impact left a 500-kilometre wide and, in some places, more than 10-kilometre deep basin surrounded by a ring of elevated rock. In the centre of Rheasilvia is a more than 20-kilometre high central peak. What surprised the researchers was the discovery of a second, older basin with a diameter of 400 kilometres, which was named Veneneia. In the right-hand image, dashed lines indicate the outlines of Rheasilvia and Veneneia. The centres of the basins are each marked with an ‘X’.

Credit: Science/AAAS.
