Flexure of Europa's lithosphere due to ridge-loading. T.A. Hurford, B. Preblich, R.A. Beyer and R. Greenberg, Lunar and Planetary Laboratory, University of Arizona, Tucson Az 85721, (hurfordt@lpl.arizona.edu).

Introduction: Europa's surface is covered with ice over a liquid water ocean ~150 km thick [1,2]. The thickness of the ice shell remains unknown, yet has important implications for future European spacecraft missions and the habitability of Europa's ocean. A related issue is the thickness of the elastic portion of the ice, which overlies the warm viscous ice that lies directly above the ocean.

Early investigation of images sent back by the Galileo spacecraft showed a few clear cases of crustal downwarping near ridges, which followed the expected flexure geometry for a loaded lithosphere, including a secondary uplift [3].

These cases were observable because favorable lighting conditions highlighted the flexure, and yielded estimates of the thickness of the elastic portion of Europa's ice crust of ~200 m [4]. Other observations of flexure near chaos regions were used to infer a similar elastic thickness for Europa between 100-500 m [5].

Shading and secondary fractures allowed Tufts to determine the distance to the crest of the secondary uplift in some cases [3]. The thickness, h, of the elastic lithosphere is then given by the expression [from 6]

$$h^3 = 3d^4 (4/3)\mu \rho g (1-\nu^2)/E$$  (1)

where d is the distance to the secondary uplift, \(\mu\) is the density of the elastic lithosphere, \(\rho\) is the surface gravity, \(\nu\) is the possion’s ratio and E is the Young’s modulus of ice.

We use a technique of profiling photoclinometry, based on point photoclinometry [7], to extend the investigation of flexure near ridges. We build up a profile of surface topography by modeling the slope of each pixel based on its brightness in a down-sun profile. We make a basic assumption that all changes in pixel values are due to changes in illumination and not caused by other effects such as albedo changes. Topography profiles show uplift near ridges due to flexure of the elastic plate, giving the distance to the crest of the secondary uplift. Photoclinometry allows for the identification of this secondary bulge at a variety of locations across Europa’s surface.

We use Eq. 1 in this study and in the plots shown in this abstract. We adopt values for \(\mu\) to be 1055 kg/m³ [8] and for g of 1.35 m/s². We have assumed various values for E but for work shown here we adopt a value of 1x10¹⁰ Pa.

The above estimate of elastic plate thickness assumes a line load on a cracked plate. However, ridges on Europa have a finite width. Therefore, in addition to using Eq. 1, we have numerically modeled flexure along ridges of finite width, to supplement the results from Eq. 1.

We have investigated the elastic thickness over a wide range of longitudes and latitudes and in a variety of geological settings. The amount of flexure seen yields an elastic thickness of generally ~100-400 m, consistent with earlier estimates.

Analysis and Results: Measurements of topography in the higher resolution Galileo images has allowed us to identify flexure at a variety of locations on Europa's surface. Figure 2 shows a plot of all of the measurements we have made thus far. Measurements span the surface from about -80° latitude to as far north as 60° latitude. Furthermore we have investigated flexure on a wide variety of terrains.

For example, our results contrast terrains near and on Astypalaea Linea. Figure 3 shows the elastic thickness on the dilated parts of Astypalaea and on the ridged terrain that surrounds it. The elastic lithosphere in the dilational portion of Astypalaea Linea is systematically thicker than the surrounding terrain. This result is consistent with the model by
Tufts et al. [9], in which dilational bands thicken if they are worked by diurnal tides (Figure 4), as must have been the case at Astypalaea according to Hoppa et al. [10].

Figure 3. Elastic thicknesses near Astypalaea are shown. Ridge terrain surrounding Astypalaea Linea, a band structure, shows a thinner elastic plate.

Figure 4. The thickening of the ice shell when dilation is accompanied by diurnal tidal working [reproduced from 9].

In addition to the thicker elastic lithosphere under Astypalaea Linea, evidence of a change in thickness with time is also seen. Ridges that cut across Astypalaea Linea formed at different times. Using cross-cutting relations relative ages of these features can be found. Younger features were supported by a thinner elastic lithosphere, suggesting that the elastic lithosphere under Astypalaea Linea may not have been constant but changed with time, getting thicker. In Figure 5 we plot this relationship. There is a about a 400 m difference in thickness between the oldest and youngest measurements.

The technique described here has the potential for placing important constraints on the structure and origins of terrains and features on Europa.

Figure 5. The thickness of the elastic lithosphere under Astypalaea Linea. The data have been grouped based on the relative age of the ridge producing the flexure.