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Stagnant lid convection in the medium-sized icy satelites of Saturn

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The multi-faceted Saturnian system includes a group of medium-sized, regular satellites in a size range from bareley 200 km to well over 700 km. They comprise Mimas, Enceladus, Tethys, Dione, Rhea and Iapetus. Their low densities indicate that ice is a major constituent. We construct models of thermal evolution for all of these bodies except the tidally heated Enceladus, as we do not take into account heat sources other than accretional and radiogenic heating in the silicate fraction of the satellites.

Previous models of terrestrial planetary bodies have assumed the boundary between the lithosphere and the convecting mantle to be defined by an isotherm at the minimum temperature enabling solid state creep on geological time scales. As was demonstrated in laboratory experiments and verified in theoretical studies, convection in a volumetrically heated fluid with strongly temperature-dependent viscosity occurs in a sublayer located underneath a stagnant lid. The viscosity contrast across the sublayer remains constant, while the temperature at the bottom of the stagnant lid varies with time.

In our model calculations, we apply the concept of stagnant lid convection to the icy satellites stated above. The most significant model parameters are satellite radius, mean density, silicate volume fraction, and ambient temperature at time of accretion. Furthermore, we assume homogeneous accretion.

Initially, heat generated in the satellites is transported by conduction. If internal heating is sufficient, a stagnant lid covering a convecting sublayer may form during thermal history. At first, the convecting sublayer may enclose a conducting core, which quickly dissolves. As the satellite cools, its stagnant lid grows until convection ceases and conduction becomes the sole mode of heat transfer again.

The temperatures at the upper boundary of the convecting region are higher than in previous models, as is the quasi-isothermal temperature characterizing this layer. Results of thermal history model calculations are reviewed with respect to observed present-day surface features on the Saturnian satellites.