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Differentiation, mineralogy and melting of Rhea

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Rhea is a medium sized icy satellite (MIS) of Saturn. It is built of mixtures of rocks and ices. The rocky component is believed to be of chondritic composition. The main component of ices is frozen H_2O. Initially Rhea was built from a homogenous mixture of those two components. After accretion the temperature of the satellites increased that allowed for the separation of rocky component from the ices. During this differentiation the high density silicate grains sink in the liquid, eventually forming the central core. The low density matter forms an upper layer. Analysis of the Doppler data acquired by the Cassini spacecraft yields the mass of Rhea and its gravity field with unprecedented accuracy - Iess, et al., 2007, Icarus 190, 585-593. Eventually they conclude: "The one model that fits the gravity data and is self-consistent [. . .] is an "almost undifferentiated" Rhea, in which a very large uniform core is surrounded by a relatively thin ice shell containing no rock at all".

In the present paper we try to find explanation of these observations by thermal model of evolution. Comparing to our previous models, we include here also the influence of the chemical reactions. Our numerical model is based on the parameterized theory of convection combined with FDM (Finite Difference Method). The approach is based on the 1 dimensional equation of the heat transfer in spherical coordinates. The model includes sources and sinks of the heat: radiogenic heat resulting from the decay of isotopes, latent heat of melting, latent heat of solidification, and chemical reactions. The heat of accretion is included as initial temperature of the accreted layer. The heat transported by convection is included by multiplying the coefficient of the heat conduction in the considered layer by the Nusselt number.

We found that partial differentiation followed by uprising of light component is consistent with observations of gravity and surface of Rhea if silicate density is high (i.e. 3500 kg/m3). However, our calculation indicates that partial melting is possible only for narrow range of parameters. It makes possible to determine the time of accretion of Rhea. Without consideration of chemical reaction the time from forming CAI to the end of accretion is probably from 2.9 to 4.1 My. However, if chemical reactions are included the age cannot be determined with the same precision because the observational data are in agreement with the fully differentiated model.