Paper N° P51A-1175

EJECTAS COVERAGE ON ASTEROID 433-EROS : EFFECT ON THE FREQUENCY SIZE DISTRIBUTION OF THE CRATERS

C. Blitz (1), P. Lognonné (1), M. Lefeuvre and D. Komatitsch (2)
(1) Institut de Physique du Globe de Paris, Département de Géophysique Spatiale et Planétaire -
(2) Université de Pau et des Pays de l'Adour, Laboratoire de modélisation et d'imagerie en Géosciences

INTRODUCTION

Present at the surface of asteroids, the regolith is generally defined as a superficial blanket of loose rock material produced by ejectas from impacts events. This regolith is thought to be, such as overprinting, erosion, or seismic shaking, a possible source explaining the deficit in small craters observed on 433-Eros (Chapman et al., 2002). Although many authors (Richardson et al., 2005, Thomas and Robinson, 2005) have shown that seismic shaking can be the process causing the paucity of small craters, we propose to study the effect of global ejectas coverage. The total area of low craters density on Eros has been estimated to be ~ 390 km², with a depth of ~ 50 m (Thomas and Robinson, 2005). Although a Shoemaker-like crater does not produce enough ejectas to explain the coverage of a such surface (15 km3 'only' according to Thomas and Robinson, 2005), the additional contribution of the 45 craters between 1 km and 5.3 km of diameter leads to 12 km3 of additional ejectas (Thomas et al., 2001). This total volume (27 km3) could fill the area of low craters density. Then, in the present study, we aim 1) to quantify the effect of ejectas coverage affecting craters all along a bombardment period, 2) to test if the distribution of Eros craters could be explained by a 4.5 Byrs bombardment. Most of Eros craters have been created during its stay in the Main Belt, we will then adopt the impactors distribution suggested by O'Brien et al., 2006. Different bombardments will be tested, all lasting 4.5 Byrs, assuming the hypothesis of a stronger impactors flux between 4.5 and 3.8 Byrs. Indeed, Gomes et al., 2005 have suggested a depletion of 97 % of the mass of the disk after the Late Heavy Bombardment, what affected the impactors flux of the Main Belt. From these simulations, an estimation of the regolith thickness of the asteroid 433-Eros will be suggested.

RESULTS / DISCUSSION:

Based on 4.5 Byrs bombardments, we have attempted to create the distribution of craters on Eros, including the deficit of small craters. Then, we display the preliminary results of R-plots from models with and without the effect of ejectas coverage (figure 3).

- The two simulated R-plots show a decreasing of the numbers of small craters when the effect of ejectas coverage is assumed. From these simulations, we suggest that the paucity in small craters observed on Eros can be a consequence of ejectas coverage from impacts.
- These R-plots can be compared to the R-plot of the craters observed on Eros (Chapman et al., 2002, Robinson et al., 2002). Although the two simulated R-plots are not superposing the data, the model that best explain the distribution of craters at the surface of Eros is the model 1. Then, the distribution of Eros craters could be explained by a 4.5 Byrs bombardment with a very high impactors flux in the first 700 Myrs and with a current impactor flux from 3.8 Byrs to now. This implies that Eros is very old.

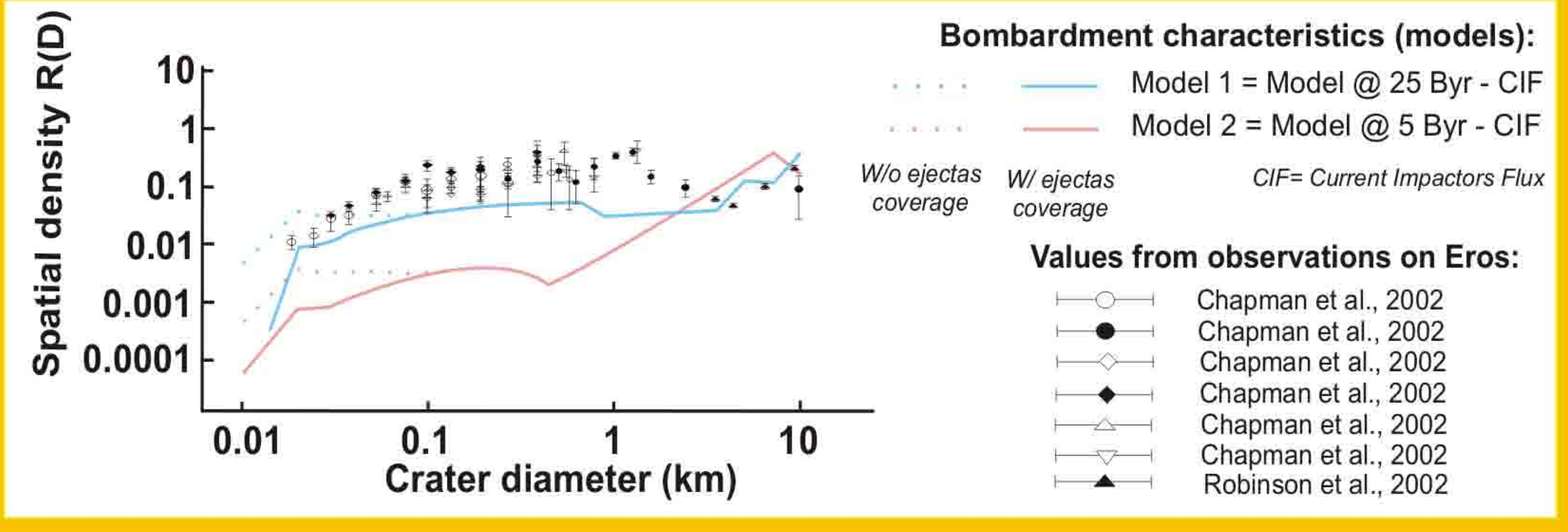

Figure 3. Relative frequency size distribution of craters as a function of crater diameter.

THE SIMULATION:

We assume a population of projectiles of density 3g/cm3, impacting the asteroid randomly at a main belt velocity of 5.3 km/s (Bottke et al., 1994) during 4.5 Byrs. The impactors sizes are ranging from 1 m to 600 m (to create craters as large as 10 km), as it can be seen on the figure 2. Two different bombardments have been tested, each leading to different numbers of impactors, and thus, different rates of filled craters (see Table 1). The two simulations performed are considering a variation in the impactors flux: during the first 700 Myrs (from 4.5 Byrs to 3.8 Byrs) the flux of projectiles is 5 times (model 2) or 30 times (model 1) higher than the current one, and during the remaining 3.8 Byrs, the impactors flux is the current one, obtained from O'Brien et al., 2006. When the impactors flux is 5 or 30 times the current one, the number of projectiles of a given size is 5 or 30 times the number of projectiles with the current flux. Thus, considering the number of projectiles, the combination of two different impactors flux corresponds to an equivalent exposure time with a current impactors flux. Assuming a current impactors flux all along the simulations, we have then performed one simulation with an equivalent bombardment duration of 25 Byrs (model 1), and the other simulation with an equivalent bombardment duration of 5 Byrs (model 2, see figure 1).

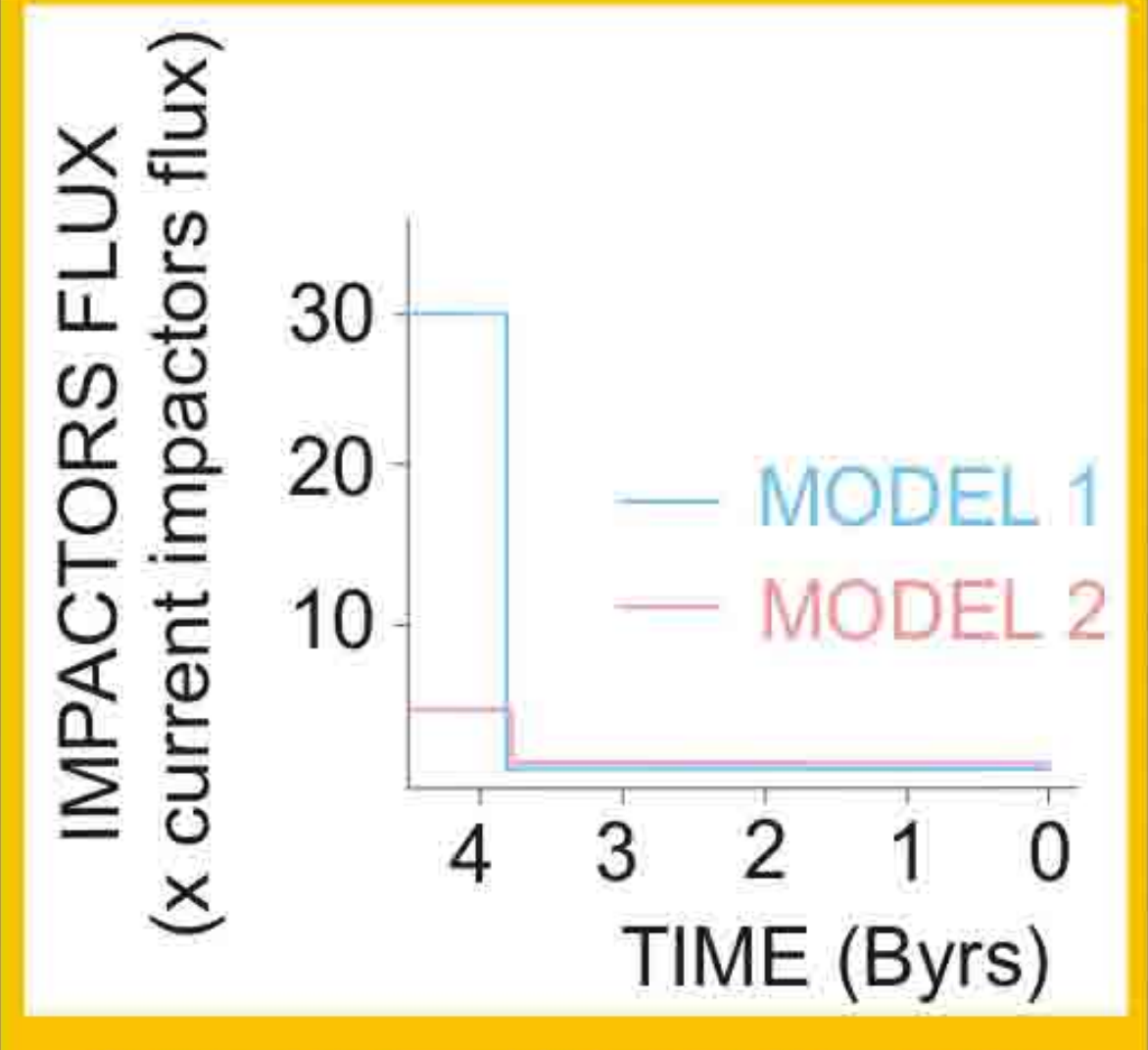

Figure 1. Description of the models

Considering a mean escape velocity of 10 m/s on Eros, the reimpacted volumes of ejectas from each crater are estimated with the scaling laws (Holsapple, 1993). From this method, and given the impactors and target characteristics, all the events are strength dominated, with a constant rate of 33% of escaped ejectas. We assume that each crater leads to a homogeneous layer of regolith, then, all the impacts produce cumulative regolith thicknesses. From the figure 5, we can see that the impacts linked to the largest projectiles have the highest contribution in the creation of the regolith blanket. For example, an impactor of 600 m leads to a crater of ~ 10 km of diameter, creating 20 m of regolith thickness. For a given crater, if the total regolith thickness produced by the following successive impacts is greater than the depth of the crater, it is assumed that the crater is entirely filled with material. With this consideration, we can quantify the number of totally filled craters (see Table 1), and knowing the number and the sizes of not filled craters (those that could be seen on the surface of Eros), we can plot a relative frequency size distribution of these craters (R-plots, figure 3).

Equivalent exposure time	Number of impacts	Number of filled craters	Number of not filled craters	% of not filled craters
25 Byrs (model 1)	626,224	371,309	254,915	41
5 Byrs (model 2)	375,720	342,485	33,235	9

Table 1. Numbers of impacts and states of the resulting craters after the tested bombardments.

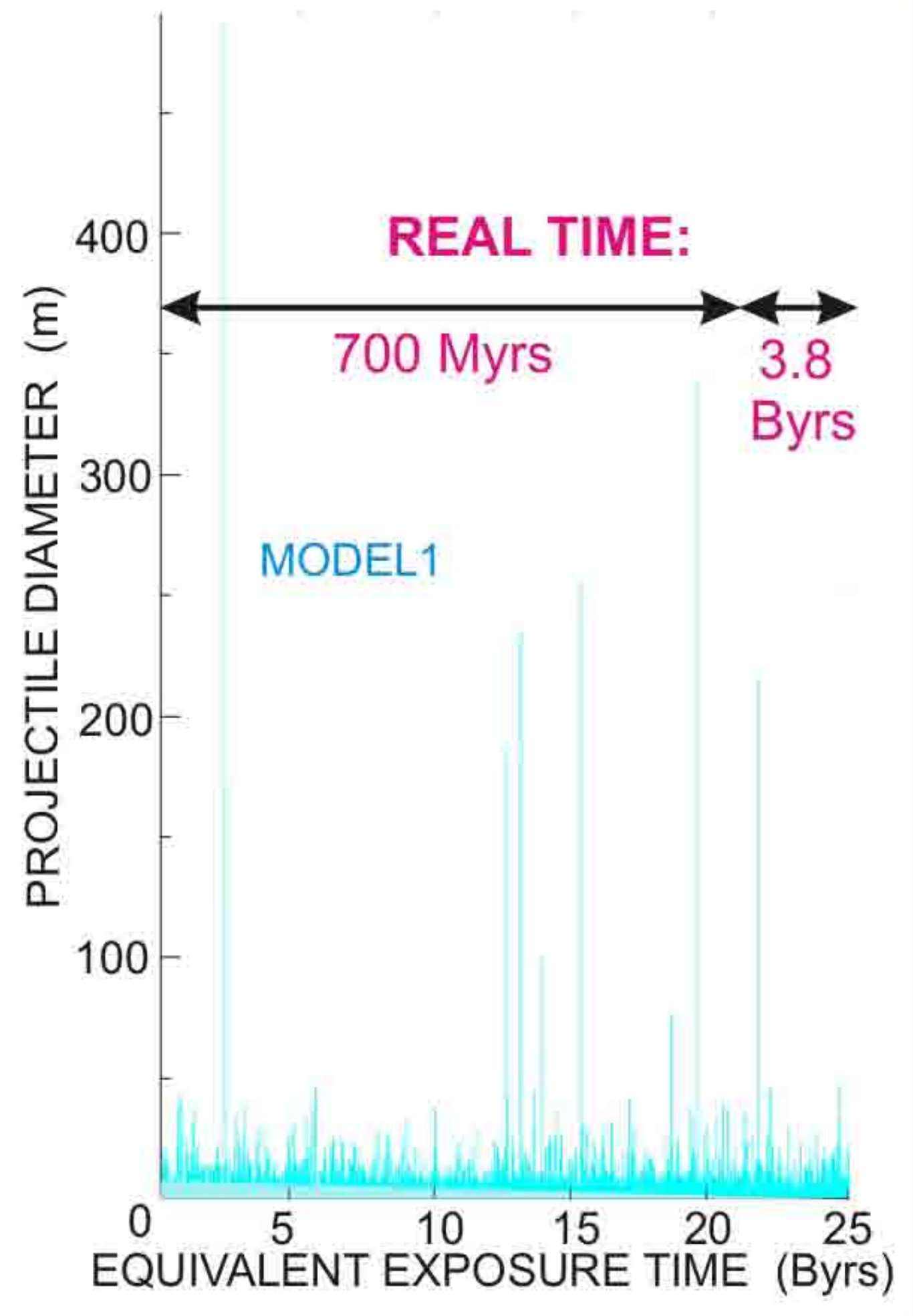

Figure 2. Diameters of projectiles as a function of time for the model 1.

IMPLICATIONS ON REGOLITH THICKNESS :

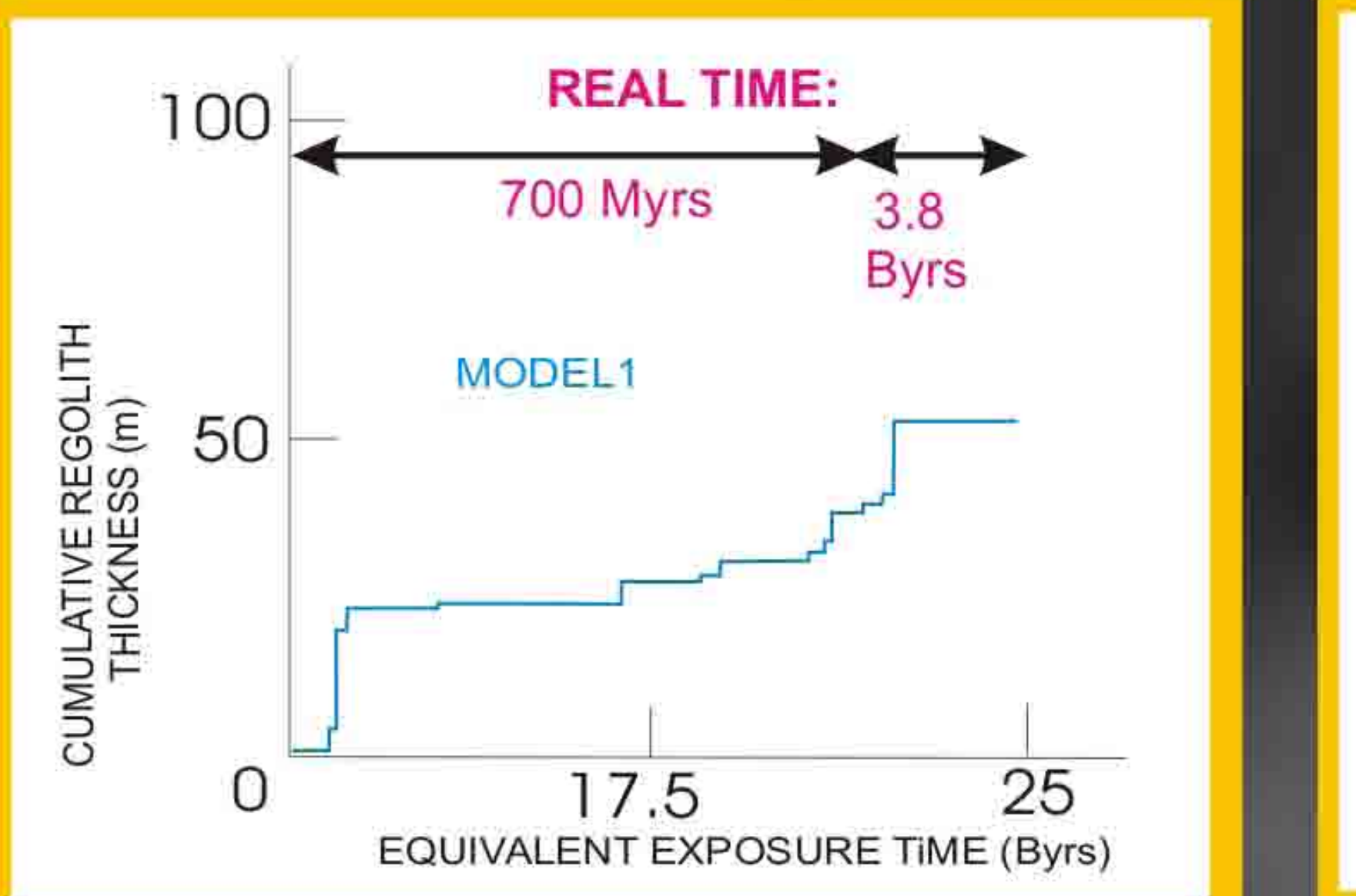

Figure 4. Cumulative regolith thickness as a function of equivalent exposure time for the Model 1

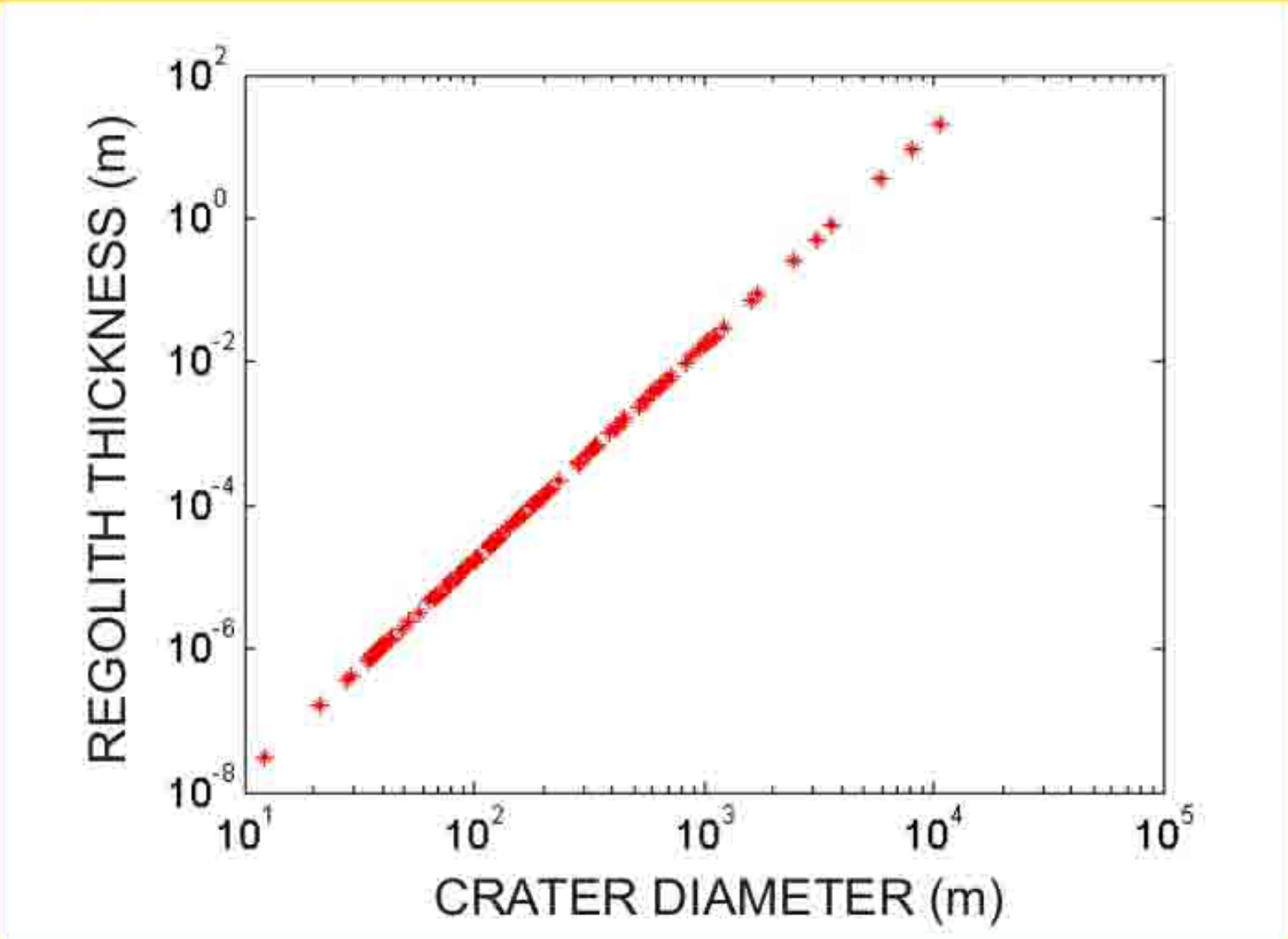

Figure 5. Regolith thickness produced by each one of the 104 largest craters observed on Eros.

1/ Estimation fom this study

Longer is the equivalent exposure time of a model, higher is the number of impacts, and thicker is the regolith produced. If we assume a best agreement between data and models for the bombardment model 1, such bombardment leads to a total regolith thickness of 52 m, as it can be seen on figure 4 (the model 2 leads to 25 m of regolith thickness). The figure 5 displays the thickness of regolith created by a given crater diameter. It is shown that craters of 8 km and 10 km create respectively 10 m and 20 m of regolith. From this, it can be inferred that the main contribution on the regolith formation comes from the largest craters.

2/ Contribution from the visible caters

To make an estimation of the contribution of the visible craters on Eros, we have computed the volume of reimpacted ejectas from the population of the 104 largest craters observed on Eros (data from Olivier Barnouin-Jha). The figure 5 displays the regolith thicknesses created by each one of the 104 largest craters of Eros. The cumulative regolith thickness (total thickness) is estimated at 35 m. Then, if an impactors flux 30 times stronger than the current one has occurred during the first 700 Myrs (odel 1), the visible craters on Eros surface have contributed to 70% of the total regolith thickness.

CONCLUSION

The comparison between the modelled R-plots and the R-plot obtained from the data of Eros craters show that the process of ejectas coverage can be a plausible mechanism to explain the paucity of small craters. The best agreement between our models and the data is obtained for a 4.5 Byrs bombardment with an impactor flux 30 times stronger than the current one during the first 700 Myrs. This implies that Eros has been affected by the strong bombardment of the early Solar System, and thus, Eros would be older than 3.8 Byrs. However, this R-plot model does not superpose the data points, so other hypothesis should be considered such as the instability of the asteroids orbits in the Main Belt during the Heavy Late Bombardment. The ejectas coverage simulations lead to an estimation of 52 m of regolith thickness. This is in good agreement with the litterature (Robinson et al., 2002), and 70% of this thickness could have been created by visible craters, with a major contribution of craters with diameters greater than 7km. Since the ejectas coverage mechanism seems to have a contribution on small craters paucity such as the seismic shaking process, maybe a mix of these 2 mechanisms could be responsible for the deficit of small craters observed on the asteroid Eros.

REFERENCES

Bottke, W. F. J., Nolan, M. C., Greenberg, R. and Kolvoord, R. A . (1994). Velocity distributions among colliding asteroids. Icarus, 107:255-268. Chapman, R. C., Merline, W. J., Thomas, P. C. et al. (2002), Impact history of Eros: craters and boulders. Icarus, 155:104-118. Holsapple, K. A. (1993), The scaling of impact processes in planetary sciences. Annual Review of Earth and Planetary Sciences, 21:333-73. Michel, P., Farinella, P., Froeschlé, C. (1998). Dynamics of Eros. Astron. J. 116 :20232031. O'Brien, D.P., Greenberg, R. And Richardson,J. E. (2006), Craters on asteroids: Reconciling diverse impact records with a common impacting population. Icarus, 183:79-92. Richardson, J. E., Melosh, H. J., Greenberg, R. J. and O'Brien, D. P. (2005), The global effects of impact-induced seismic activity on fractured asteroid surface morphology. Icarus, 179:325-349. Robinson, M. S., Thomas, P. C, Veverka, J. et al. (2002), The geology of 433 Eros. Meteoritics and planetary sciences, 37:1651-1684. Thomas, P. C., Veverka, J., Robinson, M. S. and S. Murchie (2001), Shoemaker crater as the source of most ejecta blocks on the asteroid 433-Eros. Nature, 413:394-396. Thomas, P. C.; Robinson, M. S. (2005), Seismic resurfacing by a single impact on the asteroid 433 Eros. Nature. 436, Issue 7049:366-369. Gomes, R., Levison, H. F., Tsiganis, K. And Morbidelli, A. (2005). Origin of the cataclysmic Late Heavy Bombardment period of the terrestrial planets. Nature, 435:466:469