Interior thermal state of Enceladus: an inference from the relaxation state of its icy shell

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The South Polar Terrain of the icy Saturnian satellite, Enceladus, is one of the most geologically active regions among icy worlds. The origin of the anomalously large amount of heat observed over this region by the Cassini spacecraft is still unclear. To understand the heat budget of Enceladus, the interior thermal state should be investigated. This study attempts to constrain the thermal structure of Enceladus by comparing two timescales: those for viscous relaxation and melting. The subsurface ocean underneath the South Polar Terrain is thicker than other areas; the crust is thin in this region. Such “topography” at the base of the shell should viscously relax over time, and its timescale depends on the temperature of the deep part of the shell. If the shell is hot and has a low viscosity, the relaxation timescale should be short; a regionally thickened subsurface ocean cannot be maintained.On the other hand, if the laterally flowing portion of the shell melts, then a regionally thickened subsurface ocean can be maintained. In this study, we conduct numerical calculations of viscoelastic deformation under a wide variety of parameter conditions and compare timescales of viscoelastic relaxation and melting of the shell. Our results indicate that the former timescale is much shorter than the latter if we consider conventional values for radiogenic heating (0.3 GW [Roberts & Nimmo, 2008]) and tidal heating (1.1 GW [Meyer & Wisdom, 2007]). Our results also indicate that >10 GW, about one order of magnitude larger than the conventional value, is necessary to make those timescales comparable. This result suggests that the current Enceladus is unlikely to be in a steady-state; previous episodic heat production may contribute significantly to the current thermal state of Enceladus.

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