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Dawn at Vesta and Ceres

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The NASA Dawn Discovery mission was designed to study two of the largest objects in the asteroid belt that formed on opposite sides of the snow line, Vesta and Ceres. Vesta formed dry and is covered with bright basaltic material, some of which has made it to the Earth in the form of HED meteorites. From these meteorites we knew in advance that Vesta was differentiated early in its history, forming a metallic core. Before Dawn arrived we were expecting to find evidence of volcanism on its surface. After a year in orbit, nothing conclusive was found. We did find an extensively battered surface with much mass wasting, and evidence for two large basin impacts covering the South pole, Rheasilvia and Venenia. The Venenia impactor appears to have been a large carbonaceous object which contaminated an entire hemisphere of Vesta and buried over time by ejecta from other collisions. This may be the source of the dark material excavated by impacts and seen in crater walls. There are also mysterious depressions on the floors of some large craters that suggest devolatilization in a surface that is not supposed to have any volatiles. In December 2014, Dawn arrived at the dwarf planet Ceres. Ceres formed "wet," with much ice and much dark carbonaceous material (which covers its surface). Thermal models suggest that Ceres also differentiated, but with a rocky core surrounded by an ice-rich mantle. A liquid water ocean is also expected to have formed, with the question of whether it could have persisted over the age of the solar system. Herschel Space Telescope made exciting observations of water vapor emission at two longitudes as Ceres approached its perihelion. One of these longitudes has been found to correlate with that of a "great white spot" complex, which may be cryovolcanic in origin, possibly connected to a deep interior reservoir of water or arisen from impact-driven hydrothermal activity. In some ways a negative of Vesta, Ceres has numerous other small white spots over areas of its surface, primarily associated with craters, but qualitatively different than the "great white spot." Ceres also sports a mountain, the "pyramid," which bears striking resemblance to the newly discovered mountains on Pluto. Could similar processes be in operation on these greatly separated planetary bodies?