Erosion and contamination of the surface of Vesta

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Abstract

The data supplied by the Dawn mission revealed us that Vesta is a small world whose surface underwent a complex and violent evolution. Moreover, the ancient age of Vesta revealed by the HED (Howardite, Eucrite, Diogenite) meteorites indicates that Vesta crossed the whole history of the Solar System and suggests that its surface should have undergone an intense reprocessing due to the interplay of erosion, ejecta blanketing and contamination by exogenous material. Here we discuss how these processes could have affected the surface of Vesta during the different phases of the evolution of the Solar System.

1. Introduction

The first results of the Dawn mission revealed that Vesta underwent a complex geological and collisional history [1, 2, 3] that produced very diversified surface morphology and composition [4, 5, 6]. The confirmation of the compositional link between the HED (Howardite, Eucrite, Diogenite) meteorites and Vesta [5] implies that Vesta is one of the first planetary objects to have formed in the Solar Nebula and that only a small amount of material equivalent to a shell of thickness varying between several hundreds of meters to tens of kilometres [11]. This primordial erosion of the surface of Vesta should be summed to that due to subsequent collisional evolution of Vesta (see e.g. [7, 8] and references therein) and to that due to the formation of Rheasilvia basin [12] and compared to the observed surface composition of Vesta [5] in order to constrain the evolution of the asteroid belt [13] and of the Solar System [7].

Table 1: Erosion of the surface of Vesta due to the Jovian Early Bombardment in a primordial, quiescent protoplanetary disk [11].

<table>
<thead>
<tr>
<th>Migration Scenario</th>
<th>( N_{\text{coll}} )</th>
<th>Crustal Erosion (km)</th>
<th>High-Energy Impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00 AU</td>
<td>2574.13</td>
<td>0.80</td>
<td>0.00</td>
</tr>
<tr>
<td>0.25 AU</td>
<td>3322.95</td>
<td>0.71</td>
<td>0.00</td>
</tr>
<tr>
<td>0.50 AU</td>
<td>4608.26</td>
<td>3.26</td>
<td>0.00</td>
</tr>
<tr>
<td>1.00 AU</td>
<td>7184.23</td>
<td>14.38</td>
<td>0.09</td>
</tr>
</tbody>
</table>

3. Surface Contamination

The collisional evolution of the surface of Vesta during the Jovian Early Bombardment caused the production of a large amount of volatile-rich material from the outer Solar System [9]. The fraction of this material that can survive the impacts...
Table 2: Erosion of the surface of Vesta due to the Jovian Early Bombardment in a collisionally evolved protoplanetary disk [11].

<table>
<thead>
<tr>
<th>Migration Scenario</th>
<th>( N_{\text{coll}} )</th>
<th>Crustal Erosion (km)</th>
<th>High-Energy Impacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00 AU</td>
<td>15158.5</td>
<td>0.58</td>
<td>0.00</td>
</tr>
<tr>
<td>0.25 AU</td>
<td>20976.3</td>
<td>0.70</td>
<td>0.00</td>
</tr>
<tr>
<td>0.50 AU</td>
<td>36132.1</td>
<td>4.56</td>
<td>0.66</td>
</tr>
<tr>
<td>1.00 AU</td>
<td>66419.1</td>
<td>28.07</td>
<td>5.09</td>
</tr>
</tbody>
</table>

and remain on the surface of the asteroid is, however, uncertain and likely extremely small due to the high impact velocities associated to these events and the volatile nature of the material [9]. After the end of the Jovian Early Bombardment and of the depletion of the asteroid belt [7, 8] the rate of delivery of exogenous material on Vesta greatly diminished. It can be estimated, in fact, that all the impacts of asteroids that took place on Vesta across the last 3.5 Gya cumulatively delivered a few \( 10^{19} \) g of exogenous material, of which a few \( 10^{18} \) g would be constituted by dark, carbonaceous material. The overall amount of exogenous material that should be delivered to Vesta is equivalent to a shell with a thickness of a few meters overlapping the present surface of Vesta.

4. Summary and Conclusions

The evolution of the surface of Vesta has been complex and strongly linked to that of the asteroid belt and the Solar System, and the interplay of the different processes across the age of the asteroid make it difficult to separate the various contributions. The low gravity of Vesta likely favoured the mixing of the surface material (both indigenous and exogenous) on a planetary scale. Nevertheless, estimating and accounting for the contribution of the contrasting processes of erosion and contamination is fundamental to link the evolution of Vesta to that of its surrounding environment and thus explore the past of our own Solar System.

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References