WHY VESTA'S SURFACE IS UNWEATHERED?

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In spite of the fact that surface composition of Vesta-like asteroids (vestoids) and Vesta is apparently related, spectra of the vestoids have a redder continuum across the visible and NIR interval in contrast to a Vesta's continuum in the same wavelength range. The first polemics about nature of the vestoids and Vesta took place ten years ago [3, 4] but the question is still opened. The reddish spectra of asteroids (not only vestoids) are usually explained by optical maturation of their surface owing to the space weathering [1, 2]. There is obvious mismatch in that case: surface of Vesta's chips excavated from Vesta's crust is weathered, whereas parent body of vestoids (i.e. Vesta itself) has the fresh unweathered surface.

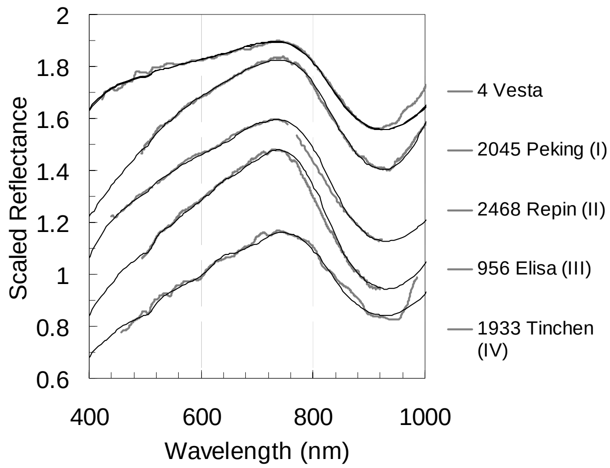

Figure. Observed (in gray) and theoretical (in black) spectra of Vesta and some vestoids of the various spectral types in accordance with [11]. The red continuum of the vestoid spectra occurs due to optical maturation of their surface.

Using theory [5] we modeled the Vesta and vestoid spectra obtained in [6 – 10] and came to the same conclusions. The Vesta surface as well as vestoid surfaces has on the whole eucrite-howardite composition. Minor amount of olivine and chromite is needed to explain faint absorption bands around 600 and 650 nm in the spectra of some vestoids [11], however these minerals can not explain distinction between continuums of the Vesta and vestoid spectra (see Figure). Principal singularity of the vestoids consists in a necessity of optical maturation of their surfaces, whereas this requirement is not necessary for Vesta. Notably, whether the vestoids are members of the dynamical Vesta family or not, they have weathered rocks, confirming universality of the space weathering effect. Why ever Vesta has the unweathered surface?

The probable causes, as we assume, can be connected with a 450-km impact basin near the Vesta south pole and a material ejection out of it. Now we see some of the ejected fragments of Vesta's crust as Vesta family asteroids [12, 13, and 14].

In accordance with [13], relaxation time for the 450-km impact basin on Vesta is approximately 10^8 years. It may result in a long-term seismic activity of the Vesta surface. Deformation energy, accumulated owing to this impact in the Vesta crust and upper mantle, dissipates over the previously mentioned period by means low-amplitude vibrations of its surface. One can imagine a large number of point-like sources of seisms, distributed in the volume of the Vesta crust and mantle. If a spectrum of the seismic vibrations contains a high-frequency component and the seismic waves reach the surface, it begins to shake, actuating regolith processes. Weathered particles of upper surface layer may turn over, sift into subjacent layers and mix with unmaturated particles. The shaking of the asteroid surface leads to permanent "dilution" of the weathered material by a fresh one from subsurface layers and preserves in that way "youthful appearance" of Vesta.

The other cause of the fresh Vesta surface can be connected with small-sized debris launched from the impact basin and remained in the gravitational sphere of influence of Vesta (sphere radius ~$1.4 \cdot 10^5$ km). The theoretical modeling impact event on Vesta [13] predicts millions of ~ 100-m chips with ejection velocities between 300 and 650 m/s. Using the size-frequency distribution for the Vesta dynamical family we estimated the number of fragments as $7 \cdot 10^6$ in the size range of 0.5 – 0.2 km. These fragments aggregate approximately a half the ejected mass and have large total cross section (~$3.7 \cdot 10^5$ km^2). Therefore the small bodies have large probability for mutual collisions and disruption into expanding cloud of the explosion. For example, only 140 fragments having size ~ 0.2 km must be fully disrupted to give ~ 10^7 – 10^8 new fragments in the size range of 100 m – 10 cm for about hour after the impact. These collisions and disruption reduce the ejection velocities and some of initial and neogenic fragments could be captured by Vesta itself. At least such a scenario is not excluded at examination of probable fate of the ejecta after asteroid collisions [15]. Owing to the tidal forces from Vesta and other asteroids as well as non-gravitational radiation force, the captured fragments revolve around Vesta on elliptic quasi-stationary orbits. Under the action of these perturbations some fragments can escape the gravitational sphere of influence of Vesta, or pass into other elliptic orbits within this sphere, or fall to the Vesta surface. The number of small and very small fragments captured by Vesta may be very large (~10^8), and the perturbing forces applied to them are very small. Therefore the survival time of the debris cloud around Vesta is thought to be long and, apparently, be comparable with that of the Vesta dynamical family. From time to time some portion of the debris falls to the Vesta surface (with speed of the order of escape speed), gardens and mixes the regolith, reducing the space weathering effect. Really, a body massage promotes rejuvenation.

If the last hypothesis is correct then one can assume that typical relief of Vesta may be grooves, topped with rubbles and/or oval shallow craters with boulders in the inside. It occurs owing to the fact that small and large boulders from "Vesta's reservoir" have to fall on its surface at small angles in relation to horizon. The first images of Vesta, which will be obtained by Dawn, may show its surface feature.

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