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The Geology of Vesta

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Abstract

The Dawn spacecraft collected over 28,000 images and a wealth of spectral data of Vesta's surface. These data enable analysis of Vesta's diverse geology including impact craters of all sizes and unusual shapes, a variety of ejecta blankets, large troughs, impact basins, enigmatic dark material, and considerable evidence for mass wasting and surface alteration processes [1,2,3]. Two large impact basins, Veneneia underlying the larger Rheasilvia basin dominate the south polar region [1,4]. The depression surrounding Vesta's south pole was formed by two giant impacts about one billion and two billion years ago [4,5]. Vesta's global tectonic patterns (two distinct sets of large troughs orthogonal to the axes of the impacts) strongly correlate with the locations of the two south polar impact basins, and were likely created by their formation [1,6]. Numerous unusual asymmetric impact craters and ejecta indicate the strong influence of topographic slope in cratering on Vesta [1]. One type of gully in crater walls is interpreted to form by dry granular flow, but another type is consistent with transient water flow [7]. Very steep topographic slopes near to the angle of repose are common; slope failures make resurfacing due to impacts and their associated gravitational slumping and seismic effects an important geologic process on Vesta [1]. Clusters of pits in combination with impact melt [8] suggest the presence of volatile materials underlying that melt in some crater floors. Relatively dark material of uncertain origin is intermixed in the regolith layers and partially excavated by younger impacts yielding dark outcrops, rays and ejecta [1,9]. Vesta's surface is reworked by intense impacts and thus much younger than the formation of its crust [2,5].

Major Geological Findings

1. Vesta's surface is characterized by diverse geology including impact craters of all sizes, a variety of ejecta blankets, large troughs extending around the equatorial region, enigmatic dark material, and considerable evidence for mass wasting (Fig. 1, 2)[1-12].

2. Dawn confirms the large impact basin covering Vesta's south pole (Rheasilvia), inferred from the Hubble Space Telescope images, and reveals evidence for an earlier, underlying large basin [1,4,5].

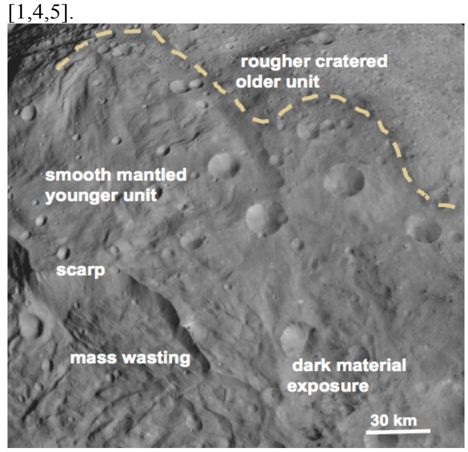

Fig 1: Geologic surface features on Vesta

3. Vesta's global tectonic patterns (two distinct sets of large troughs) strongly correlate with the locations of the two south polar impact basins, and were likely created by the formation of the basins [1,6].

4. Impact craters on Vesta range from fresh to highly degraded, comparable to the Moon, indicating an intensive cratering history over the age of the solar system [1,4].

5. Impact craters on Vesta have characteristics similar to those on smaller asteroids as well as those on the Moon and Mars, making Vesta a transitional

body between asteroids and planets [1,2].

6. The primary crust is covered by a thick (100 meters to a few kilometers), multilayered, sheet of debris (regolith) formed by the accumulation of ejecta from the numerous impacts that have resurfaced Vesta over time [1].

7. Vesta exhibits rugged topography ranging from -22 km to 19 km relative to a best-fit ellipsoidal shape. Vesta's topography has a much greater range in elevation relative to its radius (15%) than the Moon and Mars (1%) or the Earth (0.3%), but less than highly battered smaller asteroids like Lutetia (40%). This also identifies Vesta as a transitional body between asteroids and planets [1].

8. The surface of Vesta exhibits very steep topographic slopes that are near to the angle of repose. Impacts onto these steep surfaces, followed by slope failure, makes resurfacing due to impacts and their associated gravitational forces and seismic activity an important geologic process on Vesta that significantly alters the morphology of geologic features and adds to the complexity of its geologic history (Fig. 2) [1,4,10]. Linear gullies are interpreted to form by flow of dry granular material and curvilinear gullies are interpreted to form by transient flow of water [7].

9. Deposits of dark material is intermixed into the regolith and partially excavated by younger impacts exposed as blocks or layers out-cropping in crater walls. The mixing of dark material with impact ejecta indicates that this material is processed together with the ejected material. Small craters possess continuous dark ejecta similar to lunar dark-halo impact craters, indicating that the impact excavated the material from beneath the surface. Asymmetric distribution of dark material in impact craters and ejecta suggests non-continuous distribution in the local subsurface. The composition of the dark material resembles that of the Vesta regolith. Dark material is distributed unevenly across Vesta's surface. The wide variety of the surface exposures of dark material and their different geological correlations with surface features as well as their uneven distribution indicate a globally inhomogeneous distribution in the subsurface. However on a global scale the dark material seems to be correlated with the rim and ejecta of the older Veneneia south polar basin structure. The origin of the dark material is still debated and it is tentatively suggested that dark material could be either exogenic, from carbon-rich low velocity impactors, or endogenic, from freshly exposed mafic material or impact melt, created or exposed by impacts The broad correlation between dark material and OH hydration band, suggest the presence of carbonaceous chondrites as darkening agent. [1,9,12,13, 14]

10. In contrast to models and expectations from the mineralogy of the HEDs, direct evidence for volcanic activity is lacking so far. This may be due to a dearth of large-scale volcanic features on Vesta and/or to the volcanism ending early in Vesta's evolution so that the evidence has been destroyed and covered up by extensive subsequent cratering, regolith formation, and resurfacing [1].

11. In general, Vesta's geology is more like the Moon and rocky planets than other asteroids [1,2].

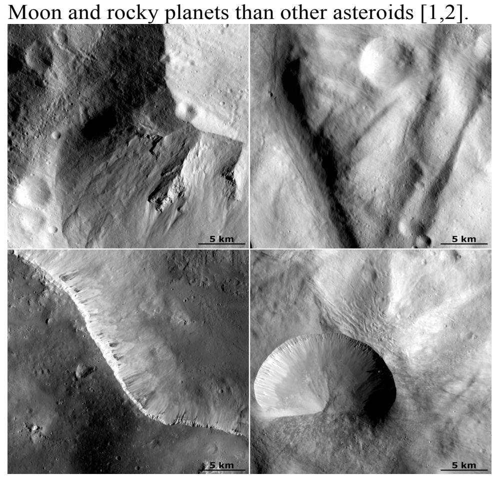

Fig 2: Surface processes on Vesta: (left) mass wasting and talus formation from scarps that also include bright and dark material (bottom); (right) surface mantling and slumping of fine material (top) and slumping of material within a crater located on a slope either due to ballistic ejecta deposit or rim failure (bottom).

References:

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