

**PHASE TRANSITIONS AND 2D SPHERICAL CONVECTION IN A LARGE ICY SATELLITE;** O.Forni <sup>1</sup>, C. Federico <sup>2</sup> and A. Coradini <sup>3</sup> <sup>1</sup>IAS - Université Paris XI, Orsay, France ; <sup>2</sup>Dipartimento di Scienze della Terra - Università degli Studi, Perugia (Italy); <sup>3</sup>IAS - Planetologia, Roma (Italy)

Three ice phase transitions, based on experimental and theoretical results<sup>1</sup>, have been incorporated into a 2D spherical convection model. These phase transitions are the exothermic Ice I-II, the endothermic Ice II-VI and the exothermic Ice VI-VIII phase transitions. The fluid is assumed isoviscous and the anelastic liquid formulation<sup>2</sup> has been used. The object is an icy satellite whose physical characteristics resemble those of Ganymede or Callisto. Structural models, similar to those of Mueller and McKinnon<sup>2</sup>, with different core sizes i.e. with different degree of differentiation have been studied. The shells i.e. the mantle of the satellite is heated both internally and from below to account for the decaying radiogenic heating and the heat flow from the solid core. The lower boundary of the mantle is rigid and isothermal, the upper boundary is isothermal. Calculations with rigid and shear stress free upper boundary are carried out in order to assess the role of the different boundary conditions. Two different Rayleigh numbers, depending on the assumed value of the viscosity, have been used in the calculations and the thermal evolution of the satellite has been studied.

The suit of calculations presented in this study demonstrates that phase transitions cannot be ignored when the thermal evolution of a large icy satellite has to be studied. The importance of the construction of realistic phase diagram for ice has been also documented. On the other hand the degree of differentiation, simulated with structures with different core's radius does not seem to drastically influence the overall behaviour of the convective activity. Within the limits of our simulations, the post-accretionnal evolution seems to be independent on the degree of primordial differentiation.

The convective style show a dramatic difference between rigid and shear stress free boundary condition. Generally it can be said that shear stress free boundary condition favours a whole mantle convection while a rigid boundary condition favours a double layered convection. In this last case the ice II-VI endothermic phase transition acts as a barrier to the convective flow. However, for both cases, the increase of the Rayleigh number enhances the layering. Above the endothermic phase transition, temperatures are high enough to produce melting only when shear stress free boundary conditions are applied and viscosity is high enough to reduce the efficiency of heat removal.

From this point of view, if the observed tectonic difference between two similar objects like Ganymede and Callisto must be explained by some degree of melting during the post-accretionnal evolution, then it must assumed that the thermal evolution of Ganymede is controlled by a relatively large  $\Delta T$  with a relatively low Rayleigh number i.e., relatively high viscosity. This is true in our modelling as far as shear stress free boundary condition is imposed, in fact with rigid boundary condition melting never occurs. Thus, while the characteristics of Callisto can be explained by low Rayleigh number and rigid boundary, those of Ganymede require shear stress free. In the light of these results the explanation of the different tectonic activity between Ganymede and Callisto seem to reside in a more mobile lithosphere on Ganymede than on Callisto. These conclusions are also supported

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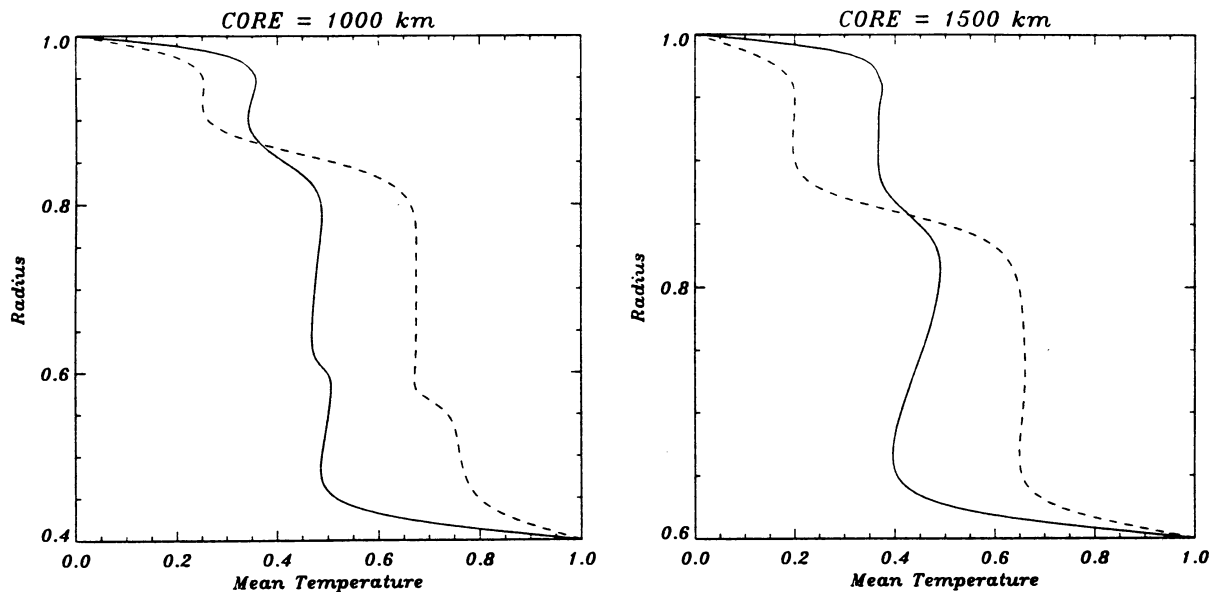


Figure 1: Mean temperature profiles for both core sizes and boundary conditions are represented. The solid lines represent the shear stress free condition and the dashed lines represent the rigid boundary condition. In the rigid case, a well developed boundary layer appears at the Ice II-VI endothermic phase transition. Mean temperatures in the upper mantle are higher for the free slip boundary condition so that melting can occur. Mean temperatures in the lower mantle are higher for the rigid case.

by the comparison between the thermal gradients we derived from our simulations and the thermal gradients obtained from the analysis of the geometry and the evolution of characteristic surficial features on Ganymede and Callisto<sup>4,5</sup>.

**References.** (1) Mishima, O. and S. Endo *J. Chem. Phys.*, **73**, 2454-2456, 1980. (2) Jarvis, G.T., and W.R. Peltier, in *Mantle convection Plate tectonics and global dynamics*, edited by W.R. Peltier, pp.479-594, Gordon and Breach Science Publishers, 1989. (3) Mueller, S., and W.B. McKinnon, *Icarus*, **76**, 437-464, 1988. (4) Allemand, P. and P.G. Thomas, *J. Geophys. Res.*, **96**, 20981-20988, 1991. (5) Passey, Q., and E.M. Shoemaker, In *Satellites of Jupiter*, D.Morrison, Ed., pp.379-454, Univ. of Arizona Press, Tucson, 1982.