Study of Phobos' geological anisotropy: Implication for the co-evolution of resurfacing and orbital dynamics

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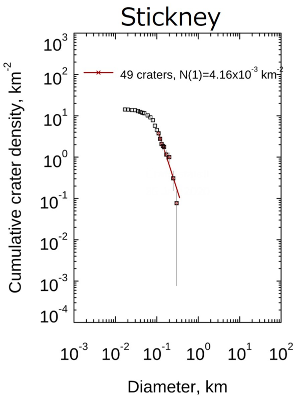
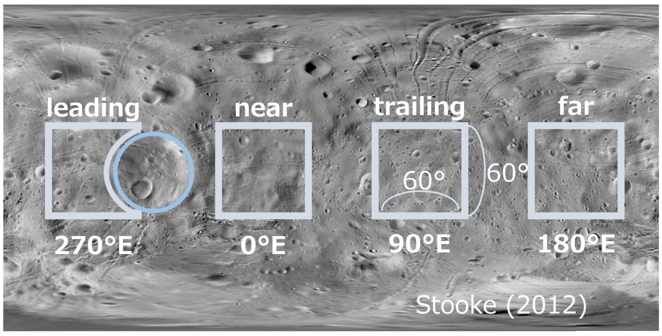
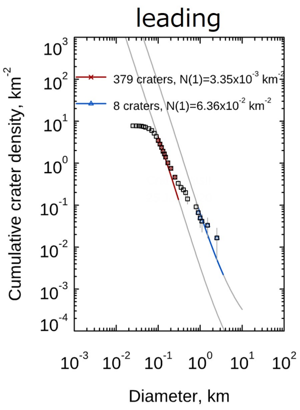
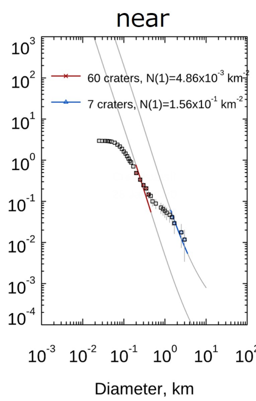
Comparative study of the Moon and Martian satellites is crucial for understanding their formation and evolution. Both the Moon and Martian satellites are tidally locked, undergoing complex resurfacing in planetary gravity. Our study examines the geological anisotropy of Phobos for the understanding of the co-evolution of its resurfacing and orbital dynamics.
We selected five regions to analyze the anisotropy in crater distribution and density with respect to the axis of rotation and the effects associated with the Stickney impact. The four square areas individually cover 60° longitude ×60° latitude along the equator on the near (0°E), far (180°E), leading (270°E), and trailing (90°E) sides, respectively. The rest is the interior of the Stickney crater. We obtained Crater-Size Frequency Distribution (CSFD) for the five regions and yielded "D_{kink}" to the largest crater diameter showing deflection in the CSFD. By fitting the Phobos' crater production function, which is the CSFD model corresponding to the crater formation rate per unit time and area, to the acquired CSFD data, we derived the cumulative crater densities for craters with diameters greater than 1km: $N_{old}(D>1\text{km})$ [km^{-2}] for craters with diameters exceeding D_{kink} and $N_{young}(D>1\text{km})$ [km^{-2}] for craters with diameters smaller than D_{kink}. We estimated the maximum thickness of the ejecta blanket in each square area from the D_{kink} of each CSFD. We measured the volume of the ejecta blanket deposited within each 90° longitude quadrant. The volume of the blanket layer [km^3] within each of the four quadrants was computed by multiplying the quadrant's area [km^2] by the blanket thickness [m] within each square area. The sum for all four quadrants yields the volume of the ejecta blanket layer for the entire surface of Phobos.
The CSFDs showed no kink in Stickney but were evident in the four square areas. Specifically, the blanket thickness, $N_{young}(D>1\text{km})$, and $N_{old}(D>1\text{km})$ were minimal in the leading and maximal in the far side. The total volume of the ejecta blanket covering the entire surface of Phobos was estimated to be 90 km^3. Previous studies reported 80-95% of impact ejecta re-impacting and depositing on its surface. 90 km^3 of the ejecta blanket volume is consistent with 80-95% of the volume of Stickney (50–120km^3). The observed consistency provides compelling evidence supporting Stickney's substantial impact on the global resurfacing of Phobos. Moreover, our findings support the hypothesis suggesting that Phobos underwent a process of de-spinning, eventually reaching its current tidal lock position, which is approximately 180° in longitude from its original orientation before the Stickney impact. This de-spinning is inferred from a more pronounced $N_{old}(D>1\text{km})$ on the trailing side compared to the leading side. Finally, the far side displays the most substantial resurfacing caused by the Stickney ejecta. Then, we propose a scenario where the maximum Stickney ejecta flux is impacted and deposited on the current far side during the period of the desynchronization from its tidal lock.

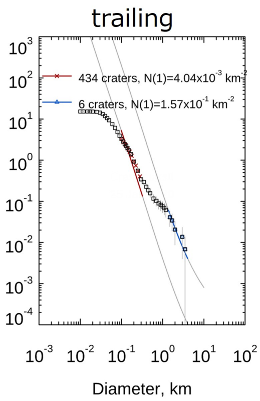
Keywords: Martian satellites, Crater counting, Resurfacing, Orbital dynamics

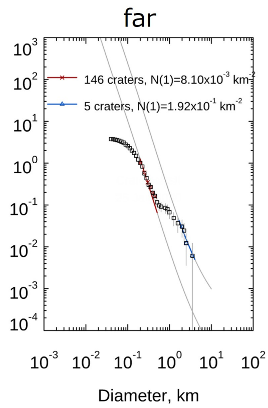

Stickney
49 craters, N(1)=4.16x10^-3 km^-2
Cumulative crater density, km^-2
Diameter, km


leading
near
trailing
far
60°
60°
270°E
0°E
90°E
180°E
Stooke (2012)


leading
379 craters, N(1)=3.35x10^-3 km^-2
8 craters, N(1)=6.36x10^-2 km^-2
Cumulative crater density, km^-2
Diameter, km


near
60 craters, N(1)=4.86x10^-3 km^-2
7 craters, N(1)=1.56x10^-1 km^-2
Diameter, km


trailing
434 craters, N(1)=4.04x10^-3 km^-2
6 craters, N(1)=1.57x10^-1 km^-2
Diameter, km


far
146 craters, N(1)=8.10x10^-3 km^-2
5 craters, N(1)=1.92x10^-1 km^-2
Diameter, km