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Medium-sized icy satellites in the outer solar system – differentiation due to radiogenic heating in Charon or the moons of Uranus?

K. Multhaup (1), T.Spohn (1,2)

(1) Institut für Planetologie, (2) Deutsches Zentrum für Luft- und Raumfahrt

A thermal history model developed for medium-sized icy satellites containing silicate rock at low volume fractions is applied to Charon and five satellites of Uranus. The model assumes stagnant lid convection in homogeneously accreted bodies either confined to a spherical shell or encompassing the whole interior below the immobile surface layer. We employ a simple model for accretion assuming that infalling planetesimals deposit a fraction of their kinetic energy as heat at the instantaneous surface of the growing moon. Rheology parameters are chosen to match those of ice I, although the satellites under consideration likely contain admixtures of lighter constituents. Consequences thereof are discussed.

Thermal evolution calculations considering radiogenic heating by long-lived isotopes suggest that Ariel, Umbriel, Titania, Oberon and Charon may have started to differentiate after a few hundred million years of evolution. Results for Miranda – the smallest satellite of Uranus – however, indicate that it never convected or differentiated. Miranda's interior temperature was found to be not even close to the melting temperatures of reasonable mixtures of water and ammonia. This finding is in contrast to its heavily modified surface and supports theories that propose alternative heating mechanisms such as early tidal heating. Except for Miranda, our results lend support to differentiated icy satellite models.

We also point out parallels to previously published results obtained for several of Saturn's icy satellites (Multhaup and Spohn, 2007). The predicted early histories of Ariel, Umbriel and Charon are evocative of Dione's and Rhea's, while Miranda's resembles that of Mimas.