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The Coriolis Effect on Vesta's Southern Basin Rheasilvia

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Abstract

Vesta's giant south polar impact basin Rheasilvia exhibits a spiral deformation pattern. We tested whether or not the Coriolis force has caused the curved features of the pattern. For this we mapped the curved features and calculated the velocities along them using the Coriolis theory. The resulting velocities indicate that the Coriolis force is a candidate to have caused the spiral deformation pattern.

1. Introduction

The Dawn space craft orbited asteroid Vesta from August 2011 to August 2012 [1]. The on-board Framing Camera (FC) collected image data with a resolution up to 20 m/pixel in the Low Altitude Mapping Orbit (LAMO) [2]. Stereo images from the High Altitude Mapping Orbit (HAMO) were used to construct a Digital Terrain Model (DTM) of Vesta's surface [3].
The FC images and the DTM revealed a large impact basin in the southern hemisphere, named Rheasilvia. Rheasilvia is a complex crater with the central peak nearly coinciding with Vesta's south pole. Its diameter of about 500 km has the dimension of Vesta's diameter (525 km) [2, 4]. This and Vesta's relatively short rotation period of 5.3 hours indicate that the Coriolis force is likely to have an effect on mass motions within the Rheasilvia basin [5]. Indeed, a pervasive spiral deformation pattern has been observed [6]. The spirals can be caused by Coriolis deflected mass motions correlated with the formation or degradation process of Rheasilvia.
We mapped the spiral pattern and determined the Coriolis velocity along each mapped curved feature. The result is the velocity, a moving mass has to have in order to cause the mapped curvature with the given rotation period of Vesta.

2. The Coriolis Effect

The Coriolis force is a fictional force associated with rotating systems. The rotation deflects the motion perpendicular to the rotation axis to cause curved trajectories. The effect is well known from oceanic currents and wind movements on Earth [7]. The Coriolis force $\vec{F_C}$ is given by

$$\vec{F_C} = -2m\vec{\Omega} \times \vec{v} \tag{1}$$

where m is the mass of the moving body, $\vec{\Omega}$ the angular velocity of the rotating body and $\vec{v}$ the velocity of the moving object.
The trajectory of a mass moving in the horizontal plane on a rotating sphere is described by a circle with inertial radius R. The inertial radius is dependent on the magnitude of the velocity $|\vec{v}|$, the latitude ϕ and the magnitude of the angular velocity $|\vec{\Omega}|$. It is given by

$$R = \frac{|\vec{v}|}{2|\vec{\Omega}|\sin\phi}. \tag{2}$$

Note that the radius is only dependent on the speed of the moving body but not on its mass. Solving Eq. 2 for the velocity $|\vec{v}|$ yields

$$|\vec{v}| = 2R|\vec{\Omega}|\sin\phi. \tag{3}$$

3. Method

We mapped the most prominent curved features of the spiral deformation pattern in the Rheasilvia basin and used the data to calculate their three dimensional location. A reference spheroid of 285 km by 229 km was used to approximate Vesta's shape and to determine the three dimensional location. At each point along a curved feature we approximated a circle and determined the inertial radius R. Knowing the angular velocity $\vec{\Omega}$, the latitude ϕ and the inertial radius R, we calculated the velocity of the motion using Eq. 3.

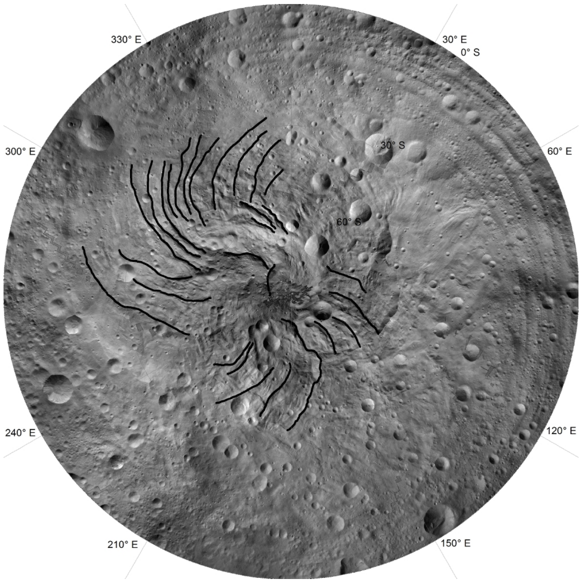

Figure 1: Stereographic projection of Vesta's southern hemisphere with curved features.

4. Results

We calculated the velocity of mass movements along a number of curved features in the Rheasilvia basin and produced a velocity profile for each feature. The velocities indicate that moving masses on Vesta are likely to be deflected by the Coriolis force to form the observed curved features.

The sign of the velocity on the central peak requires a motion away from the rotation axis whereas the sign of the velocity on the crater rim requires a motion towards the axis. Both movements can be explained by masses being accelerated towards the basin floor. This is expected during the crater collapse process.

However, there other possible explanations for curved features within the Rheasilvia basin such as the crater collapse process of a bi-layered target with a lower ductile and and a upper brittle layer [8], or an oblique impact [9].

5. Summary and Conclusions

We mapped and analysed the spiral deformation pattern within Vesta's south polar basin Rheasilvia to understand its origin. Assuming that the Coriolis force has caused the curvature of the pattern, we calculated the corresponding velocities at each point along a curved feature. The velocities are in agreement with the idea of the collapse process of a crater. Thus the Coriolis effect is a possible candidate to have caused the spiral pattern within Rheasilvia.

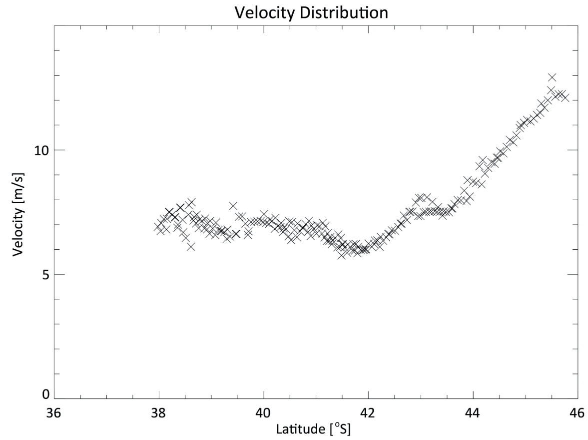

Figure 2: An example velocity profile along a curved feature on the crater wall. The velocity increases towards the crater floor (higher latitudes).

References

[1] Russell, C. T. et al.: Dawn completes its mission at 4 Vesta, Meteorit. Planet. Sci., pp. 1-14, 2013.

[2] Jaumann, R. et al.: Vesta's shape and morphology, Science, Vol. 336, pp. 687-690, 2012.

[3] Preusker, F. et al.: Topography of Vesta from Dawn FC stereo images, European Planetary Science Congress, 23 – 28 September 2012, Madrid, Spain, 2012.

[4] Russell, C. T. et al.: Dawn at Vesta: Testing the protoplanetary paradigm, Science, Vol. 336, pp. 684-686, 2012.

[5] Jutzi, M. et al.: The structure of the asteroid 4 Vesta as revealed by models of planet-scale collisions, Nature, Vol. 494, pp. 207-210, 2013.

[6] Schenk, P. et al.: The geologically recent giant impact basins at Vesta's south pole, Science, Vol. 336, pp. 694-697, 2012.

[7] Etling, R. et al.: Theoretische Meteorologie: eine Einführung, Springer, 2008.

[8] Allemand, P. and Thomas, P.: Small-scale models of multiring basins, J. Geophys. Res., Vol. 104, pp. 16501–16514, 1999.

[9] Scherler, D. et al.: Structural record of an oblique impact, Earth Planet. Sci. Lett., Vol. 248, pp. 43-53, 2006.