

**DIFFERENTIATION, MINERALOGY AND MELTING OF RHEA** L. Czechowski<sup>1</sup>, A. Łosiak<sup>2</sup>. <sup>1</sup>Institute of Geophysics, Department of Physics, University of Warsaw, ul. Pasteura 7, 02-093 Warszawa, Poland ([lczecho@op.pl](mailto:lczecho@op.pl)). <sup>2</sup>Department of Lithospheric Research, University of Vienna, Althanstrasse 14, 1090 Vienna, Austria ([anna.losiak@univie.ac.at](mailto:anna.losiak@univie.ac.at))

**Introduction:** 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 [5, 6]. The main component of ices is frozen H<sub>2</sub>O. Initially Rhea was built from a homogeneous mixture of those two components. After accretion the temperature of the satellites increased [eg. 3, 7] what allowed for the separation of rocky component from the ices (known as differentiation). The differentiation is possible if the icy component is molten in the large part of the satellite interior. 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 on November 26, 2005 yields the mass of Rhea and its gravity field with unprecedented accuracy [4]. It was found that Rhea is in hydrostatic equilibrium. Moreover, models with a constant silicate mass fraction throughout the body cannot account for the determined quadrupole coefficients of the gravity. Eventually, [4] 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.

**Numerical model:** The parameterized theory of convection combined with FDM (Finite Difference Method) approach is chosen for the present research [1, 2]. The approach is based on the 1 dimensional equation of the heat transfer in spherical coordinates:

$$\rho c_p \frac{\partial T(r,t)}{\partial t} = \text{div}(k(r,T) \text{grad} T(r,t)) + Q(r,T), \quad (1)$$

where  $r$  is the radial distance (spherical coordinate),  $\rho$  is the density [kg m<sup>-3</sup>],  $c_p$  [J kg<sup>-1</sup> K<sup>-1</sup>] is the specific heat,  $Q$  [W kg<sup>-1</sup>] is the heat rate, and  $k$  [W m<sup>-1</sup> K<sup>-1</sup>] is the thermal conductivity. Note that  $Q(r, t)$  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.

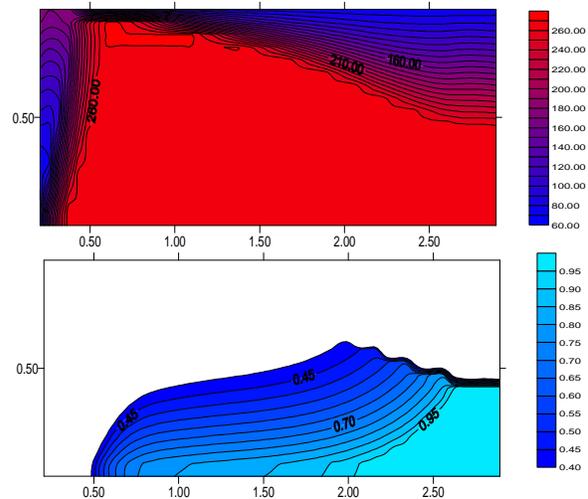


Figure 1. Thermal and melting history in Rhea according to our model for accretion starting 0.4 My after formation of CAI and lasting for 1 My. The reference viscosity of ice at melting temperature is  $\eta_m = 10^{12}$  Pa s. The vertical axes give  $r/R_{\text{sat}}$ , the horizontal axes give  $\log_{10}(t [\text{My}])$ , where  $t$  is the time from the beginning of accretion. The upper panel presents isotherms in Kelvin, the isolines in the lower panel give supplied fraction of latent heat of melting (1 means fully molten matter). Note substantial phase shift between temperature distribution and melting distribution and that the melting starts after 100 My only [2]. No chemical reactions are included in this calculation.

The heat transported by convection is included by multiplying the coefficient of the heat conduction in the considered layer by the Nusselt number  $Nu$ :

$$k_{\text{conv}} = Nu k, \quad (2)$$

where for  $Nu$  we use the formula given by [8] for temperature dependent viscosity and for the medium viscosity contrast.

**Preliminary results of the model:** 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 (e.g. 3500 kg m<sup>-3</sup>). 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 if density of silicate corresponds to density of serpentinites.

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