Surface manifestation of Solid-state Convection in Europa's Ice Shell

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Europa's surface displays a diversity of geologic terrains. The two dominant terrain types are the ridged plains, which consist of successive generations of overprinted ridge pairs, and the chaos terrains, which are comprised of hummocky material and disrupted crustal blocks. In addition, numerous small (< 20 km) landforms were imaged by Galileo, including pits, domes, platforms, irregular uplifts, irregular lobate features, and smooth, flat regions embaying topographic lows. The formation mechanisms of these features are hotly debated. Pappalardo et al. (1998) suggested from early Galileo observations that the pits, domes, and "mini-chaos" regions have a characteristic size of ~ 10 km. Furthermore, several of the pits and uplifts appeared to alter the topography of the existing surface without disruption, indicating local flexure of the lithosphere. As a result, Pappalardo et al. suggested that Europa's ice shell undergoes solid-state convection vigorous enough to flex, and perhaps fracture, the lithosphere, producing the observed landforms. More recently, Riley et al. (2000) and Greenberg et al. (2002, under revision) used more complete Galileo imaging coverage to map the spatial and size distribution of chaos, pits, and uplifts. They found that, contrary to the results of Pappalardo et al., pits, uplifts, and chaos come in a range of sizes, with numbers increasing with decreasing size. Greenberg et al. correctly pointed out that the convective model has difficulty accounting for the small (< 3 km-diameter) features. Nevertheless, the nature of the < 3 km-diameter features is unclear, and it is not obvious that they were formed by the same mechanisms that formed the larger features. Numerous pits, uplifts, and platforms ranging in size from 5–50 km exist and remain unexplained. Therefore, there is merit in determining with a physical model whether convection in Europa's ice shell can produce some of the observed features.

We will present preliminary two-dimensional numerical simulations of solid-state convection in Europa's ice shell performed using the Conman finite element code. The goals are to determine (i) the parameter regimes under which convection can occur, (ii) whether the convection can produce topographic features tens to hundreds of meters in vertical relief, and the horizontal scale and time-dependence of these features, and (iii) whether the convection is likely to fracture the lithospheric ice. Internal tidal heating, and a flux of heat from below, are included. The simulations use temperature-dependent viscosity, with a viscosity variation across the layer of 10^{20}. This value is appropriate for Europa and implies the formation of a stagnant lid unable to participate in the convection (viscosity contrasts of $< 10^6$, which have been commonly used in terrestrial-planet mantle convection simulations in the past, are not realistic for a single-plate planet because they allow even the stiffest regions to participate in the convection). Greenberg et al. (2002) also pointed out that the spatial distribution of pits and uplifts sometimes appears tectonically controlled (e.g., pits often lie between lineaments but avoid the lineaments themselves). To address this intriguing observation, we will include faults in some simulations and determine their effect on the surface manifestation of the convection.