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Vesta and the basaltic material in the Main Belt

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Abstract

Asteroid 4 (Vesta) is the only large object in the Main Belt (MB) which shows an almost intact basaltic crust. In recent years, however, an increasingly large number of small basaltic asteroids have been discovered from the outer to the innermost regions of the Main Belt. We will review the data on these objects and discuss how it challenges the accepted general scenario of a unique origin while suggesting that differentiation was quite common in the early stages of the Main Belt.

1. Introduction

Basaltic material is reckoned as the result of an extensive geochemical differentiation. By this process small chondritic material accrete in larger bodies leading to its partial fusion and resulting in a body with a dense metallic core, a mantle of lighter olivine-rich material and an even lighter basaltic surface. The basaltic nature of 4 (Vesta) was first inferred by [1] being confirmed in all subsequent works. The spectrum of this asteroid presents two deep absorption bands, at 0.92 and at 2.0 microns, which are representative of basaltic material. Its composition is also similar to that of basaltic achondrite meteorites, specifically the HED suite of meteorites. Due to this similarity, 4 (Vesta) has been considered the parent body of these meteorites being the result of great impacts excavating Vesta´s surface. Part of these fragments, were then transported in near-Earth orbits and further on to the Earth.

In the last twenty years, several basaltic asteroids have been discovered throughout the Main Belt. All these objects, classified as V-type in the diverse taxonomies, have a surface composition similar to that of the HED meteorites. The identification of many V-type asteroids located in the region near Vesta, but far away from the limits of the dynamical family ([2], [3]) first raised the question whether they originated from another parent body. This was strengthen with the discovery [4] of the basaltic surface of 1459 (Magnya), located in the outer MB, as well as other small V-type asteroids in the intermediate MB [5]. Nowadays there are more than 130 asteroids spectroscopically identified as V-type and over two thousand photometrically [6] recognized as putative V-type (Figure 1). The question that arises, thus, is whether they all originate from Vesta, or whether distinct origins can better explain the basaltic material distribution in the MB. The quest to answer this fundamental question has been the object of intense work in the last years and is here reviewed.

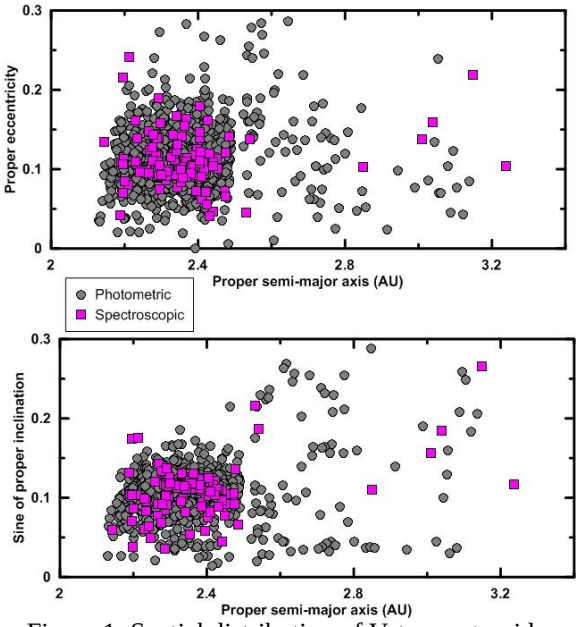

Figure 1: Spatial distribution of V-type asteroids.

2. Methodology

We have compiled all the available observational data for the large set of known V-type small asteroids aiming to identify similarities and differences with Vesta and HED´s laboratory data. In particular, regarding the V-type asteroids in the neighborhood of Vesta, we searched for clues that could relate them to

the two large impact basins recently discovered by the Dawn spacecraft on Vesta [7]. Dynamical results were then, taken into account in order to have a realistic picture on the origin of the diverse V-type asteroids.

3. Discussion and Conclusions

The observational data on a large sample of V-type small asteroids indicate a variety of basaltic compositions which make it difficult to relate to a unique body. The Dawn preliminary spectroscopic data indicate a predominance of Howardite-like composition [8], with great compositional variations across de surface, as most of the observed V-type asteroids. On the other hand, dynamical considerations make it almost impossible for diverse V-type asteroids, in particular in the outer and intermediate MB, to have a common parent body. Our conclusion is that distinct origins can better fit all the observational and dynamical results, although a large fraction of the inner main belt V-type most probably were formed by one or more cratering events on 4 (Vesta). The presence of isolated V-type asteroids not linked to any dynamical family strength the hypothesis of the formation of small basaltic asteroids and, thus, the idea that differentiation was quite common in the early stages of formation of the MB of asteroids. The differentiation of small objects would have occurred in the early stages of the Solar nebula, when the ^{26}Al was abundant and in accordance with recent works [9] which tend to indicate that the HED parent body formed before the H chondrite parent body.

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