New Insights on the Differentiation of Asteroid Vesta.

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Introduction: Asteroids offer an unique opportunity to study processes of planetesimal accretion and differentiation that took place at the dawn of our Solar System. Fortunately, the current main belt -a reservoir of rocky asteroids between the orbit of Mars and Jupiter- contains planetesimals that survived the latest stages of planetary accretion [1-4]. Among the multitude of main belt asteroids, the 500-km Vesta emerges as one of the best bodies to study the early processes of accretion, differentiation, and subsequent collisional evolution of planetesimals. Much of our ability to study and constrain Vesta's internal structure and differentiation processes come from Howardite, Eucrite and Diogenite (HED) meteorites [e.g., 6].

Pre-Dawn models based on HEDs petrology were consistent with both a i) vertically layered body resulting from the solidification of a magma ocean having a deep olivine-rich mantle [e.g., 7], or ii) heterogeneous internal structure due to serial magmatism resulting in fractional crystallization of diogenitic plutons at the base or within the mantle-crust boundary [e.g., 8].

Olivine on the surface of Vesta: The Dawn spacecraft [9] acquired high-resolution global imaging and spectral and elemental mapping from which surface composition is derived, which enabled us to narrow down differentiation models. In particular, the global mapping unveiled the collisional history of Vesta [10], providing geological setting for the HEDs source location and the observed heterogeneity of the surface composition. The latter data showed the presence of olivine-rich (~50-70%) terrain admixed with howarditic material distributed on the surface at high northerly latitudes [11].

A possible explanation for this unexpected discovery is that the olivine-rich material has been accreted by a collision with an olivine-rich asteroid. While Dawn data cannot definitely rule out this scenario, it appears unlikely given the scarcity of such asteroids within the main belt [12].

On the other hand, the geological setting of this olivine-rich terrain -apparently not associated with the largest Rheasilvia and Veneneia basins- precludes that it is the result of material excavated from the mantle [12], unless some of the degraded large craters seen on the northern hemisphere were capable of exposing mantle rocks. The latter possibility cannot be ruled out with present data, but it seems unlikely given the shallow excavation depth of such impact structures.

Conclusions: Therefore, these results favor both classical and recent magma ocean models [e.g., 13] that predict i) the formation of olivine diogenite in the lower crust, and ii) an internal heterogeneous distribution of lithologies, perhaps due to a non-uniform crustal thickness or to the presence of magma chambers. Interestingly, the presence of crustal non-uniformities may be inferred with the aid of a recent Bouguer gravity map obtained by Dawn [14] and by the distribution of large-scale troughs [15].

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