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# ガニメデの内部進化と地形形成：JUICE 計画での実証に向けて
# Interior evolution of Ganymede and its surface manifestation: toward JUICE measurements

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Jovian moon Ganymede is the largest moon in our solar system and its icy surface is shared by global-scaled tectonics, termed as grooved terrain, which has been interpreted as grabens resulting from lithospheric extension and the average impact crater density on the grooved terrain corresponds to an age of 2 Gyr. According to geological estimates, 3-4% increase in the satellite radius may be required for their formation. In addition, the small value of the moment of inertia factor and the strong intrinsic magnetic field observed for Ganymede are consistent with a highly differentiated interior with a conductive dense core. Hence Ganymede has likely undergone significant temperature rise inside allowing the separation of a conductive core and global expansion during its history. However, the release of accretional energy is insufficient for the melting of metallic materials. Either the short-lived radio nuclides or the late stage heavy bombardment should heat the interior too early to explain the global expansion at 2 Ga from the formation of Ganymede. Thus its mechanisms still remain an open question.

This study numerically investigates the possible influence of hydrated rock on the thermal history of Ganymede. Here we assumes that Ganymede had an initial structure with a relatively thin water ice mantle and a low temperature primordial core made of the mixture of hydrous rock and Fe-sulfide similar to hydrated primitive meteorites. This may be supported in part by the similarity in reflectance spectra among hydrated carbonaceous chondrites and asteroids near Jovian orbit. In order to investigate above influence, we perform numerical simulations for the internal thermal evolution using a spherically symmetric model for the convective and conductive heat transfer with radial dependence of viscosity and heat source distribution. The primordial core is heated by the decay of long-lived radioactive nuclides. The rise of core temperature is kept slow after the occurrence of effective thermal convection in the core having low viscosity of hydrous rock. However, once the temperature reaches the dehydration point then the highly viscous, anhydrous region begins to grow associated with the release of water to the mantle. The core temperature thereby becomes to increase faster with accelerating the further dehydration of primitive matter. Dehydration of serpentine occurs at 1 to 2 Gyr after the satellite formation, giving an explanation for the cratering age of grooved terrain, and increasing in total volume of the moon by the dehydration is expected from calculation of temperature, pressure, and density with depth profiles extending from the center to the surface of the moon using 3rd-order Birch-Murnaghan equation of state with the thermal effect incorporated into the thermal expansion coefficient. In addition, the core temperature subsequently exceeds the eutectic point of the Fe-bearing sulfide and oxide so that the formation of a conductive dense core could occur by their gravitational segregation. Meanwhile, Callisto does not heat up sufficiently to melt the sulfide component or dehydrate the primordial core because of the efficient heat loss for smaller body. The difference of radiogenic heat and moon's size between Ganymede and Callisto may have potential to create the surface and interior dichotomy between two moons.

Finally, we expect these hypothesis can be validated through the JUICE mission. Coverage and resolution of current data for Ganymede's surface acquired by Voyager and Galileo spacecraft are quite poor, and considerable part of the surface has been classified as 'unclassified unit' in the current geologic map. GALA and JANUS onboard JUICE spacecraft will perform a full global mapping of surface morphology of Ganymede, thus we will be able to constrain an amount of surface area increment associated with the groove formation and a regional surface age of each groove to see a tectonic history and interior evolution.