Japan Geoscience Union Meeting 2010
(May 23-28 2010 at Makuhari, Chiba, Japan)

PPS010-03 Room: 201A Time: May 27 14:15-14:30

Topographic relaxation time of small-middle icy satellites estimated from Maxwell visco-elastic model

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Icy satellites are classified into two groups according to their shapes: they are irregular and spherical. From recent explorations by spacecrafts, it has been clarified that the critical radius of icy satellite changing from irregular to spherical is about 50-100 km. Farinella et al. [1983] and Croft [1992] proposed that the transition of the shape might be controlled by the ratio of the stress exerted by the gravity and the viscosity of materials constituting icy satellite. Particularly, a viscous relaxation which causes the height change of the relief depends on temperature and stress, so Croft [1992] calculated the physical condition necessary for the relaxation by using Maxwell visco-elastic model, and estimated the suitable temperature. However, the internal temperature distribution of icy satellites changes with time in the thermal history, so we should examine whether the temperature necessary for the relaxation was able to be kept for a long time enough or not. Therefore, we compared the duration at each temperature with the corresponding Maxwell relaxation time. In this study, we estimate them by using an equation of the heat conduction and the visco-elastic model proposed by Croft [1992].

We calculated the heat conduction by using an analytic solution derived by Carslow and Jaeger [1986], and obtained the effect of radius on the internal temperature distribution. As a result, the temperature increased with time at first, and then it became the maximum, after that, it decreased. Furthermore, the duration between the beginning and the time at the maximum temperature increased as the radius increased. From this result, we can obtain the interval, t_1, in which the temperature is higher than T_1. So, we assumed that the topographic relaxation could occur when the interval at the temperature higher than $T_1$was longer than the Maxwell relaxation time for T_1, and we estimated the effects of icy satellite radius, rock content and porosity. The Maxwell relaxation time can be expressed by the ratio of the viscosity and the Young's modulus. We calculated the viscosity by using the flow laws of ice-silica mixtures obtained by Yasui and Arakawa [2009], and the Young's modulus by using the empirical equations obtained from the measurement of sound velocity of the mixtures. From these calculations, the critical radius necessary for the topographic relaxation was found to decrease with increasing the rock content and the porosity; for example, it was larger than 450 km for the rock content of 30 wt.%, and 250 km for 50wt.%.

Reference: Farinella et al., The moon and the Planets, 28, 251-258, 1983; Croft, Icarus, 99, 402-419, 1992; Carslaw and Jaeger, Conduction of heat in solids, 2nd ed., 1986

Keywords: shape of icy satellite, Maxwell relaxation time, heat conduction, ice-silica mixture, flow law, sound velocity