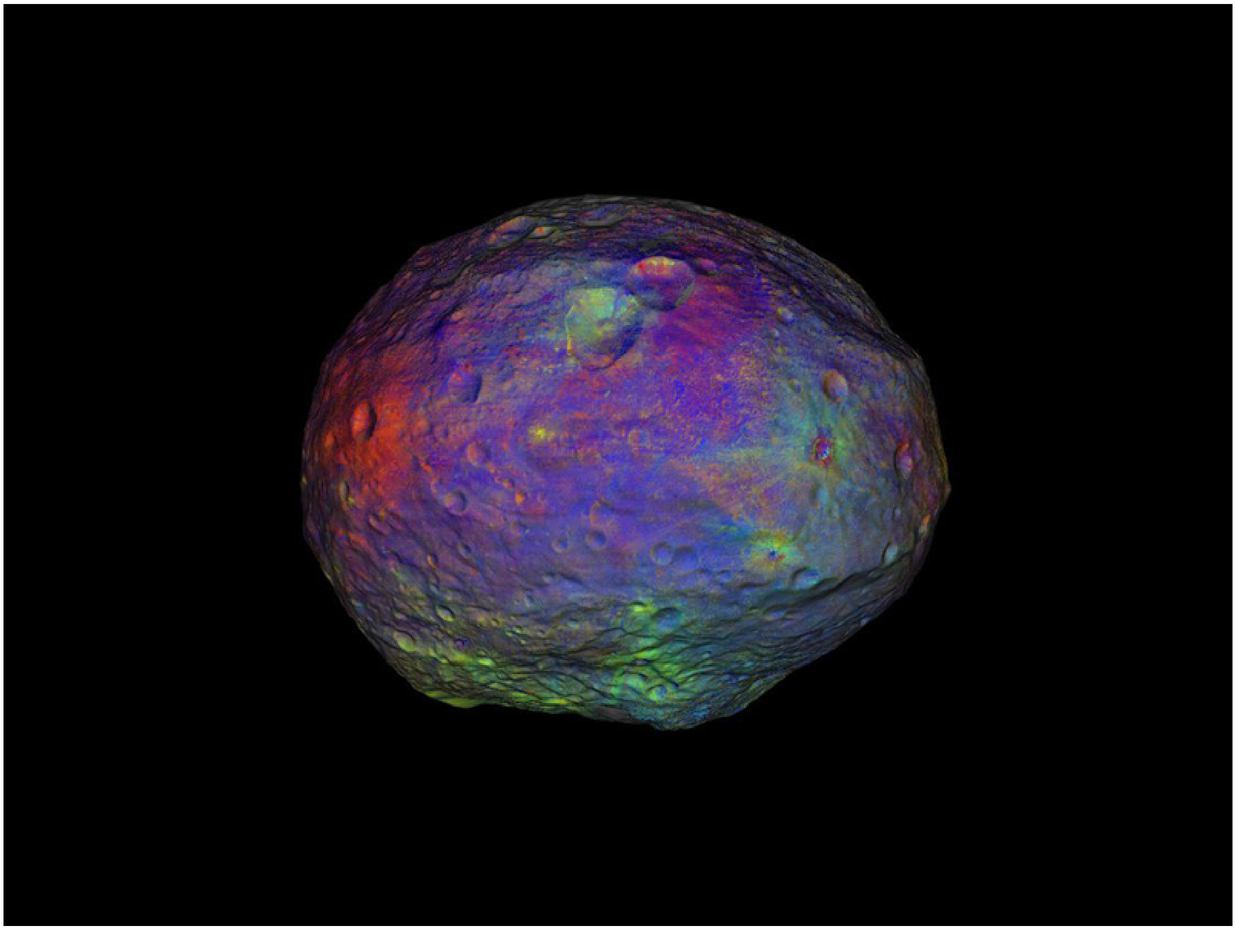
Vesta—Ceres' little sister

April 21 2015, by Birgit Krummheuer



The asteroid is rockier and has more geological diversity than the current destination of the Dawn mission. Credit: NASA/JPL-Caltech/UCLA/MPS/DLR/IDA/PSI

Only around 60 million kilometres closer to the Sun than Ceres, another large rock is orbiting in the remote asteroid belt: Vesta. Although its diameter of approximately 530 kilometres makes it a bit too small to be counted as a dwarf planet, it is nevertheless big enough to be the second heaviest and third largest body in this region between the orbits of Mars and Jupiter. Ceres' little sister has already gone through what is in store for the asteroid in the coming months: As the first destination of the US Dawn mission, the spacecraft's three onboard measuring instruments subjected Vesta to more than a year of permanent monitoring from July 2011 to September 2012. As it turned out: Vesta was originally well on its way to developing into a planet.

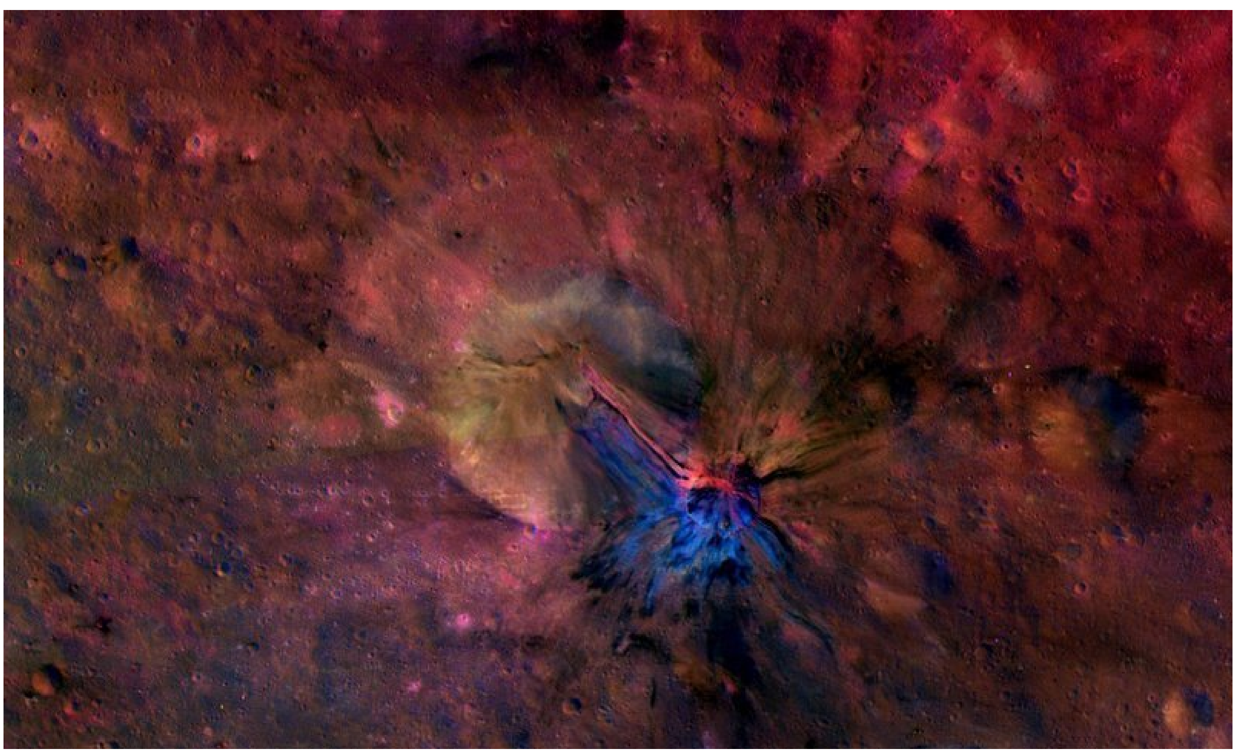
Viewed from the outside, Vesta looks like a typical asteroid: unusually large admittedly, but with a bizarre, rather irregular shape - quite different from the almost spherical dwarf planets Ceres, Pluto, Haumea, Makemake and Eris. The tens of thousands of photos taken during Dawn's photo-shoot show that Vesta's southern hemisphere in particular deviates from the ideal proportions of a dwarf planet: two huge impacts here gouged large craters out of the rock.

The 22-kilometre high central mountain in the more recent of the two basins and deep, parallel grooves near the equator bear witness to the force of this particular impact. The material ejected even forms its own class of asteroid: the so-called vestoids, fragments of which occasionally cross our own planet's orbit before falling to Earth as meteorites.

The fact that Vesta nevertheless has more to offer than the overwhelming majority of its smaller asteroid siblings is down to its inner characteristics, among other things: measurements made by the Dawn space probe show that the giant asteroid has an onion-like structure similar to Earth's – comprising an iron-nickel core, rocky mantle and crust. Around 4.6 billion years ago, Vesta must therefore have been a hot, molten body. Heavy materials, such as iron, were able to sink into the interior, lighter elements arranged themselves further out.

"We assume that Vesta had started to develop into a planet. If it had succeeded in amassing more and more material and growing further, it would possibly now be the fifth inner planet alongside Mercury, Venus, Earth and Mars," says Andreas Nathues from the Max Planck Institute for Solar System Research, scientific manager of the Dawn camera team. The effect of the gaseous giant Jupiter, which was forming at exactly the same time, prevented this, however.

Despite the flood of measurement data which Dawn was able to collect near Vesta, taking a detailed look into the interior is still problematic. "There are many indications, however, that the outer crust is very thick," says Nathues. It could even measure between 30 and 80 kilometres. That would be more than eleven percent of its radius. By comparison: the crust of the much bigger Earth has a similar thickness.



Magnificent landscapes: Vesta's beauty is shown in this false colour image of the Aelia crater, for example. The flow structures, which are highlighted in blue and red against the background here, are not visible to the naked eye. The crater has a diameter of 4.3 kilometres. The precise origin of the flow structures is not yet known. The impact which formed the crater possibly created fluid material, which has a different mineralogy or grain size than the surroundings. Credit: NASA/JPL-Caltech/UCLA/MPS/DLR/IDA

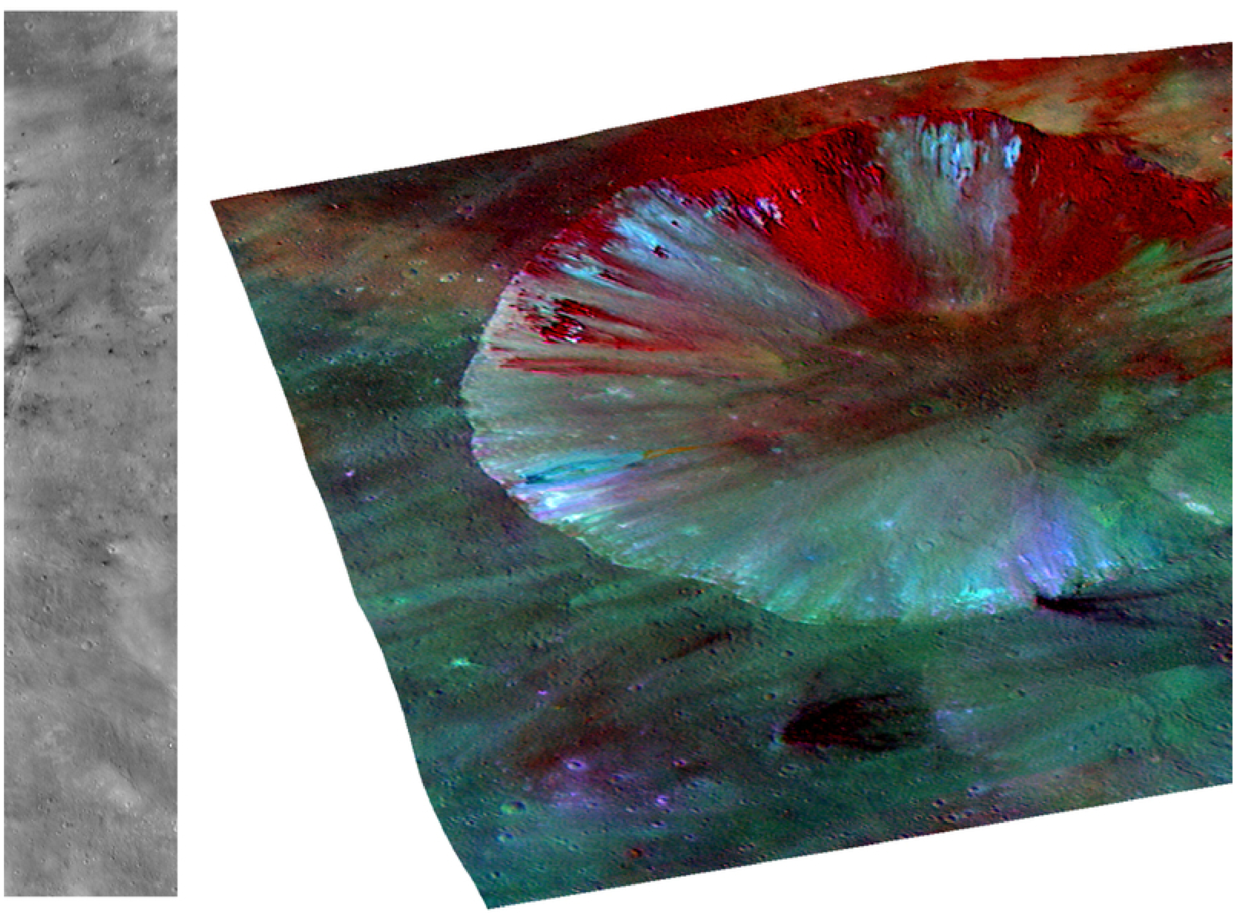
The huge craters in the southern hemisphere provide crucial evidence. Despite the depth of the craters, the researchers did not detect any olivine there – a mineral that is typically found in the inner rocky mantle . The impacts obviously merely scratched the crust, without having exposed the deeper layers, however.

A more detailed look reveals that the surface of Vesta is also clearly different from most of the millions of smaller and larger rocks that inhabit the asteroid belt. These bodies, which the scientists call "primitive", are usually characterised by a kind of uniformity: small worlds of grey, as far as the eye can see. Vesta, on the other hand, is different.

There are regions on the surface of the asteroid which reflect light as efficiently as snow – next to those which are as black as soot. In false colour images that represent the reflectivity of the surface in different wavelength ranges, Vesta appears as an iridescent body with a rich variety of different minerals. "Vesta's extremely varied surface geology does indeed resemble more that of a planet," says Max Planck researcher Andreas Nathues.

Particularly striking is the dark material which can be found primarily at the edge of the older, large impact basin in the southern hemisphere, and close to and in the interior of further craters. As evaluations of the scientific cameras and the VIR spectrometer aboard Dawn suggest, this material is not only rich in carbon, but also contains the mineral serpentine.

"At high temperatures as must have existed in Vesta's childhood, serpentine cannot form," says Andreas Nathues. The researchers conclude that the dark material did not originally belong to Vesta, but was imported primarily from the outside by the earlier of the two big impacts.



Relic of an impact: The Numisia crater immediately south of the equator measures 30 kilometres in diameter. Images taken by the camera system on board NASA's Dawn space probe using a clear filter (left) show dark material both on the crater walls as well as in the material that was ejected on impact. The camera system uses its colour filters to disperse the reflected light into individual wavelength ranges, thus making further differences in the surface composition visible (right). The researchers found the characteristic fingerprints of the mineral serpentine in this kind of data. Credit: NASA/JPL-Caltech/UCLA/MPS/DLR/IDA

"It is very likely that impacts of this type also supplied other bodies in the solar system with carbon-rich material," says Nathues. The researchers want to understand how our cosmic home became the place we know today over the course of billions of years. Which substances were present at the birthing hour of our solar system? And where? And how did they subsequently redistribute?

"Although Vesta is only one single, comparatively small body, it can make important contributions to putting this puzzle together, piece by piece," says Nathues. Since the giant asteroid remained stuck in an early phase of planet formation, the conditions 4.6 billion years ago are conserved in it to a certain extent. Vesta thus provides scientists with a glimpse into the past.

The scientists are also investigating whether Vesta contains water. Its high density, among other things, argues clearly against extensive reservoirs in the interior; but systems of grooves and channels can be found in some crater walls that look as if they once contained water. Similar structures are known from craters on Mars or the Barringer crater in Arizona, for example, where they are thought to be associated with water.

Scientists surmise that Vesta was supplied with water from outside for some of the time, and that several small, icy patches were able to survive below its surface. The heat of an impact at these locations could then release a stream of melt water for a short time.

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