ERODING THE HYDROSPHERE OF 1 CERES: WATER MASS LOSS DUE TO IMPACT INDUCED SUBLIMATION.
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Introduction: Asteroid 1 Ceres, the current target of NASA's Dawn mission, is thought to be composed of a silicate core overlain by an H_2O-ice rich mantle [1]. Depending on the thickness of this mantle and the abundance of salts leached from an early phase of hydrothermal activity, a liquid water ocean may exist above Ceres' core-mantle boundary: a potential habitat for life [2].

Water ice is not stable at Ceres' surface. If not protected by a volatile-poor regolith, ice sublimates into vapor and escapes the body [3]. Crater excavation is incredibly efficient at exposing water ice- and melt-rich material at Ceres' surface, which will be lost from the body until a new protective regolith can be rebuilt. As such, each impact that occurs on Ceres leads to a net loss of water from the asteroid. This 'impact-induced sublimation' gradually erodes the hydrosphere and, over time, can expose deeply buried material.

Estimating the Total Water Volume Lost from Ceres over Solar System History: 4 Vesta, the other target of the Dawn mission, is dominated by impact craters. Because Ceres is larger than Vesta and has a similar heliocentric orbit, it should experience a proportionally larger flux of impacts [4]. We assume that the size-frequency distribution of this impactor flux matches observations of the main asteroid belt and relate impactor size to final crater diameter following [5]. The total number of craters formed on Ceres over solar system history is determined by matching the crater size-frequency distribution observed on Vesta. To address the stochastic variability in cratering at large impactor sizes we use a Monte Carlo method to sample our impactor population, producing 100 potential impact cratering histories for Ceres.

We assume that each crater will expose icy material within an area $\mathrm{A} = \pi(\gamma \mathrm{r})^2$, where r is the radius of the crater and γ is a dimensionless scaling constant that accounts for both the crater's ejecta blanket and the amount of ice-rich material actually exposed within the crater. γ does not necessarily scale linearly with r, and is not neccesarily greater than one. Ice will sublimate from this region until a new protective lag deposit of depth H, composed of silicates left behind after the icy component has sublimated, is rebuilt. For an initial silicate concentration $\mathrm{c} = \mathrm{V_{silicate}}/\mathrm{V_{total}}$ the total water ice volume lost per impact is $\mathrm{V_{loss}} = \mathrm{AH}(\mathrm{c}^{-1} - 1)$. Combining this very simple per-impact estimate with Monte Carlo determined impact histories quantifies the total amount of water lost from Ceres over solar system history [Fig. 1], and demonstrates that impact-induced sublimation may have removed many kilometers of ice from the asteroid's hydrosphere.

This simple model is a preliminary estimate, meant only to demonstrate the importance of this process on Ceres. The effects of ice loss from the ejecta blankets of craters ($\gamma > 1$), and impact melt (which vaporizes on extremely short timescales) will add to these results.

Effect of Ice Loss on Exposing Deep Materials: While comparative planetology with icy satellites is warrented in many areas, extensive ice shell erosion via impact-induced sublimation may be a process specific to Ceres and other icy asteroids, as their surfaces are warmer by ~100 K, which allows for rapid sublimation and vaporization [5]. The removal of mass via this mechanism may lead to the gradual exposure of material increasingly enriched in salts, providing constraints on the chemistry of Ceres' early ocean, and helping to assess the astrobiological significance of this protoplanet.

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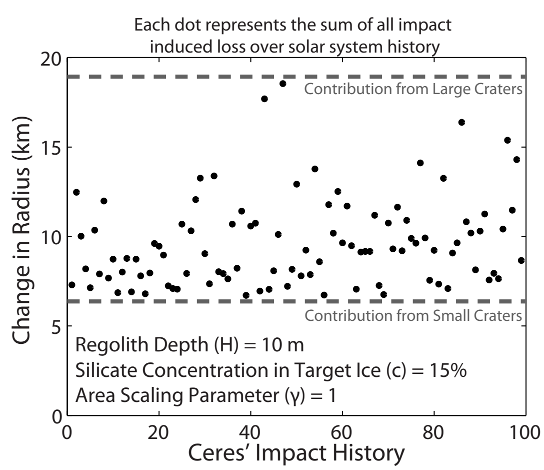

Fig 1: Total volume of water lost via impact-induced sublimation for 100 potential impact histories, expressed as reduction in Ceres' radius.