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Evolution and diversity of the large icy moons

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Large icy moons in the solar system, Ganymede, Callisto, and Titan, have a similar size of Mercury but smaller bulk density (~2.0 g/cc) than the terrestrial planets, which indicates that the bulk composition is half water ice and half rocky material. However, there are quite different state on its surface and interior at present among these moons. Ganymede has globally-tectonic surface and completely differentiated interior having the central metallic core which generates the intrinsic magnetic field, while Callisto's surface is saturated by the impact craters, suggestive of an old age, and its interior seems to be incompletely differentiated which is implied by a large value of the moment of inertia factor. Titan has an intermediate size, density, and moment of inertia between Ganymede and Callisto, and has experienced some internally driven geology. Although many studies have proposed hypotheses explaining this contrasting states between the two moons, none of these theories has been sufficiently convinced.

We construct a new model for the evolution of large icy moons, especially in order to explain the origin of surface tectonics and strongly differentiated interior on Ganymede and the different current state and history between Ganymede and Callisto. That is, "Dehydration model" of primordial hydrous silicate and metal-mixed core so that only Ganymede undergoes significant temperature rise inside allowing the separation of a conductive core and the global tectonics during its history. This model assumes that during the stage of accretion rocky component is possibly hydrated because of the chemical reaction with liquid water generated by accretional heating. The similarity in reflectance spectra among hydrated carbonaceous chondrites and asteroids near Jovian orbit also implies that the constituent material of the icy moons has already been hydrated prior than their incorporation into circum-Jovian nebula in which the regular satellites accreted. After the end of accretion, primordial core starts to warm due to only the decay heating of long-lived radioactive elements. Once the dehydration starts to occur, the temperature of rocky core would increase more rapidly and exceed the melting point of the metallic component, and thereby metal segregates from rocky material. The difference of radiogenic heat and moon's size between Ganymede and Callisto may have potential to create the dichotomy between two moons.

In addition, applicability of this model is not limited to Ganymede and Callisto but extends to other similar-sized icy moons, e.g., Europa and Titan, and an implication for the "Super-Ganymede" exoplanets will be addressed. If extrasolar planetary systems are analogous to our own, then icy moons could be the most common habitats in the universe, probably much more abundant than Earth-like environments which require highly specialized conditions that permit surface oceans.

Finally, we will propose a possible contribution to the JUICE (Jupiter Icy Moon Explorer) mission, which is planned by ESA (European Space Agency) to visit the Jovian system and will launch in June 2022 on an 11-year mission to explore the giant planet and three of Jupiter's moons; Ganymede, Callisto, and Europa.

Keywords: satellite, thermal history, interior, tectonics, evolution, exploration