Partial Differentiation of Mimas by Tidal Heating preserves its Geologically Inert Surface

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Abstract

Mimas, Saturn's closest mid-sized moon, has orbital properties that favor even stronger tidal heating than in Enceladus, where an intense tidal dissipation drives spectacular geysers. Yet, observations made by the Cassini-Huygens mission revealed that Mimas has a heavily cratered surface, suggesting a cold and frozen interior. However, analyses of its librations [1] and periapsis drift [2] indicate that a 20-30 km thick ice shell above a subsurface ocean is needed to explain these dynamical constraints. Within the classical framework for icy moon assuming already differentiated interiors [3], the formation of such an ocean should induce global contraction and widespread fracturing of the ice shell, not observed on Mimas. An ocean without surface disruption thus challenges the standard picture of a fully differentiated interior, but could be explained if Mimas remains partially undifferentiated. In this study, we couple the 1D code BOREAS solving biphasic advection-compaction equations [4] and a code computing 1D tidal heating profiles [5], to investigate the effect of tidal heating on the differentiation of Mimas. We start from an undifferentiated interior made of an ice-rock mixture and prescribe an initial eccentricity about 3 times the current one. We show that the formation of an ocean in Mimas occurs in timescales of about 100-200 Myrs, for a current ocean beneath an ice shell 20-30 km thick and without exceeding a radius change which would imply breaking of the ice shell. These dynamics of partial differentiation by tidal heating in a few hundred millions years could change the usual representations of Saturn's mid-sized moons interiors, and our understanding of the recent evolution of the Saturn's environment.

References

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