TIME EVOLUTION OF ICE-SHELL THICKNESS: IMPLICATIONS FOR CRYOVOLCANIC ACTIVITY ON EUROPA. D. Allu Peddinti[1] and A. R. Rhoden[1,2], [1]School of Earth and Space Exploration, Arizona State University, Tempe, AZ 85287, [2]Southwest Research Institute, Boulder, CO 80302.

Introduction: Europa, amongst other icy bodies in our solar system, exhibits a suite of surface features with aligned chemistry [1][2] indicative of transport between the ice-shell and ocean. Some of the important factors determining its cryovolcanic potential are its orbital-tidal evolution and consequentially, the thickness of its outer ice-shell. Tidal dissipation within Europa's ice-shell is caused by its eccentric orbit around Jupiter which is forced by its 4:2:1 resonance with Ganymede and Io [3]. It has been proposed [4] that, as Europa's orbit evolved around the gas giant, oscillations in its orbital eccentricity may have generated episodic variations in tidal dissipation within the ice. The potential feedback between shell thickness and the tidal dissipation within Europa should cause changes in ice-shell thickness [4] that may have resulted in different surface features as the ice-ocean system evolved over geological time. The ice-shell thickness and associated heat flow is critical to understanding the extent of cryovolcanism and resurfacing of the ice-shell, ultimately influencing the astrobiological prospects.

We perform numerical experiments to study how episodic changes in tidal dissipation within the ice could produce variation in the ice-shell thickness and convective behavior. The aim is to couple predictions of tidal dissipation from orbital models with the geodynamical models, and determine the stresses generated near the surface as a function of time.

Methods: We modify the Citcom 2D code for thermochemical convection [5][6] to model the two-phase ice-ocean system. It solves the incompressible equations for conservation of mass, momentum and energy under the Boussinesq approximation.

A temperature dependent viscosity formulation [7] is employed for pure water ice with a melting viscosity of 10^{16} Pa-s. As a proxy for the ocean, we use a low viscosity fluid that is ~100x less viscous than the lowest viscosity ice, which sufficiently decouples convection in the ice and ocean layers [6].

Numerical Model. All the numerical experiments begin from an initially warm ocean (100 km thick) that cools from the top. The velocity boundary conditions of the domain are free-slip. The temperature at the top boundary is isothermal (set to zero) while the bottom temperature boundary is insulating (no heat flow). We set this to isolate and examine the effect of tidal dissipation on shell thickness.

Tidal Heating. The viscoelastic behavior of pure water-ice on Europa at the mean motion frequency is modeled according to the Maxwell model [7]. For the current set of numerical experiments, we first implement uniform tidal dissipation, by applying a heating rate $q = q_0$ throughout the ice-shell.

Discussion: We vary both the period and magnitude of tidal dissipation episodes. Figure 1 below shows the ice-shell thickness as a function of time for a case where a uniform tidal heating rate (non-dimensional value of 40) is applied to the ice-shell every 10 million years. The ice-shell forms from a cooling ocean and grows in thickness. It responds to the heat pulses by melting, and becomes conduction dominated as the shell thins. When the heating pulse is turned off, the shell thickens and convection dominates the dynamics of the ice-shell.

Hence, it is plausible that changes in tidal heating can cause changes in the resulting geologic activity on Europa, perhaps leading to episodic cryovolcanic behavior.

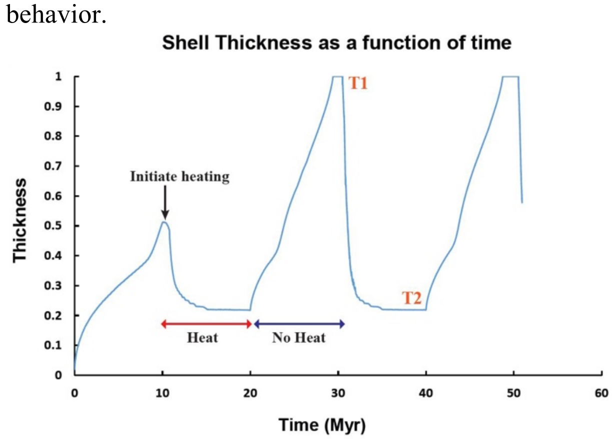

Figure 1. *Regular pulses of heat (q = 40) are applied to the ice-shell every 10 Myr. The non-dimensional thickness vs time plot above demonstrates the oscillations in shell thickness due to the episodic tidal dissipation in ice. In the absence of heating (T1), the ice-shell thickens (~92 km) and is convection dominated. At the end of a heating pulse (T2), the shell has thinned (~22 km) and is dominated by conduction.*

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