THE DAWN REVOLUTION. C. T. Russell[1], C.A. Raymond[2] and the Dawn team. [1] UCLA, Earth, Planetary and Space Sciences, 603 Charles Young Drive, Los Angeles, CA 90095-1567, USA; ctrussell@igpp.ucla.edu, [2]Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, CA 91109, USA.

Introduction: The objective of the Dawn mission was to explore the two most massive objects in the asteroid belt, Vesta and Ceres [1]. Vesta, through its reflectance spectrum, had been associated with the Howardite, Eucrite, and Diogenite families of meteorites, but Ceres had not been associated with any meteorite family. Vesta was expected to be a dry, heavily cratered body, perhaps with an iron core. Ceres was also expected to be a dry, heavily cratered body, but with different composition since it was much less dense. Dawn was equipped with only a camera, a visible and infrared mapping spectrometer, a Gamma Ray and Neutron Detector, and a communication (radio) system. It was propelled by ion engines that enabled it to travel from Earth under its own power using the energy from the Sun to accelerate the xenon propellant.

Arrival at Vesta revealed the expected battered surface and confirmed the expected differentiation that produced an iron core [2]. It also confirmed that the HED meteorites were associated with Vesta, most possibly produced when the Veneneia and the Rheasilvia basins were excavated. While Vesta was very dry, it had not always been so.

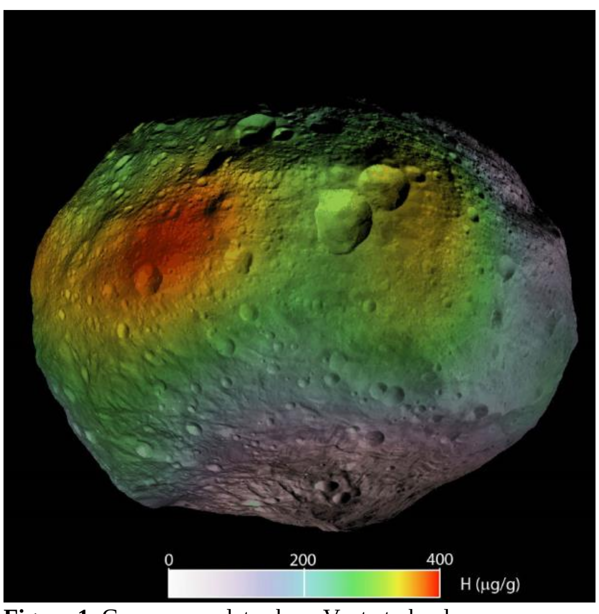

Figure 1. Gamma-ray data show Vesta to be dry.

The Marcia crater and several others had pits in the bottom of the crater that pointed to ponding and subsequent drainage of water.

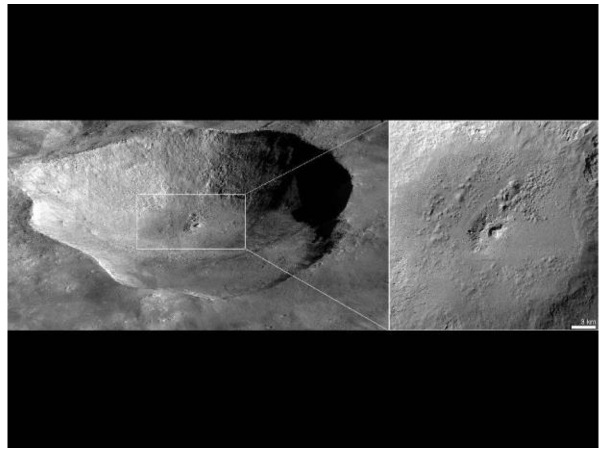

Figure 2. Marcia crater (left) and pits in central crater (right).

The walls of these craters had flow channels that showed where the source of the water was located. After approximately a year of orbiting Vesta, Dawn fired its xenon thrusters to leave Vesta and head to Ceres.

Arriving in March 2015, Dawn revealed a most unexpected surface. It had bright spots that suggest recent hydrothermal activity, transporting material from Ceres' interior to the surface.

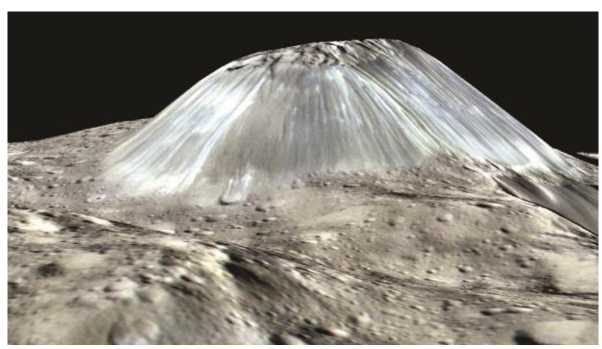

Figure 3. Occator overview.

This material was identified by VIR to be sodium carbonate, the largest such reservoir known in the solar system.

The surface was dry and heavily cratered. While large craters were rare to absent, the crust was very rigid and much more rigid than the expected ice or rock-ice should be. The rigid layer was about 40 km thick.

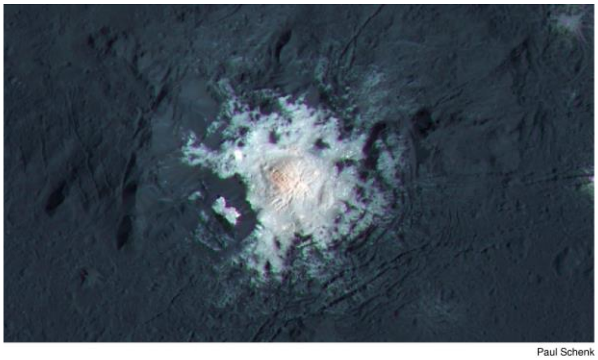

Figure 4. Cerealia crater close-up.

The surface had more than just craters; it also had a tall mountain and suggestions of earlier mountains. While the surface was more rigid than ice, it contained patches of ice. It also revealed prebiotic organic material and tectonic processes that seemed not trivially linked to impacts. Ceres was very, very interesting and overnight became a subject of astrobiological interest, a small water planet conveniently located at the gateway to the outer solar system [3].

Dawn was designed to map the surfaces of Vesta and Ceres at two altitudes, called Survey and HAMO, and to obtain gamma-ray and neutron data as well as gravity data in a lower orbit called LAMO. In fact, Dawn operated so well that much more LAMO data were obtained than expected, and there was extensive mapping from LAMO.

Example studies of the Dawn analyses are being presented at this meeting that demonstrate Dawn's data gathering and unforseseen capabilities. Anna Galiano and coworkers [4] have shown how to obtain mineral composition with depth below the surface by examining central crater peaks using the VIR spectrometer. Each crater peak explores principally one depth, but by putting together measurements of craters of differing size and depth exposure, she concluded that NH_4-phyllosilicate varies with depth and that Mg-phyllosilicate and NH_4-phyllosilicate are connected beneath the surface and are well correlated.

Mauro Ciarniello [5] shows another important capability of Dawn, that is to maneuver to obtain precise photometric data not possible with ground-based telescopes on most other missions. At Ceres, Dawn altered its orbit so that the solar beta angle was zero. The Sun was right overhead so that the opposition effect could be studied. Was this increase in reflectance due to shadow hiding or coherent backscatter? In Ceres' case, the opposition surge is as expected from shadow hiding by a surface with a low albedo and a large porosity.

Dawn began a revolution in our understanding of the asteroid belt. It has made the main asteroid belt interesting and opened it up to in-situ observations. Following in Dawn's footsteps is the Psyche mission being prepared for flight to 16 Psyche and Lucy being prepared for the Jovian Trojans. They will continue that revolution.

References: [1] Russell C.T. and Raymond C.A. (2011) *Space Sci. Rev.*, *164*, 1-2. [2] Russell C.T. et al. (2012) *Science, 336,* 684. [3] Russell C.T. et al. (2016) *Science, 353,* 1008–1010. [4] Galiano A. et al (2018) *LPSC 2018*. [5] Ciarniello M. et al (2018) *LPSC 2018*.